Expanding the Dialogue on Climate Change & Water Management in the Okanagan Basin, British Columbia

FINAL REPORT

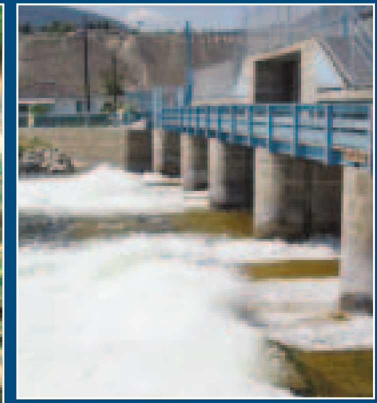
JANUARY 1, 2002 TO JUNE 30, 2004

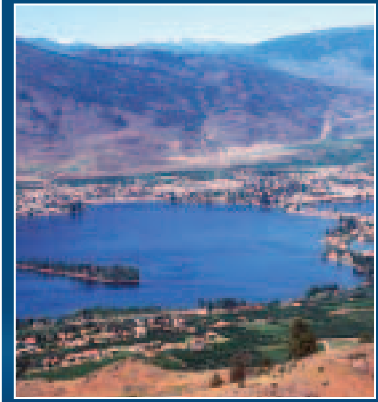
Edited by
STEWART COHEN
DENISE NEILSEN
RACHEL WELBOURN

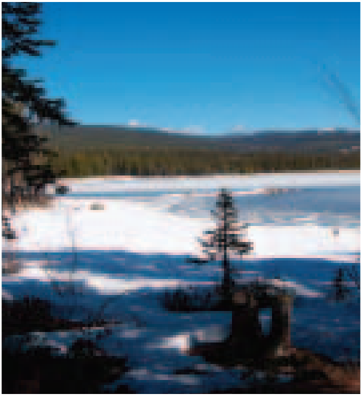
Principal Investigators
STEWART COHEN,
Environment Canada and UBC

DENISE NEILSEN,
Agriculture & Agri-Food Canada

SCOTT SMITH,
Agriculture & Agri-Food Canada







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An electronic copy of this report is available at the following web site:
http://www.ires.ubc.ca

The study team also produced an interim report in 2003. It is available at the following web site:
http://www.sdri.ubc.ca/documents/Okanagan_2003_Interim_Report_Final.pdf

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Cover photo caption

1. *Trickle Drip Irrigation (Denise Neilsen)*
2. *Dam at South End of Okanagan Lake, Penticton (Wendy Merritt)*
3. *The Town of Osoyoos, and Osoyoos Lake (Denise Neilsen)*
4. *Ellis Creek Reservoir East of Penticton (Brian Symonds)*
5. *Overhead Sprinkler Irrigation (Denise Neilsen)*

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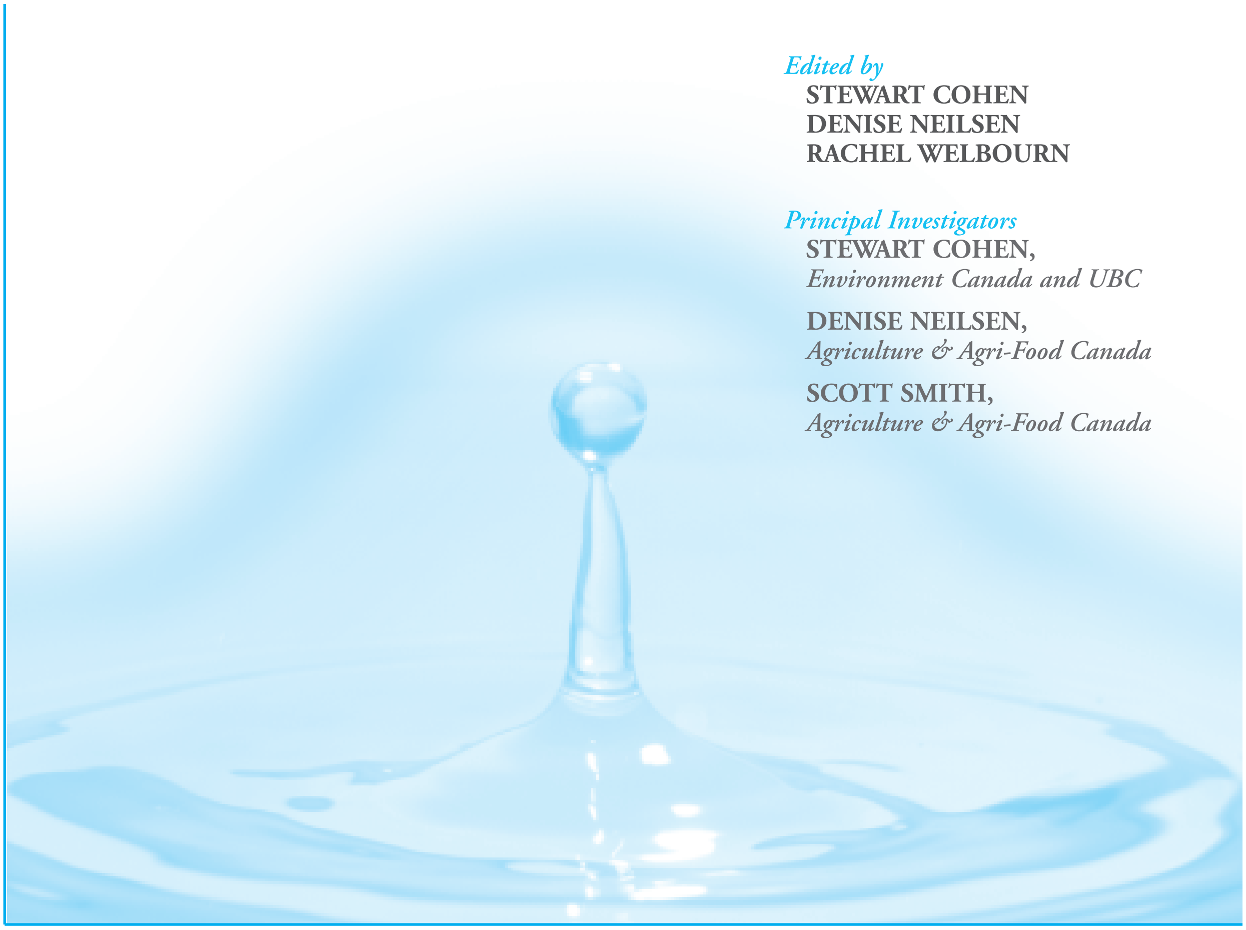

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STEWART COHEN,
Environment Canada and UBC
DENISE NEILSEN,
Agriculture & Agri-Food Canada
SCOTT SMITH,
Agriculture & Agri-Food Canada

NOTICE TO READERS

The results presented in this report were obtained using data available from published sources and standard monitoring techniques, and methods developed or modified by the study team consistent with peer-reviewed literature. However, this report has not been peer reviewed outside of the study team. Readers are advised to be aware of the uncertainties and limitations of this research. Details are provided for the various study components in this report.

Simulations of future changes in hydrology and crop water demand are based on scenarios of climate change obtained through the Canadian Climate Impact Scenarios project (http://www.cics.uvic.ca/). The results presented herein are for the purposes of research, and are not to be used for commercial exploitation. Although care has been taken in the preparation of these scenarios and in their use by the project team, no liability is accepted by the project team for errors or omissions, and no warranty is given as to the suitability of these scenarios.

CO-INVESTIGATORS

NAME	ORGANIZATION
Stewart Cohen (PI)	Adaptation & Impacts Research Group, Meteorological Service of Canada; Institute for Resources, Environment and Sustainability, University of British Columbia.
Denise Neilsen (PI)	Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada
Scott Smith (PI)	Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada
Grace Frank	Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada
Walter Koch	Pacific Agri-Food Research Centre, Agriculture & Agri-Food Canada
Younes Alila	Department of Forest Resources Management, University of British Columbia
Wendy Merritt	Department of Forest Resources Management, University of British Columbia (current affiliation: Australian National University, Canberra)
Roger McNeill	Environment Canada, Pacific & Yukon Region
Mark Barton	Environment Canada, Pacific & Yukon Region
Bill Taylor	Environment Canada, Pacific & Yukon Region
Philippa Shepherd	Institute for Resources, Environment & Sustainability, University of British Columbia
Tina Neale	Adaptation & Impacts Research Group, Meteorological Service of Canada Institute for Resources, Environment & Sustainability, University of British Columbia
Jeff Carmichael	Institute for Resources, Environment & Sustainability, University of British Columbia
James Tansey	Institute for Resources, Environment & Sustainability, University of British Columbia
Stacy Langsdale	Institute for Resources, Environment & Sustainability, University of British Columbia (2003-2004)
Rachel Welbourn	Adaptation & Impacts Research Group, Meteorological Service of Canada (2003-2004) Institute for Resources, Environment & Sustainability, University of British Columbia (2003-2004)
Brian Symonds	Ministry of Water, Land & Air Protection, Government of British Columbia

For further information, please contact **Stewart Cohen** at **scohen@sdri.ubc.ca**.

Okanagan study team and guests at a research meeting held June 12, 2002 at PARC, Summerland, BC.

BACK ROW: Michelle Boshard *(Habitat Conservation Stewardship Program)*, Jenny Fraser *(Ministry of Water, Land & Air Protection)*, Walter Koch, Grace Frank, Stewart Cohen, Younes Alila, Brian Symonds, Andrew Reeder *(District of Summerland)*, Tina Neale.

FRONT ROW: Howie Wright *(Okanagan Nation Fisheries Commission)*, Mark Barton, Bronwyn Sawyer *(Simon Fraser University)*, Wendy Merritt, Denise Neilsen, Philippa Shepherd, Scott Smith

MISSING: Jeff Carmichael, Stacy Langsdale, Roger McNeill, James Tansey, Bill Taylor, Rachel Welbourn

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Acknowledgements

The authors of this report are members of a collaborative study team that also contributed to the interim report, cited as Cohen and Neale (eds.), 2003. Some authors were also members of one of two study teams that contributed to Cohen and Kulkarni (2001) and Neilsen *et al.* (2001) (see Chapter 1). Additional contributors to the Cohen and Kulkarni study were: Roxanne Brewer, Erin Embley, Ken Hall, Stuart Hamilton, Dave Hutchinson, John Martin, Jacek Scibek, Maggie Julian, Tanuja Kulkarni, Rob Van Wynsberghe, Wendy Avis and Paul Whitfield. Thank you also to Dave Hutchinson for contributions to the crop water demand component of this report.

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Several manuscripts on various components of this study have been prepared by study participants and submitted to refereed journals. As of this date, these manuscripts are still undergoing the review process.

Opinions expressed in this report are those of the authors and not necessarily those of Environment Canada, Agriculture and Agri-Food Canada, University of British Columbia, Natural Resources Canada, or any collaborating agencies.

Executive Summary

This is the final report of project A463/433 under the Climate Change Impacts and Adaptation Program (Natural Resources Canada) entitled, "Expanding the Dialogue on Climate Change and Water Management in the Okanagan Basin, British Columbia." The research activity described in this report is a collaborative, interdisciplinary effort involving researchers from Environment Canada, Agriculture and Agri-Food Canada, the University of British Columbia, the BC Ministry of Water, Land and Air Protection and the District of Summerland.

The goal of this study is to develop integrated climate change and water resource scenarios in order to stimulate a multi-stakeholder discussion on the implications of climate change for water management in the region. The study team hopes to achieve two main objectives: a) providing a set of research products that will be of relevance to regional interests in the Okanagan, and b) establishing a methodology for participatory integrated assessment of regional climate change impacts and adaptation that could be applied to climate-related concerns in Canada and other countries.

The study comprises five key components:

1. **Climate change scenarios:** downscaling global climate change scenarios to the regional level;
2. **Hydrological scenarios:** determining impacts of climate change on basin hydrology;
3. **Water demand scenarios:** developing future demand scenarios particularly for irrigated agriculture and municipalities, factoring in socio-economic trends;
4. **Adaptation options:** exploring previous management experiences and potential future approaches for augmenting water supply and/or reducing water consumption; and
5. **Adaptation dialogue with stakeholders:** learning about regional perspectives on adapting to climate change.

Climate

The 8200 km^2 Okanagan valley is a long narrow basin stretching 182 km from Armstrong in the north to the Washington state border near Osoyoos in the south. The climate ranges from arid near Osoyoos to moist at higher forested elevations. Semi-arid conditions characterize much of the valley bottom. Annual and decadal variations are influenced by varying phases of the El Niño/Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO), which have led to periods of warming and cooling. In 1976, a warm PDO phase began, but there is evidence that it may have shifted to a cool phase in the late 1990s.

Local climate stations and snow courses have been analyzed for trends, and to determine the influence of ENSO, PDO, and other large scale atmospheric features. Significant warming, particularly during winter and spring, has been observed at two long term stations: Summerland CDA and Vernon Coldstream Ranch. Daily minimum temperatures have increased at a faster rate than daily maximum temperatures. Spring and summer precipitation has been increasing during the last few decades, which is likely contributing to recent increases in lake inflow. The percentage of precipitation falling as snow (the "snow fraction") has been decreasing at low elevation valley stations, but not at higher elevations. Cloud cover has increased at Penticton Airport, especially at night. This has likely contributed to a decrease in annual mean solar radiation, while net radiation (sum of solar and terrestrial) has increased. The 1976 PDO phase change appears to have led to a reduction in snow water equivalent until the mid-1990s. Date of onset of snowmelt is occurring earlier than in previous years.

Conditions during 2002-2003 were considerably drier than in previous years. The 2003 drought was severe. Flows at Camp Creek were at 24-49% of the 1965-2003 mean due to low snowpacks and hot dry summer weather. This may be climatically similar to the drought of the 1920s and 1930s, but the impacts were probably worse due to the higher populations and expanded housing developments. Fires during 2003 destroyed more than 200 homes.

Many crops in the Okanagan Basin rely on various microclimates created by the complex topography. Microscale topographic variations in slope, aspect and elevation, and the different crop types give rise to an assortment of microclimates that have yet to be studied in detail. This project has used a network of 47 Hobo computerized temperature loggers to collect temperature data so that the microscale variations in climate could be mapped to aid the understanding of crop water demand and crop suitability. This network was set up at sites around Summerland and Naramata. Results for 2002-2003 shows that climate variation within these sites is as large as the differences in mean annual temperature between Armstrong and Osoyoos. The difference in accumulation of GDD10 between the warmest and coolest site was 31%.

Superimposed on the above variations and trends is the potential effect of increasing concentrations of greenhouse gases. Global Climate Model (GCM) experiments suggest that some warming has already occurred, and will continue to occur in the future. For this study, climate change scenarios were developed from three different GCMs (CGCM2-Canada, HadCM3-UK, CSIROMk2-Australia), and two scenarios of global greenhouse gas emissions from the Intergovernmental Panel on Climate Change's SRES series (A2—high increase, and B2—moderate increase). Simulations for three 30-year periods, centred on the 2020s, 2050s and 2080s, were obtained from the website of the Canadian Climate Impact Scenarios project.

For the 2050s, increases in winter temperature relative to the 1961-90 baseline lie in the range 1½ to 4 degrees Celsius with winter precipitation increases on the order of 5 to 25%. For summer, all models show a warming of roughly 2 to 4 degrees Celsius and precipitation changes ranging from almost no change to a 35% decrease in precipitation compared to the 1961-90 baseline. The greatest change in winter conditions is reflected by the Australian model (CSIROMk2) while the UK Hadley Centre model (HadCM3) shows the greatest change in summer climate.

Hydrology

The UBC Watershed Model has been chosen to model precipitation-runoff processes. The model has been used extensively in British Columbia, and has been shown to adequately reproduce the hydrologic response of watersheds, and has previously been used in climate change studies.

Overall, the UBC Watershed model has been shown to be a suitable model for application to the Okanagan Basin. The arid climate of the basin and the deficiencies in the meteorological network make successful calibration of the model more difficult than in humid watersheds that exhibit less variability in precipitation across the watershed. Despite problems with representativeness of available climate data, the model was generally shown to perform adequately when the average parameter set and estimated precipitation parameters were used to drive the model. Likewise, model performance over the verification period indicates that the model is capable of predicting hydrologic response over different climatic periods.

The climate scenarios generated by the three climate models provide different, although equally plausible, outlooks for the future hydrology of watersheds in the Okanagan Basin. All climatic change scenarios consistently included an early onset of the spring snowmelt, a tendency towards a more rainfall dominated hydrograph and considerable reductions in the annual and spring flow volumes in the 2050's and 2080's. Of the three climate models, the CGCM2 model provided the most conservative predictions of the impacts of climate change in Okanagan Basin.

Simulations based on the CSIROMk2 climate model suggested greatly reduced snow pack and flow volumes despite a sizeable increase in the winter precipitation. The HadCM3 model exhibits the greatest increase in summer mean temperatures of the three climate models.

The scenarios raise questions over the availability of future water resources in the Okanagan Basin, particularly as extended periods of low flows are likely to coincide with increased demand from agricultural and domestic water users. With the HadCM3 climate model, the hydrograph is peaky and quite confined in the period of elevated flows. Such a scenario would pose difficulties for water managers who would have to cope with the majority of water entering their reservoirs in a very short time frame. They would have to manage water levels in the reservoir(s) keeping in mind the prolonged shortage of flows downstream of the reservoir during the dry season. In contrast, the CSIROMk2 scenarios produce flatter hydrographs that distribute water more evenly through the season, in this sense making the job of managers easier. However, this would be offset by the extreme reduction in flows predicted by the climate model. Under both situations, managing for environmental flows may be more difficult. While provisions exist for maintaining sufficient flows for indigenous species during spawning and other key periods, what options are available if water resources are over-stressed, or peak flows increase? Additionally, a move towards a more rainfall dominated precipitation regime under warming may make forecasting more difficult. Managers of the lakes and reservoirs use the winter snowpack as a guide for releasing or storing water based on whether or not a water surplus or deficit is foreseen. With less snowfall events, anticipating extreme high or low flow periods and instigating pre-emptive management practices to cope with extreme flow conditions may prove problematic.

Water Demand—Agriculture

The Okanagan Basin is highly subscribed to supply water for high value crops. Irrigated agriculture consists primarily of high value tree fruits and wine-grapes, pasture and forage, and a small area of vegetables. An agricultural land use database for the Okanagan basin has been compiled and incorporated into a GIS using ArcInfo™. These data have been incorporated into a valley wide model for crop water demand estimates.

The crop water demand model requires calculation of potential evapotranspiration (ET), based on temperature and solar energy, and length of growing season, based on seasonal start and end of accumulating growing degree days above critical minimum temperatures for each crop.

Another important consideration in the model is potential effects of elevated CO_2 concentration on plant transpiration. Although water demand reduction has been suggested for various crops in an elevated CO_2 environment, the literature does not give clear indication of any changes in water use by intensively managed irrigated tree fruit and vine crops. Field crops such as alfalfa may experience water demand reductions, but other investigators have shown these to be relatively modest for the U.S. Pacific Northwest. For this study, we have therefore assumed no effect.

Crop water demand scenarios generated from the climate change scenarios indicated increases for the Okanagan Basin above model estimates of current annual demand, which is around 200 million m^3. Increases would be 12-20% in the 2020s, 24-38% in the 2050s, and 40-61% in the 2080s. The greatest increase is for the HadCM3 scenario in the 2080s, which has the highest summer temperatures. This worst case scenario for the 2080s approaches the current total irrigation allocation of 323.7 million m^3.

There are also seasonal and regional differences among the scenarios, as well as differences among individual crops. From modeled demand the largest total amount of water was required for pasture and the least (44% of pasture requirement) for grapes. Apple required approximately 78% and cherry 87% of the amount needed for pasture. The low irrigation demand for grapes results from a shorter growing season and lower crop requirements during peak ET. In contrast, pasture and forage, being cooler season crops have a longer growing season with high demand. Tree fruits have a shorter growing season than pasture, but peak demand was higher. Given the differences among crops, regional and seasonal variations in demand were largely determined by the predominant land use. Thus, under conditions of future water shortage, crop profile may have a bearing on potential adaptation strategies. In addition, some crops, e.g. row crops, tree fruits and grapes are suitable for efficient micro-irrigation systems, which can lead to a considerable reduction in water use.

In the absence of an overall estimate of basin water supply, modeled inflows to Okanagan Lake were used as indicators of changing basin hydrology and compared to estimates of crop water demand. Over the century, modeled Okanagan Lake inflow declined to around 69% of current inflows, suggesting an overall decline in supply which would potentially exacerbate shortfalls caused by increased crop water demand

Water Demand--Residential

Analysis has taken place on the degree to which climate change, through changes in maximum temperatures, may affect residential outdoor water use, in the context of other socioeconomic patterns that also affect demand. Historical analysis and projections have been created that represent three principal patterns of change in the Okanagan region, using the city of Penticton as a case study. The three patterns considered were 1) population change, 2) changes in preferred dwelling types, and 3) climate change induced temperature change. As people in the Okanagan region age, they are more likely to live in ground-oriented dwellings with lawns and gardens, with consequent and significant outdoor water use.

Three different population scenarios were considered, and were combined with independently generated dwelling projections. Future indoor and outdoor water use for each dwelling type was estimated for the period 2002 to 2069, with adjustments to outdoor water use based on six different climate change scenarios, as well as a scenario in which climate change has not been taken into account.

Water use appears to vary significantly across the three population scenarios in all cases. Climate change is expected to have an additive effect to any population scenario. However, the variations across climate scenarios appear to be moderate. For example, in the high population growth scenarios, usage growth relative to 2001 is 297 to 328 %. Under a scenario of no population growth and no changes in dwelling preferences, water use increases for the climate scenarios range from 5.6 to 9.5 % between 2001 and the 2020s and from 9.1 to 17.8% between 2001 and the 2050s. This may be contrasted with the increases in use associated with population projections alone, which range from 54 to 265% between 2001 and the 2050s.

According to these initial results, if the climate change effect is considered in comparison with the effects of population growth, a 9% increase from climate change (the lowest change among the climate scenarios) from 2001 to the 2050s is equivalent to an acceleration of the 50-year population growth effect by 11 years for low growth, 7 years for medium growth, and 4 years for high growth. For the most dramatic climate scenario, HadCM3-A2, the 18 percent increase in use is equivalent to an acceleration of 18 years for low growth, 13 years for medium growth, and 7 years for high growth.

More case studies are needed in order to assess the interacting effects of population growth and climate change on residential water demand for various communities around the Okanagan. If climate change speeds up the population effect, this has implications for long range planning, especially when combined with projected increases in crop water demand.

Water Supply and Demand Scenarios

One of the major risks facing Okanagan agriculture is the occurrence and frequency of drought. In production systems that are entirely dependent on irrigation, drought may be defined by the inability to provide an adequate water supply to maintain an economic return. There are two components to drought in this case; high demand and low supply. It might be expected that risk would increase when high demand and low supply are combined. In the current study we define risk thresholds associated with 1) operational limits on demand and hydrological limits on supply for Trout Creek which provides water for the District of Summerland, and 2)modeled maximum supply and demand for the period 1961-90 for Ellis and Penticton Creeks which supply the City of Penticton. Annual estimates for supply and demand were produced for four periods: 1961-90 historic climate, 2020s, 2050s and 2080s.

For Summerland, in an average year, total Trout Creek flows are estimated to be around 84.1 million m^3, of which 2.5 million m^3 would be withdrawn for commercial and domestic use, and a maximum of 10.5 million m^3 for irrigation. This value is about half of the licensed allocation for irrigation of 20.93 million m^3. In the CGCM2-A2 climate change scenario, the number of years when the modeled 1990s irrigation demand threshold of 10 million m^3 might be exceeded increased over time, to around eighteen years out of thirty by the 2080s. Differences in response between the A2 and B2 emission scenarios only became evident by the end of the century. Estimates of demand varied among GCMs, with the most extreme responses occurring in the HadCM3-A2 scenarios, so that by the 2080s, demand exceeded the threshold in every year. During 1961-90, there were no modeled occurrences of demand exceeding this 1990s threshold.

While demand is expected to increase, supply is projected to decline. A drought threshold of 30.3 million m^3 (36% of average annual flow) has been proposed for Trout Creek. During 1961-1990, there was only one occurrence in 30 years of modeled, unrestricted flow lower than the drought threshold, for a frequency of 3%. For the A2 scenarios, this increased to 7% by the 2020s, 17-24% by the 2050s, and 31-44% for the 2080s. The CSIROMk2 model provided the driest A2 scenarios. For the B2 scenarios, there were fewer extreme low flows than for A2, except for the CSIROMk2-B2 scenarios which produced more drought years in the 2020s and similar event frequencies in the 2050s and 2080s, when compared to A2.

It is apparent that the existing water infrastructure, which provides around 9.1 $m^3 \times 10^6$ of effective storage, will be unable to meet demands in years of extreme future climate. Crop water demand is more likely to exceed the current demand threshold in all climate change scenarios. Meanwhile, the frequency of annual flows below the drought threshold show similar increases under all scenarios. High risk outcomes to the Trout Creek system are defined as years in which demand exceeds 10.5 million m^3 and supply remains below the drought threshold of 30.3 million m^3. A2 scenarios resulted in high risk outcomes for HadCM3 in the 2050s (1 year in 6) and for all GCMs by the 2080s (1 year in 4 to 1 year in 2). Incidence of 'high risk' response for B2 scenarios was less than under A2.

A further concern is the timing of supply and demand. Model hydrographs generated with the UBC watershed model for Okanagan streams show that a characteristic response to climate change scenarios is earlier peak flow. Under such conditions, water available for irrigation from in-stream flow would not be available for much of the growing season, causing the supply system to be taxed by early dependence on stored water, as occurred in 2003.

Similar results were obtained for Penticton. For the A2 scenarios, the number of years when the 1961-90 demand threshold might be exceeded at Penticton Creek increased over time, from six years out of thirty by the 2020s to thirty years out of thirty by the 2080s. Estimates of demand varied among GCMs with the most extreme responses occurring in the HadCM3-A2 scenarios, so that by the 2050s, demand exceeded the threshold in every year. Similar responses were seen for the south irrigation area supported by Ellis Creek.

In contrast to the Trout Creek/Summerland water supply system, Penticton's water demand is dominated by domestic requirements. Modeled irrigation requirements for the combined north and south irrigation systems for the period 1961-2003 suggest that currently, irrigation requires just below half the amount of water required for domestic needs. The frequency with which modeled annual irrigation demand exceeded the most extreme years in the reference period of 1961-1990 increased for all models and scenarios throughout the century. Similarly, for both Penticton and Ellis Creeks, the scenarios resulted in an increased frequency of years with flow below the minimum modeled for the reference period. Consequently, for both north and south irrigation systems, there was increased risk of high demand coinciding with low supply over time. For all three GCMs, the A2 scenarios resulted in an increased frequency of these high risk outcomes; in the 2050s, between 1 year in 10 and 1 year in 6, and by the 2080s, between 1 year in 3 and 1 year in 2. High risk outcomes were fewer under B2 scenarios. In some very extreme years, there is a potential for demand to be greater than supply.

Water Management (from the 2003 Interim Report)

There are three primary features of the Okanagan watershed which emphasise the complex, convoluted and multi-scale structure of interacting organisations and institutions involved in water management decisions:

- The water system crosses an international border
- Multiple levels of government
- Multiple in-stream and out-of-stream water uses meaning many advocacy organisations at different scales

Water management is shared by various levels of government (federal, provincial, local), as well as by regional bodies established to focus on particular issues. The latter include the Okanagan Basin Water Board that has recently worked on liquid waste disposal and Eurasian water milfoil, and the Okanagan Basin Technical Working Group that identifies and steers initiatives to rebuild fish stocks.

The Okanagan Basin also presents an interesting forum for exploring water allocation and licensing given its semi-arid climate, its growing population and the importance of irrigation to the regional economy. As of July 2002, there were approximately 4130 active water licenses in the Okanagan Basin listed in the Water License Query database maintained by Land and Water BC. These licenses represent approximately 1.05 billion cubic meters of allocated water on 980 streams for both consumptive and in stream uses. Sixty-six water license applications were also listed requesting a further 209 million cubic meters. Of the 1.05 billion m^3 of water allocated in the Okanagan, 476.8 million m^3 is allocated for consumptive purposes, where water is removed form the source. Around ⅔ is used for irrigation.

In the context of adaptation to climate change in the Okanagan, British Columbia's regulatory system provides several challenges. Rising water demands due to population growth and changes in water supply and demand resulting from climate change may result in increased activation of the prior appropriation principle, resulting in increased conflict. Even though conflict is often resolved in the field through more fair methods, increased water stress makes the situation more vulnerable. Under the same conditions, the beneficial use principle could become a more significant requirement in allocating licenses as water sources become saturated. The perpetual nature of water licenses and the limited ability of managers to modify water rights e.g. transferability and conditionalities, may become restrictive in the face of increasing demands to manage water for multiple objectives (which may or may not be subject to water licensing). Balancing in-stream (e.g. fish) and out-of-stream uses (e.g. domestic & irrigation) could become increasingly difficult under a climate change scenario.

This question of balancing various water uses is made more difficult by the failure to define acceptable minimum fish flows. Also, the BC government's Fisheries Protection Act, which has language which would allow managers to grant water licenses to protect in-stream flow, and to reduce water use during drought conditions, has not yet been proclaimed.

Adaptation Case Studies

Adaptation to climatic change impacts, and other stressors, on water resources in the Okanagan is an important challenge for both local and provincial decision-makers, but how have local authorities in the Okanagan Region adapted to current pressures on water resources? In order to learn more about what adaptation entails and to identify specific local challenges, four case studies of water management practices at the local authority level were selected. Each represents the adoption of a different water efficiency approach, specifically: domestic metering in Kelowna, irrigation metering in SEKID, wastewater reclamation in Vernon and institutional change, specifically amalgamation of individual water utilities, in Greater Vernon. The latter three represent "early adopters" in the region.

The primary objective of the case studies was to explore how local authorities are *adapting* to changing circumstances that impact their water resources: what factors trigger early adaptation, the options selected and the success or failure of implementation, as well as what capacities facilitated adaptation i.e. *adaptive capacity*. Exploration of adaptation from a multi-stress perspective accentuates the contextual nature of adaptation to climatic change; that many factors i.e. other environmental pressures, socio-economic and political issues, will ultimately constrain, impede or encourage effective adaptation. Secondary objectives of the study included analysing the *effectiveness* of the four management practises and exploring the role of *learning* in the adaptation process. 28 semi-structured interviews with local water managers, Council/Board members and other key informants were undertaken.

These cases show that adaptation is not a linear, clear-cut process. Although, in each case a specific trigger could be identified, specifically drought episodes and provincial lead studies, different conditions shaped attribution i.e. interpretation of cause, and the appropriate mode of action to be taken. Action was immediate or lagged, depending on the interpretation of signal characteristics such as magnitude (relative to previously experienced related events), immediacy and tangibility, as well as socio-political factors. Ultimately in each case, action was pursued when a perceived coping threshold was fast approaching. Option selection was influenced by option availability, local and provincial agendas and values (including financial incentives), and previous proved effectiveness. Decision and implementation processes were less fraught with conflict when user groups were well informed. The effect of short political cycles on the development and continuation of a given management approach was especially evident in one case; at each cycle, new authority values resulted in a shift in direction, diffusing ultimate effectiveness.

Overall, the actions employed in the four cases appeared to be successful. Water "savings" were achieved in both metering examples. Kelowna achieved the pre-set 20% reduction target of their single family metering project. Allocated yearly water allotments in SEKID were reduced by 10%. Although water reclamation was initially implemented as a water treatment strategy (and an effective one), it is now considered as a potential water re-use, and therefore, efficiency strategy. As for amalgamation of local authority water utilities in Greater Vernon, effectiveness is not easily measured. This action could eventually lead to a more efficient use of available water sources through sharing of water sources that were previously earmarked for individual authority use. Cost sharing has been another advantage to amalgamation.

There are some clear lessons learned from these case studies that are important in answering the question - how to adapt to climate change in the Okanagan? The fear of change - the challenge of transition - runs throughout. Many factors either exacerbate the difficulty of change or smooth out the process: public perceptions and differing political agendas are two key issues. Agricultural users have a strong sense of ownership over water resources due to historical dominance in the region. In addition, low water rates are expected, as this has been the norm for many years. The divergent relationship between local, regional and provincial authorities means that finding any unified approach in the region could be a long-winded political struggle. Finally, any adaptation option will ultimately achieve efficiencies to simply allow for further development in the region, without a change in the development agenda. Such approaches will not reduce local vulnerability to climatic change impacts.

Costs of Adaptation Options (from the 2003 Interim Report)

A number of adaptation options are available that can help meet possible shortages due to climate change and other factors such as population growth. These options include both demand side measures and supply side measures. Demand side options include water conservation alternatives such as irrigation scheduling, public education, metering and adoption of efficient micro irrigation technologies. Supply side options include increasing upstream storage and switching to the mainstem lakes or rivers as a supply source, thereby relying on the large storage capacity of Okanagan lake.

The costs of both demand and supply side options will vary greatly depending on various features of the individual water supply systems and the type of demands served. In summary, there is no one least cost adaptation option for all water systems since costs will vary significantly from system to system. The lowest cost option in one area may turn out to be a higher cost option in other areas. Other factors, such as water quality and treatment options will also enter into the decision. Often a combination of options will be necessary in order to achieve full insurance against future water shortages and demand increases.

For future budgeting purposes, it appears that systems that are already near capacity would have to consider costs of at least $1000 per acre-foot to conserve or develop supplies of water to adapt to climate change. If projections indicate that large amounts of water must be conserved or supplied then probably $2000 per acre-foot would be a reasonable figure to consider in future budgets. Site-specific engineering studies would have to follow to obtain more accurate figures.

Dialogue with Stakeholders

Dialogue with stakeholders has been used to communicate research results to local water practitioners and interests, and also to learn about regional perspectives on how adaptation options might be implemented at the community and basin scales.

Two case study locations, Oliver and the Trepanier Landscape Unit, were selected for the two community adaptation workshops in the Okanagan. Oliver is a small agricultural community in the south of the Valley. Trepanier Landscape Unit, including Peachland and unincorporated areas around Westbank, is a fast-growing area to the west of Kelowna. Participants in the workshops were presented with a range of technically viable supply and demand side water management options and were asked to evaluate them according to eight questions. The questions addressed three broad themes: the social acceptability of the options, the current legal acceptability and political/jurisdictional concerns.

The results of these workshops reveal the complex political landscape that overlay the physical landscape of the region. Historical commitments to users in the agricultural community shape the current allocation of water resources and strongly influence the acceptability of adaptation options. Education and conservation interventions were considered useful in both communities. With respect to groundwater utilisation, many participants pointed out that while it may represent a viable alternate source in some areas, extraction is currently unregulated. Increasing drought pressure on traditional water sources may therefore result in largely unregulated groundwater withdrawal.

A third workshop focused on the topic of implementing an adaptation portfolio at the basin scale. This event was an additional opportunity to discuss the feasibility of anticipatory adaptation measures, but this time the discussion centered on changes that would affect, or be implemented in, the entire region. Because the scale of discussion was broader in geographic area, the adaptation measures discussed were also broader. General supply side and demand side approaches were discussed rather than site-specific strategies. There was also a greater emphasis on governance structures that could implement and orchestrate change on this scale.

Dialogue at this scale was more strategic. Participants expressed support for expanding the role of the Okanagan Basin Water Board (OBWB) and Okanagan Mainline Municipal Association (OMMA) in regional water quantity management. There was support for basin-wide management of various measures, including increased use of Okanagan Lake and groundwater sources, a coordinated “water smart” program for residential users, and various measures that could be regionally coordinated for agricultural users such as irrigation scheduling.

One recurring theme at the regional scale was the need for support from the local level, and encouraging a sense of “belonging to the basin.” Participants also expressed the need for better integration of water issues with local development and planning.

Sommaire executif

Voici le rapport final du projet A463/433 du Programme sur les impacts et l'adaptation liés aux changements climatiques, Ressources naturelles Canada, intitulé «Susciter le dialogue sur les changements climatiques et la gestion de l'eau dans le bassin de l'Okanagan, en Colombie-Britannique». Les activités de recherche décrites dans le présent document sont le fruit d'un travail interdisciplinaire et concerté auquel ont pris part des chercheurs d'Environnement Canada, d'Agriculture et Agroalimentaire Canada, de l'Université de la Colombie-Britannique, du Ministry of Water, Land and Air Protection (ministère de la Protection des eaux, des terres et de l'air) de la Colombie-Britannique, ainsi que du district de Summerland. Une copie électronique du présent rapport est offerte sur le site Web suivant : http://www.ires.ubc.ca.

L'équipe chargée de l'étude a également produit en 2003 un rapport intérimaire, qui peut être consulté sur le site Web suivant : http://www.sdri.ubc.ca/documents/ Okanagan_2003_Interim_Report_Final.pdf

La présente étude a pour but d'établir des scénarios intégrés concernant les changements climatiques et les ressources en eau afin de stimuler une discussion multipartite des intervenants concernés au sujet des répercussions des changements climatiques sur la gestion des eaux dans la région. L'équipe chargée de l'étude espère atteindre deux grands objectifs : a) offrir une série de produits de recherche qui s'avéreront utiles pour les secteurs d'activité régionaux de la vallée de l'Okanagan, et b) établir, pour les répercussions des changements climatiques et les options d'adaptation connexes à l'échelle régionale, une méthode d'évaluation intégrée et participative qu'il serait possible d'appliquer à des sujets de préoccupation concernant le climat au Canada ainsi que dans d'autres pays.

L'étude comporte cinq éléments clés :

1. **Des scénarios de changements climatiques :** réduire à l'échelle régionale les scénarios des changements climatiques globaux;
2. **Des scénarios hydrologiques :** déterminer les répercussions des changements climatiques sur l'hydrologie du bassin;
3. **Des scénarios relatifs à la demande en eau :** élaborer des scénarios de demande future, notamment pour les cultures irriguées et les municipalités, en tenant compte des tendances socio-économiques;
4. **Des options d'adaptation :** analyser les expériences de gestion antérieures et les démarches futures possibles en vue d'accroître l'approvisionnement en eau et/ou de réduire la consommation d'eau;
5. **Un dialogue avec les intervenants au sujet des options d'adaptation :** se renseigner sur les perspectives régionales concernant l'adaptation aux changements climatiques.

Climate

La vallée de l'Okanagan, dont la superficie est de 8 200 km^2, est un bassin long et étroit qui s'étend sur 182 km, depuis Armstrong dans le nord jusqu'à la frontière de l'État du Washington, près d'Osoyoos, dans le sud. Le climat est aride près d'Osoyoos et humide dans les élévations boisées. Une bonne part du fond de la vallée est caractérisée par des conditions semi-arides. Les variations annuelles et décennales sont influencées par des phases variables de l'ENSO (El Niño/Oscillation australe) et de l'ODP (Oscillation décennale du Pacifique), qui ont occasionné des périodes de réchauffement et de refroidissement. En 1976, une phase de réchauffement liée à l'ODP a débuté, mais il y a des preuves que celle-ci s'est peut-être changée en une phase de refroidissement à la fin des années 90.

Les stations climatiques et les lignes de relevés d'enneigement locales ont été analysées en vue de relever des tendances, ainsi que de déterminer l'influence de l'ENSO, de l'ODP et d'autres importants observé à deux stations de longue durée : la station CDA de Summerland et le ranch Vernon Coldstream. Les températures minimales quotidiennes se sont élevées à un taux plus rapide que les températures maximales quotidiennes. Les précipitations printanières et estivales sont en hausse depuis quelques décennies, ce qui contribue vraisemblablement aux augmentations récentes des eaux d'arrivée du lac. Le pourcentage des précipitations tombant sous forme de neige (la « fraction nivale ») diminue dans les stations de la vallée situées à faible altitude, mais non aux altitudes supérieures. La couverture nuageuse a augmenté à l'aéroport de Penticton, surtout la nuit. Ce fait a vraisemblablement contribué à une diminution du rayonnement solaire moyen annuel, tandis que le rayonnement net (la somme du rayonnement solaire et du rayonnement terrestre) s'est intensifié. Le changement de phase lié à l'ODP qui est survenu en 1976 semble avoir causé une réduction de l'équivalent en eau de la neige jusqu'au milieu des années 90. La fonte des neiges survient plus tôt que dans les années antérieures.

Au cours de la période 2002-2003, les conditions ont été nettement plus sèches que dans les années antérieures. La sécheresse de 2003 a été fort intense. À Camp Creek, les débits d'eau se situaient à un niveau de 24 à 49 % de la moyenne de 1965-2003, en raison des faibles quantités de neige accumulées et des conditions atmosphériques chaudes et sèches en été. D'un point de vue climatique, cette situation est peut-être similaire à la sécheresse des années 1920 et 1930, mais les impacts ont probablement été pires à cause du nombre plus élevé d'habitants et d'ensembles résidentiels. Au cours de l'année 2003, des incendies ont détruit plus de 200 foyers.

Dans le bassin de l'Okanagan, de nombreuses cultures dépendent de divers microclimats créés par la topographie complexe. Des microvariations topographiques de pente, d'aspect et d'altitude, de même que les différentes sortes de cultures donnent lieu à un assortiment de microclimats qu'il reste encore à étudier en détail. Le présent projet a eu recours à un réseau de 47 enregistreurs de température informatisés Hobo en vue de recueillir des données sur la température, de sorte qu'il a été possible de cartographier les variations climatiques à micro-échelle afin de comprendre les besoins en eau des cultures et le caractère approprié de ces cultures. Ce réseau a été établi à divers endroits autour de Summerland et de Naramata. D'après les résultats obtenus pour 2002-2003, à ces endroits, la variation climatique est aussi marquée que les différences de températures annuelles moyennes entre Armstrong et Osoyoos. Pour ce qui est de l'accumulation de GDD10, la différence entre l'endroit le plus chaud et l'endroit le plus froid était de 31 %.

S'ajoute aux variations et aux tendances susmentionnées l'effet potentiel de l'accroissement des concentrations de gaz à effet de serre. Les expériences menées dans le cadre de modèles climatiques du globe (MCG) donnent à penser qu'un certain réchauffement a déjà eu lieu, et qu'il se poursuivra dans l'avenir. Pour la présente étude, des scénarios de changements climatiques ont été élaborés à partir de trois MCG différents (MCCG2-Canada, HadCM3-R-U et CSIROMk2-Australie), et de deux scénarios d'émissions globales de gaz à effet de serre provenant de la série SRES du Groupe intergouvernemental sur l'évolution du climat (GIEC) (A2 – augmentation élevée, et B2 – augmentation modérée). Des simulations relatives à trois périodes de trente ans, centrées sur les années 2020, 2050 et 2080, ont été obtenues du site Web du Projet des scénarios canadiens de répercussions climatiques.

En ce qui concerne les années 2050, les élévations de la température hivernale par rapport à la période de référence de 1961-1990 se situent dans la fourchette de 1,5 à 4 °C, avec des augmentations des précipitations hivernales de l'ordre de 5 à 25 %. Pour l'été, tous les modèles font état d'un réchauffement de 2 à 4 °C environ, ainsi que de variations des précipitations allant d'un changement quasi nul à une diminution de 35 % par rapport au niveau de base de 1961-1990. C'est le modèle australien (CSIROMk2) qui reflète le changement le plus marqué dans les conditions hivernales, tandis que le modèle du Centre Hadley (HadCM3), au R.-U., est celui qui indique la variation la plus marquée du climat estival.

Hydrologie

C'est le modèle des bassins versants de l'UBC que l'on a choisi pour modéliser les processus de précipitations-ruissellement. Ce modèle a été abondamment utilisé en Colombie-Britannique; il a été établi qu'il reproduit convenablement la réponse hydrologique des bassins versants, et il a déjà été employé dans des études portant sur les changements climatiques.

Dans l'ensemble, il a été montré que le modèle des bassins versants de l'UBC pouvait être appliqué avec succès au bassin de l'Okanagan. Le climat aride de ce dernier, ainsi que les lacunes du réseau météorologique, font qu'il est plus difficile d'ajuster avec succès ce modèle que dans les bassins versants humides qui manifestent moins de variabilité dans les précipitations sur tout le bassin. En dépit des problèmes de représentativité des données climatiques disponibles, il a été établi que le modèle fonctionne convenablement lorsque l'on se sert de la série moyenne de paramètres et de paramètres de précipitations estimatifs pour le piloter. Dans le même ordre d'idées, il ressort du rendement du modèle au cours de la période de vérification que ce dernier est capable de prévoir des réponses hydrologiques sur des périodes climatiques différentes.

Les scénarios climatiques que prédisent les trois modèles climatiques fournissent des aperçus différents, mais tout aussi plausibles, de l'hydrologie future des bassins versants du bassin de l'Okanagan. Tous les scénarios de changements climatiques incluaient systématiquement une fonte des neiges précoce au printemps, une tendance à un hydrogramme dominé par des chutes de pluie plus nombreuses et de réductions considérables du volume de débit annuel et printanier dans les années 2050 et 2080. Des trois modèles climatiques, c'est le MCCG2 qui a fourni les prédictions les plus prudentes au sujet des répercussions des changements climatiques dans le bassin de l'Okanagan. Les simulations fondées sur le modèle climatique CSIROMk2 ont fait montre d'une nette réduction de la neige accumulée et du volume du débit, et ce, malgré une forte augmentation des précipitations hivernales. Le modèle HadCM3 est celui des trois modèles climatiques qui comporte l'augmentation la plus marquée des températures moyennes en été.

Les scénarios soulèvent des questions au sujet de la disponibilité des ressources en eau futures dans le bassin de l'Okanagan, surtout que des périodes prolongées de faible débit coïncideront vraisemblablement avec un accroissement de la demande en eau des utilisateurs d'eau agricole et domestique. Avec le modèle climatique HadCM3, l'hydrogramme présente des pics et se limite surtout à la période des débits élevés. Un tel scénario poserait des problèmes aux gestionnaires des ressources en eau, qui devraient traiter de la majeure partie de l'eau à l'entrée de leurs réservoirs dans un délai très court,. Ils auraient à gérer le niveau d'eau dans le ou les réservoir(s) en question en gardant à l'esprit le manque prolongé de débits en aval du réservoir durant la saison sèche. Par contraste, les scénarios du modèle CSIROMk2 produisent des hydrogrammes plus plats, qui répartissent l'eau de façon plus égale sur toute la saison, facilitant ainsi le travail des gestionnaires. Cependant, cela serait contrebalancé par la réduction extrême des débits que prévoit le modèle climatique. Dans les deux cas, il serait peut-être plus difficile de gérer les débits environnementaux. Même s'il existe des dispositions permettant de préserver des débits suffisants pour les espèces indigènes lors des périodes de frai et à d'autres moments clés, de quelles options dispose-t-on si les ressources en eau sont trop sollicitées ou si les débits de pointe augmentent? En outre, une orientation vers un régime de précipitations davantage dominé par les chutes de pluie en cas de réchauffement pourrait compliquer le travail de prévision. Les gestionnaires des lacs et des réservoirs utilisent la neige accumulée l'hiver comme guide pour libérer de l'eau ou en emmagasiner, selon que l'on prévoit un surplus d'eau ou une pénurie. Si les chutes de neige diminuent, il pourrait être difficile d'anticiper les périodes de débit exceptionnel, élevé ou faible et d'examiner des pratiques de gestion préventive afin de faire face aux conditions de débit extrêmes.

Demande en eau — Agriculture

Le bassin de l'Okanagan est fortement sollicité pour alimenter en eau des cultures à valeur élevée. Les cultures irriguées se composent principalement de fruits de verger et de raisins de cuve à valeur élevée, de pâturages et de fourrages, ainsi que de quelques légumes. Une base de données sur l'utilisation des terres agricoles dans le bassin de l'Okanagan a été créée et intégrée dans un SIG à l'aide du système ArcInfo^{MD}. Ces données ont été incorporées à un modèle qui s'applique à l'ensemble de la vallée et qui permet d'estimer le besoin en eau des cultures.

Le modèle de besoin en eau des cultures oblige à calculer l'évapotranspiration potentielle, en fonction de la température et de l'énergie solaire, ainsi que la durée de la saison de croissance, qui est fondée sur le début et la fin saisonniers des degrés-jours de croissance qui se situent au-delà de températures minimales critiques pour chaque culture.

Un autre aspect important du modèle concerne les effets potentiels d'une augmentation de la concentration de CO_2 sur la transpiration des végétaux. Bien que l'on ait suggéré une réduction du besoin en eau pour diverses cultures là où la concentration de CO_2 est élevée, la littérature spécialisée n'indique pas clairement si la production légumière et fruitière irriguée et intensivement gérée a occasionné des changements dans la consommation d'eau. Les plantes de grande culture, telles que la luzerne, peuvent être soumises à des réductions du besoin en eau, mais d'autres chercheurs ont montré que ces réductions sont relativement modestes pour les États américains du nord-ouest bordés par le Pacifique. Pour la présente étude, nous avons donc présumé qu'il n'y avait aucun effet.

Les scénarios relatifs au besoin en eau de cultures qui sont issus des scénarios de changements climatiques font état, pour le bassin de l'Okanagan, d'augmentations qui excèdent les estimations du besoin annuel actuel des modèles, qui varie autour de 200 millions de m3. Les augmentations seraient de 12 à 20 % dans les années 2020, de 24 à 38 % dans les années 2050 et de 40 à 61 % dans les années 2080. C'est dans le scénario HadCM3 que l'on relève l'augmentation la plus marquée pour les années 2080, où les températures estivales sont les plus élevées. Le scénario du pire cas pour les années 2080 est proche de l'affectation totale actuelle d'eau pour fins d'irrigation de 323,7 millions de m^3.

Il existe aussi des différences saisonnières et régionales entre les scénarios, ainsi que des différences entre les diverses cultures. D'après le besoin modélisé, la quantité totale la plus importante d'eau était requise pour les pâturages, et la quantité la moins élevée (44 % des besoins liés aux pâturages) l'était pour le raisin. Les pommes exigeaient environ 78 %, et les cerises 87 %, de la quantité nécessaire pour les pâturages. Le faible besoin d'irrigation pour les raisins est imputable à une saison de croissance plus courte et à des besoins de culture moindres lors de l'évapotranspiration de pointe. Par contraste, les pâturages et les fourrages, deux cultures de fin de saison, ont une saison de croissance plus longue et un besoin supérieur. Les fruits de verger ont une saison de croissance plus courte que les pâturages, mais le besoin de pointe est supérieur. Vu les différences entre les cultures, les variations régionales et saisonnières du besoin ont été déterminées en grande partie par l'utilisation prédominante des terres. C'est donc dire que dans des conditions de pénurie d'eau future, il est possible que le profil des cultures ait une incidence sur les stratégies d'adaptation potentielles. En outre, certaines cultures, telles que les cultures en ligne, les fruits de verger et le raisin, conviennent à des microsystèmes d'irrigation efficaces, ce qui peut mener à une nette réduction de la consommation d'eau.

En l'absence d'une estimation globale de l'alimentation en eau du bassin, les arrivées d'eau modélisées du lac Okanagan ont été utilisées comme indicateurs de l'évolution de l'hydrologie du bassin et comparées ensuite aux estimations du besoin en eau de cultures. Au cours du siècle dernier, les arrivées d'eau modélisées du lac Okanagan ont diminué jusqu'à 69 % environ des arrivées d'eau actuelles, ce qui dénote une réduction générale de l'approvisionnement; cette réduction pourrait peut-être exacerber les pénuries causées par une intensification du besoin en eau de cultures.

Demande en eau — Secteur résidentiel

Des analyses ont été réalisées pour déterminer dans quelle mesure les changements climatiques, en raison des variations des températures maximales, peuvent avoir une incidence sur la consommation d'eau extérieure du secteur résidentiel, dans le contexte d'autres facteurs socio-économiques qui agissent eux aussi sur la demande. Une analyse historique et des projections ont permis de représenter trois grands facteurs de changements dans la région de l'Okanagan, en utilisant la ville de Penticton comme étude de cas. Les trois facteurs pris en considération étaient les suivants : 1) les changements démographiques, 2) les changements dans les types de logement privilégiés, et 3) les variations de température dues aux changements climatiques. Comme les habitants de la région de l'Okanagan vieillissent, il y a plus de chances qu'ils vivent dans des logements bas dotés d'une pelouse et d'un jardin, ce qui donne lieu à une consommation d'eau extérieure importante.

Trois scénarios démographiques différents ont été envisagés et combinés à des projections générées de façon indépendante au sujet des logements. La consommation d'eau intérieure et extérieure future pour chaque type de logement a été estimée pour la période de 2002 à 2069, et des rajustements ont été apportés à la consommation d'eau extérieure en prenant pour base six scénarios de changements climatiques différents, ainsi qu'un scénario dans lequel les changements climatiques n'ont pas été pris en compte.

Dans tous les cas, la consommation d'eau semble varier considérablement entre les trois scénarios démographiques. Les changements climatiques sont censés avoir un effet additif sur n'importe quel scénario démographique. Toutefois, les variations entre les divers scénarios climatiques semblent modérées. Ainsi, dans les scénarios de croissance démographique élevée, l'augmentation de la consommation d'eau par rapport à 2001 varie de 297 à 328 %. Selon un scénario de croissance démographique nulle et de changements nuls dans les préférences en matière de logement, les augmentations de la consommation d'eau pour les scénarios climatiques varient de 5,6 à 9,5 % entre 2001 et les années 2020, ainsi que de 9,1 à 17,8 % entre 2001 et les années 2050. Ces résultats peuvent être mis en contraste avec les augmentations de la consommation qui sont associées aux projections démographiques seules, lesquelles varient de 54 à 265 % entre 2001 et les années 2050.

D'après ces premiers résultats, si l'on considère l'effet des changements climatiques par rapport aux effets de la croissance démographique, une augmentation de 9 % due aux changements climatiques (le changement le plus faible parmi les scénarios climatiques) entre 2001 et les années 2050 équivaut à une accélération de l'effet de la croissance démographique sur 50 ans de onze années pour une croissance faible, de sept années pour une croissance moyenne et de quatre années pour une croissance élevée. Quant au scénario climatique le plus « dramatique » - le HadCM3-A2 - l'augmentation de 18 % de la consommation équivaut à une accélération de 18 années pour une croissance faible, de 13 années pour une croissance moyenne et de 7 années pour une croissance élevée.

Il est nécessaire de réaliser un plus grand nombre d'études de cas si l'on veut évaluer les effets interdépendants de la croissance démographique et des changements climatiques sur la demande en eau dans le secteur résidentiel pour diverses collectivités situées dans la région de l'Okanagan. Si les changements climatiques accélèrent l'effet démographique, cela a des répercussions sur la planification à long terme, surtout si l'on ajoute à l'équation les augmentations projetées du besoin en eau de cultures.

Scénarios liés à l'approvisionnement et à la demande en eau

L'un des grands risques que court le secteur agricole dans la vallée de l'Okanagan est la survenue de sécheresses et leur fréquence. Dans les systèmes de production qui dépendent entièrement de l'irrigation, une sécheresse peut se définir comme l'incapacité de fournir un approvisionnement en eau suffisant pour maintenir un rendement économique. Une sécheresse comporte, dans ce cas-ci, deux éléments : une forte demande et un faible approvisionnement. On pourrait s'attendre à ce que le risque s'aggrave quand une forte demande et un faible approvisionnement sont combinés. Dans l'étude actuelle, nous définissons les seuils de risque qui sont associés 1) à des limites opérationnelles de la demande et à des limites hydrologiques de l'approvisionnement pour Trout Creek, qui approvisionne en eau le district de Summerland, et 2) à une demande et à un approvisionnement maximums modélisés pour la période de 1961-1990 pour Ellis Creek et Penticton Creek, qui approvisionnent en eau la ville de Penticton. Des estimations annuelles de l'approvisionnement et de la demande ont été produites pour quatre périodes : le climat historique de 1961-1990, les années 2020, les années 2050 et les années 2080.

Pour Summerland, au cours d'une année moyenne, l'abondance totale de Trout Creek est estimée à 84,1 millions de m^3 environ, dont 2,5 millions de m^3 seraient retirés à des fins commerciales et domestiques, et un maximum de 10,5 millions de m^3 pour l'irrigation. Cette valeur représente environ la moitié de l'affectation autorisée pour l'irrigation, soit 20,93 millions de m^3. Dans le scénario de changements climatiques MCCG2-A2, le nombre d'années pendant lesquelles le seuil modélisé du besoin en eau d'irrigation pour les années 1990, soit 10 millions de m^3, pourrait être excédé a augmenté à la longue, atteignant environ 18 ans sur 30 dans les années 2080. Les différences de réponse entre les scénarios d'émissions A2 et B2 ne sont devenues évidentes qu'à la fin du siècle. Les estimations de la demande variaient entre les MCG, et les réponses les plus extrêmes sont survenues dans les scénarios HadCM3-A2, où, dans les années 2080, la demande excédait chaque année le seuil.

Durant la période de 1961 à 1990, il n'y a eu aucun cas modélisé où la demande a excédé ce seuil pour les années 90.

La demande est censée augmenter, mais on prévoit que l'approvisionnement diminuera. Un seuil de sécheresse de 30,3 millions de m^3 (36 % de l'abondance annuelle moyenne) a été proposé pour Trout Creek. Entre 1961 et 1990, il n'y a eu qu'un seul cas en 30 ans de débit sans restrictions et modélisé qui était inférieur au seuil de sécheresse, ce qui donne une fréquence de 3 %. Pour les scénarios A2, cette proportion a augmenté à 7 % dans les années 2020, à un niveau de 17 à 25 % dans les années 2050 et à un niveau de 31 à 44 % dans les années 2080. Le modèle CSIROMk2 est celui qui a produit les scénarios A2 les plus secs. Pour ce qui est des scénarios B2, il y a eu moins de débits minimums extrêmes que dans le cas des scénarios A2, sauf pour les scénarios CSIROMk2-B2, qui ont produit plus d'années de sécheresse dans les années 2020 et des fréquences d'événements similaires dans les années 2050 et 2080, comparativement aux scénarios A2.

Il est évident que l'infrastructure hydraulique existante, qui assure une capacité utile de 9,1 m^3 x 106, sera incapable de suffire à la demande lors des années de climat futur extrême. Dans tous les scénarios de changements climatiques, il y a plus de risques que le besoin en eau des cultures excède le seuil actuel. Dans l'intervalle, la fréquence des débits annuels inférieurs au seuil de sécheresse montre des augmentations similaires dans tous les scénarios. Les résultats à risque élevé, pour le réseau de Trout Creek, s'entendent des années dans lesquelles la demande excède 10,5 millions de m^3 et l'approvisionnement demeure en deçà du seuil de sécheresse, qui est de 30,3 millions de m^3. Les scénarios A2 ont donné lieu à des résultats à risque élevé pour le HadCM3 dans les années 2050 (une année sur six) et pour tous les MCG dans les années 2080 (de 1 an sur 4 à 1 an sur 2). L'incidence de la réponse « à risque élevé » pour les scénarios B2 était inférieure à l'incidence relevée dans les scénarios A2.

Un autre sujet de préoccupation est le moment de l'approvisionnement et de la demande. Selon les hydrogrammes modèles générés à l'aide du modèle de l'UBC pour les cours d'eau de l'Okanagan, un débit de pointe précoce est une réponse caractéristique aux scénarios de changements climatiques. Dans de telles conditions, l'eau disponible pour l'irrigation à partir du débit d'entrée ne le serait pas pour une bonne partie de la saison de croissance; cela taxerait le système d'approvisionnement parce que l'on dépendrait tôt de l'eau stockée, comme ce fut le cas en 2003.

Des résultats similaires ont été obtenus pour Penticton. Pour les scénarios A2, le nombre d'années pendant lesquelles on pourrait excéder le seuil de demande de 1961-1990 à Penticton Creek a augmenté à la longue, passant de 6 années sur 30 dans les années 2020 à 30 années sur 30 dans les années 2080. Les estimations de la demande variaient entre les MCG, et les réponses les plus extrêmes sont survenues dans les scénarios HadCM3-A2, où, dans les années 2050, les besoins excédaient le seuil chaque année. Des réponses similaires ont été relevées pour le secteur d'irrigation sud qu'alimente Ellis Creek.

Par contraste avec le système d'approvisionnement en eau de Trout Creek/Summerland, la demande en eau de Penticton est dominée par les besoins domestiques. Les besoins d'irrigation modélisés au sujet des systèmes d'irrigation nord et sud combinés pour la période de 1961 à 2003 dénotent que, à l'heure actuelle, l'irrigation exige tout juste moins de la moitié de la quantité d'eau requise pour répondre aux besoins domestiques. La fréquence avec laquelle le besoin en eau d'irrigation annuel modélisé excédait les années les plus extrêmes au cours de la période de référence de 1961 à 1990 a augmenté pour tous les modèles et pour tous les scénarios durant le siècle tout entier. Dans le même ordre d'idées, pour Penticton Creek et Ellis Creek, les scénarios ont mené à une augmentation de la fréquence des années où le débit était inférieur au minimum modélisé pour la période de référence. De ce fait, pour le système d'irrigation nord comme pour le système d'irrigation sud, il y avait un risque accru qu'un besoin élevé coïncide à la longue avec un faible approvisionnement. Pour les trois MCG, les scénarios A2 se sont soldés par une fréquence accrue de ces résultats à risque élevé; dans les années 2050, entre 1 année sur 10 et 1 année sur 6, et dans les années 2080, entre 1 année sur 3 et 1 année sur 2. Les résultats à risque élevé étaient moins nombreux dans les scénarios B2. Lors de certaines années très extrêmes, il est possible que la demande soit supérieure à l'approvisionnement.

Gestion des ressources en eau (extrait du rapport intérimaire de 2003)

Le bassin versant de l'Okanagan comporte trois grandes caractéristiques qui font ressortir la structure complexe et multi-échelle des organisations et des institutions interdépendantes qui prennent part aux décisions relatives à la gestion des ressources en eau :

- le réseau hydrographique franchit une frontière internationale;
- la présence de multiples paliers de gouvernement;
- de multiples utilisations des eaux à l'intérieur et à l'extérieur des cours d'eau, ce qui signifie de nombreux organismes de défense situés à des échelles différentes.

La gestion des ressources en eau est assurée par divers paliers de gouvernement (fédéral, provincial et local), de même que par des organismes régionaux qui se concentrent sur des questions précises. Ces derniers comprennent l'Okanagan Basin Water Board, qui s'est récemment chargée de l'élimination de déchets liquides et de la myrophylle en épi, ainsi que l'Okanagan Basin Technical Working Group, qui relève et dirige les initiatives destinées à reconstituer les stocks de poissons.

Le bassin de l'Okanagan est aussi intéressant pour analyser la question de l'affectation des eaux et de l'attribution de permis d'exploitation à cause de son climat semi-aride, de sa population grandissante et de l'importance de l'irrigation pour l'économie régionale. Au mois de juillet 2002, on comptait environ 4 130 permis d'exploitation d'eau en vigueur dans le bassin de l'Okanagan, selon la base de données Water License Query que tient Land and Water BC. Ces permis représentent environ 1,05 milliard de m^3 d'eau allouée sur 980 cours d'eau pour fins de consommation ainsi que pour des utilisations internes. Soixante-six demandes de permis d'exploitation d'eau étaient également inscrites, représentant une quantité additionnelle de 209 millions de m^3. Sur les 1,05 milliard de m^3 d'eau alloués dans l'Okanagan, 476,8 millions le sont à des fins de consommation, pour lesquelles l'eau est retirée de la source. Environ les deux tiers sont destinés à l'irrigation.

Dans le contexte de l'adaptation aux changements climatiques dans la vallée de l'Okanagan, le régime réglementaire de la Colombie-Britannique présente plusieurs défis. L'augmentation des demandes d'eau, attribuable à la croissance démographique, et les changements dans la demande et l'approvisionnement en eau, imputables aux changements climatiques, peuvent donner lieu à une activation accrue du principe de l'appropriation antérieure, ce qui susciterait davantage de conflits. Même si l'on règle souvent les conflits sur le terrain grâce à des méthodes plus équitables, les contraintes hydriques accrues font que la situation est plus fragile. Dans les mêmes conditions, le principe de l'utilisation bénéficiaire pourrait devenir une exigence plus importante pour l'attribution des permis d'exploitation à mesure que les sources d'eau se saturent. La nature perpétuelle des permis d'exploitation d'eau et la capacité restreinte qu'ont les gestionnaires de modifier les droits relatifs à l'eau (p. ex., la transférabilité et les conditionnalités) peuvent devenir restrictives face à une intensification des besoins de gérer les ressources en eau en fonction de multiples objectifs (lesquels peuvent être assujettis ou non à l'attribution d'un permis d'exploitation d'eau). Il pourrait être de plus en plus ardu, dans le cadre d'un scénario de changements climatiques, de mettre en équilibre les utilisations internes (p. ex., le poisson) et les utilisations externes (p. ex., la consommation domestique et l'irrigation).

S'ajoute à cette question de la mise en équilibre des diverses utilisations des ressources en eau l'incapacité de définir des débits minimaux acceptables pour le poisson. En outre, la Fisheries Protection Act de la Colombie-Britannique, dont les dispositions permettraient aux gestionnaires d'accorder des permis d'exploitation d'eau en vue de protéger le débit interne des cours d'eau, et de réduire la consommation d'eau en temps de sécheresse, n'a pas encore été proclamée.

Études de cas sur l'adaptation

L'adaptation aux répercussions des changements climatiques - ainsi qu'à d'autres facteurs de stress - sur les ressources en eau de la vallée de l'Okanagan représente un défi de taille pour les décisionnaires tant provinciaux que locaux; mais comment les autorités locales, dans la région de l'Okanagan, se sont-elles adaptées aux pressions que subissent présentement les ressources en eau? Pour en savoir plus sur ce que les options d'adaptation impliquent et cerner des défis locaux particuliers, quatre études de cas portant sur les méthodes de gestion de l'eau à l'échelon des autorités locales ont été choisies. Chacune représente l'adoption d'une approche différente en matière d'utilisation efficace de l'eau, soit : le comptage de la consommation domestique à Kelowna, le comptage de l'eau d'irrigation dans le SEKID, la récupération des eaux usées à Vernon et le changement institutionnel, plus précisément la fusion de services publics individuels d'alimentation en eau, dans la région métropolitaine de Vernon. Les trois dernières approches représentent des « adopteurs précoces » dans la région.

L'objectif premier des études de cas était d'analyser de quelle façon les autorités locales s'adaptent aux circonstances changeantes qui influent sur leurs ressources en eau : les facteurs qui déclenchent une adaptation précoce, les options choisies et le succès ou l'échec de la mise en œuvre de ces dernières, de même que les capacités qui ont facilité l'adaptation, c'est-à-dire la capacité adaptative. L'étude de l'adaptation à partir d'une perspective qui comporte de nombreux facteurs de stress accentue la nature contextuelle de l'adaptation aux changements climatiques; c'est-à-dire que de nombreux facteurs - d'autres pressions environnementales - ainsi que des questions de nature politique et socio-économique, limiteront, entraveront ou favoriseront en fin de compte une adaptation efficace. Les objectifs secondaires de l'étude consistaient à analyser l'efficacité des quatre méthodes de gestion et à étudier le rôle de l'apprentissage dans le processus d'adaptation. Vingt-huit entrevues semi-structurées avec des gestionnaires locaux des ressources en eau, des membres de Conseil et d'autres informateurs clés ont été réalisées.

Ces cas montrent que l'adaptation n'est pas un processus linéaire bien net. Même s'il a été possible de relever dans chaque cas un déclencheur particulier, notamment les épisodes de sécheresse et les études principales provinciales, des conditions différentes ont façonné l'attribution, c'est-à-dire l'interprétation de la cause, ainsi que le mode d'interprétation approprié à appliquer. L'intervention a été immédiate ou retardée, suivant l'interprétation de caractéristiques indicatives telles que l'ampleur (par rapport à des événements connexes vécus antérieurement), le caractère immédiat et le caractère tangible, de même que divers facteurs sociopolitiques. En fin de compte, dans chaque cas, des mesures ont été prises lorsqu'un seuil d'intervention perçu approchait rapidement. La sélection d'une option était influencée par la disponibilité de cette option, les programmes et les valeurs à l'échelon local et provincial (y compris les encouragements financiers), et l'efficacité prouvée antérieurement. Les processus de décision et de mise en œuvre ont été moins conflictuels lorsque les groupes d'utilisateurs étaient bien informés. L'effet de cycles politiques de brève durée sur la mise au point et le maintien d'une certaine méthode de gestion a été particulièrement évident dans l'un des cas; à chaque cycle, les valeurs nouvelles de l'autorité menaient à un changement de cap, ce qui amoindrissait l'efficacité ultime de l'intervention.

Dans l'ensemble, les mesures prises dans les quatre cas semblaient fructueuses. Des « économies » d'eau ont été réalisées dans les deux exemples de comptage de la consommation. Kelowna a atteint l'objectif fixé à l'avance de réduction de 20 % pour son projet de comptage de la consommation des habitations unifamiliales. Dans le SEKID, les attributions d'eau annuelles ont été réduites de 10 %. Même si la récupération des eaux usées a d'abord été mise en œuvre en tant que stratégie de traitement des eaux (une stratégie efficace, quant à cela), on la considère aujourd'hui comme une stratégie de réutilisation potentielle de l'eau et donc, une stratégie d'efficacité. Quant à la fusion des services publics d'alimentation en eau de la région métropolitaine de Vernon, l'efficacité n'est pas facile à mesurer. Cette mesure pourrait mener à une utilisation plus efficace des sources d'eau disponibles grâce à la mise en commun des sources auparavant destinées à des services publics distincts. Le partage des coûts est un autre avantage de la fusion.

Il y a quelques leçons bien claires que l'on peut tirer de ces études de cas et qui sont importantes pour répondre à la question suivante : comment s'adapter aux changements climatiques dans la vallée de l'Okanagan? La peur du changement – le défi de la transition – est généralisée. De nombreux facteurs exacerbent la difficulté d'effectuer un changement ou aplanissent le processus : les perceptions du public et les programmes politiques divergents sont deux aspects clés. Les utilisateurs du secteur agricole ont un fort sentiment de propriété à l'égard des ressources en eau à cause de leur domination historique au sein de la région. En outre, on s'attend à des tarifs peu élevés pour la consommation d'eau, car c'est là la norme depuis bien des années. Les relations divergentes entre les autorités locales, régionales et provinciales signifient que la recherche d'une approche unifiée dans la région pourrait déclencher une lutte politique de longue durée. Enfin, n'importe quelle option d'adaptation mènera en fin de compte à des économies afin de permettre simplement de mettre davantage en valeur la région, et ce, sans changer le programme de mise en valeur. De telles approches n'amoindriront pas la vulnérabilité locale aux répercussions des changements climatiques.

Coûts des options d'adaptation (extrait du rapport intérimaire de 2003)

Il existe un certain nombre d'options d'adaptation qui peuvent aider à parer les pénuries possibles attribuables aux changements climatiques et à d'autres facteurs tels que la croissance démographique. Au nombre de ces options figurent à la fois des mesures axées sur la demande et des mesures axées sur l'approvisionnement. Les options axées sur la demande incluent des solutions de rechange en matière de conservation de l'eau, comme la planification de l'irrigation, l'éducation publique, le comptage et l'adoption de technologies de micro-irrigation efficaces. Les options axées sur l'approvisionnement comprennent l'augmentation du stockage en amont et l'utilisation des lacs ou des rivières principaux comme source d'approvisionnement, afin de compter ainsi sur la vaste capacité de stockage du lac Okanagan.

Les coûts de ces deux types d'options varieront considérablement, suivant les diverses caractéristiques des systèmes d'alimentation en eau et le genre de besoins auxquels on répond. En résumé, il n'existe aucune option d'adaptation la moins coûteuse pour l'ensemble des systèmes de distribution d'eau, car les coûts varieront considérablement d'un système à un autre. L'option la moins coûteuse dans un secteur pourrait être la plus coûteuse dans un autre. D'autres facteurs, tels que la qualité de l'eau et les options de traitement, entreront aussi en ligne de compte. Il sera souvent nécessaire d'adopter une combinaison d'options pour s'assurer entièrement contre les pénuries d'eau et les augmentations des besoins dans l'avenir.

En ce qui concerne les budgets futurs, il semble que les systèmes qui sont déjà proches de leur capacité auraient à envisager des coûts d'au moins 1 000 $ l'acre-pied pour conserver ou mettre en valeur les réserves en vue de s'adapter aux changements climatiques. Si les projections indiquent qu'il est nécessaire de conserver ou de fournir de grandes quantités d'eau, cela veut dire que la somme de 2 000 $ l'acre-pied serait probablement un chiffre raisonnable à envisager pour les budgets futurs. Il faudrait aussi réaliser des études techniques localisées de manière à obtenir des chiffres plus exacts.

Dialogue avec les intervenants

Le dialogue avec les intervenants a servi à faire part des résultats de la recherche aux praticiens et aux gens d'affaires locaux dans le domaine de l'eau, ainsi qu'à se renseigner sur les perspectives régionales concernant la façon dont les options d'adaptation pourraient être mises en application à l'échelle des collectivités et du bassin.

Deux endroits visés par les études de cas - Oliver et la Trépanier Landscape Unit - ont été choisis pour les deux ateliers d'adaptation communautaires tenus dans l'Okanagan. Oliver est une petite collectivité agricole située dans le sud de la vallée. La Trépanier Landscape Unit, qui englobe Peachland et des secteurs non constitués autour de Westbank, est une zone à croissance rapide, sise à l'ouest de Kelowna. On a présenté aux participants une série d'options de gestion de l'eau techniquement viables, tant du côté « approvisionnement » que du côté « demande », et on leur a demandé de les évaluer en fonction de huit questions. Ces dernières portaient sur trois grands thèmes : l'acceptabilité sociale des options, l'acceptabilité juridique actuelle et les préoccupations d'ordre politique/juridictionnel.

Les résultats de ces ateliers révèlent le paysage politique complexe qui recouvre le paysage physique de la région. Les engagements historiques faits aux utilisateurs du milieu agricole façonnent l'affectation actuelle des ressources en eau et influent dans une large mesure sur l'acceptabilité des options d'adaptation. Les interventions axées sur l'éducation et la conservation ont été jugées utiles dans les deux collectivités. Au chapitre de l'utilisation des eaux souterraines, de nombreux participants ont fait remarquer que bien qu'il puisse s'agir d'une source de rechange viable dans certains secteurs, l'extraction n'est actuellement pas réglementée. Les pressions qu'exerceraient des sécheresses croissantes sur les sources d'eau traditionnelles pourraient donc mener à un retrait largement non réglementé d'eaux souterraines.

Un troisième atelier portait sur la mise en application d'un portefeuille d'adaptation à l'échelon du bassin. Cette activité a été une occasion supplémentaire de discuter de la faisabilité de mesures d'adaptation préventives, mais cette fois-ci la discussion a principalement porté sur les changements qui toucheraient la région tout entière ou qui seraient mis en œuvre dans cette dernière. Comme la discussion portait sur une région géographique plus vaste, les options d'adaptation analysées étaient elles aussi plus vastes. Les participants ont discuté de démarches générales, tant du côté « approvisionnement » que du côté « demande », plutôt que de stratégies localisées. Ils ont aussi mis davantage l'accent sur les structures de gestion susceptibles de mettre en œuvre et d'orchestrer des changements à cette échelle.

Le dialogue, à cet échelon, a été plus stratégique. Les participants se sont dits en faveur d'une expansion du rôle de l'Okanagan Basin Water Board (OBWB) et de l'Okanagan Mainline Municipal Association (OMMA) sur le plan de la gestion régionale de la quantité d'eau. Ils se sont également dits en faveur de la gestion de diverses mesures pour l'ensemble du bassin, dont une utilisation accrue du lac Okanagan et des sources souterraines, un programme coordonné de consommation avisée à l'intention des utilisateurs du secteur résidentiel, de même que diverses mesures qui pourraient être coordonnées à l'échelon régional pour les utilisateurs du secteur agricole, comme la planification de l'irrigation.

Un thème récurrent à l'échelon régional a été le besoin d'un appui au niveau local, et le fait de favoriser un sentiment d'« appartenance au bassin ». Les participants ont également exprimé le besoin de mieux intégrer les problèmes d'eau aux activités locales de mise en valeur et de planification.

Vers une décision –Regard sur l'avenir

Cette étude concertée présente un scénario de changements climatiques et ses répercussions pour la gestion des réserves en eau dans le bassin de l'Okanagan au cours du XXI^{e} siècle. L'étude est basée sur des travaux de recherche sur le terrain, des modèles informatiques et des activités de dialogue, en vue d'obtenir une évaluation des répercussions futures et de se renseigner sur les vues régionales au sujet des perspectives d'adaptation. Elle a bénéficié en cours de route de solides partenariats avec les praticiens et les groupes d'utilisateurs locaux.

L'étape suivante consiste à étudier des options précises en matière de politique d'adaptation. Nous sommes heureux de signaler qu'une proposition complémentaire a été approuvée pour la période de 2004-2006 par le nouveau Programme sur les impacts et l'adaptation aux changements climatiques du gouvernement du Canada. L'objectif de cette nouvelle initiative est de créer un modèle pour le système de gestion des ressources en eau de l'Okanagan, avec le concours de spécialistes régionaux, et de se servir de ce modèle pour favoriser un dialogue nouveau sur la politique d'adaptation.

Nous sommes impatients de mener à bien cette nouvelle initiative.

chapter 1

Background and Objectives

Stewart Cohen, Denise Neilsen and Brian Symonds

This is the Final Report of the study on Okanagan water management and climate change, project A463/433 under the Climate Change Impacts and Adaptation Program (CCIAP), Natural Resources Canada. This is being offered both to fulfill reporting requirements of CCIAP, but also as a record for the research team, its partners, and interested parties in the Okanagan and elsewhere.

1.1 Will the Water be there?

Water resources, their management and use, are known to be sensitive to variations in climate, and will be influenced by climate change projected from future increases in greenhouse gas concentrations in the atmosphere. Hydrologic studies of various watersheds throughout the world (Schriner and Street, 1988; Arnell *et al.*, 2001) suggest changes in total annual flows, seasonal aspects of water supply and demand, implications for ecosystems, and challenges for managers in meeting multiple objectives (energy, irrigation, navigation, flood control, etc.). These impacts would vary between different scenarios of climate change, which depend on different storylines describing population growth and greenhouse gas emissions, and variations in climatic simulations resulting from different climate models (Arnell, 2004).

In Western North America, most rivers are dominated by snowmelt runoff, often comprising 50-80% of annual flow, and since the late 1940s, a shift in the timing of snowmelt runoff towards earlier dates has been observed (Stewart *et al.*, 2004). This has been strongly connected with observed increases in spring air temperatures. Projected warming during the 21st century would lead to a continuation of this trend, with implications for reservoir management and water users (Stewart *et al.*, 2004).

The Columbia Basin has been the subject of some detailed case studies (Mote *et al.*, 1999, 2003; Hamlet and Lettenmaier, 1999; Miles *et al.*, 2000; Payne *et al.*, 2004), and there has been an initial attempt to bring in transboundary perspectives (Cohen *et al.*, 2000). This work suggests that a warmer climate would lead to changes in hydrology, including reduced snow pack and earlier snowmelt peaks, with subsequent implications for regional water supplies and fisheries. The earlier peak would lead to increased flow during winter months and an earlier flood season. Less water would be flowing during the summer months when irrigation demand is highest. Low summer flows would also affect hydroelectricity production and salmon habitat.

One of the potential implications of climate change on fish is that higher temperature may change the timing of certain aspects of the fish life cycles. For example, warmer stream temperature may delay fish moving into the streams to spawn which may in turn affect egg to fry survival. Warmer water temperatures might result from higher air temperatures and reduced stream flows. One of the other impacts of an earlier peak would also be an early recession of the hydrograph which would require water to be released from storage sooner and for a longer period of time to meet any shortfalls between demand and natural flows. Implications of this scenario for the Columbia system are that maintaining minimum flow requirements for fish would necessitate reductions in hydroelectricity production, as well as reconsideration of flood control policy (Payne *et al.*, 2004).

These findings have contributed to a growing dialogue on water management and climate change on the American side of the Columbia Basin. This needs to be matched by a similar dialogue in Canada, and ultimately, a bi-national one. Although basin-wide hydrologic assessments have been done, detailed hydrologic studies on the Canadian side were not part of this. The Okanagan region is one such area needing attention.

The Okanagan is already experiencing rapid population growth and land use changes, with associated stresses on its water resource systems. The specific operating context of the Okanagan Basin is that it is a semi-arid region, supporting irrigated agriculture and recreational fisheries. Hydroelectric production is not a factor within this area as the tributary and mainstem streams are relatively small. Given this context, there are some specific issues to consider:

1. There is a greater sensitivity of semi-arid and arid areas to small changes in precipitation. A few centimetres of change in precipitation in the Okanagan would have a much more significant impact on the water supplies and flood risks than the same change on the Pacific coast.
2. Rapid population growth in the valley is challenging decision makers to find means to effectively integrate water management considerations into land use planning.
3. Many of the resident and anadromous fish species in the Okanagan are highly sensitive to the incremental impacts of reduced low flows, changes in the timing of peak flows and increases in water temperature.
4. Agriculture is an important component of the regional economy which is highly dependent upon there being a reliable supply of irrigation water. Climate change is expected to impact both the demand for and availability of water for irrigation purposes.
5. If the mainstem lakes at lower elevations are to be used as water sources, there will be additional infrastructure and operating costs associated with pumping of water to the upland areas. For example, most of the distribution systems are designed to be gravity fed from upland sources and may not be readily adaptable to pumping from the lakes without significant capital input.
6. There are long standing different and often conflicting economic, environmental and social water management interests in the region (e.g., flood management, water supply, instream requirement, tourism, recreation, etc.). Competition between the different interests was recognized in the 1974 Okanagan Basin Study (Canada-British Columbia Consultative Board, 1974) and in previous studies dating back to the early part of the last century.

Another important aspect is the need to broaden the dialogue on adaptation (Smit *et al.*, 2001). Changes in climate parameters may change opportunities and risks, but climate represents only one of many issues to be considered in resource management and use. In principle, there are many technical and institutional options available, but the implications of selecting any particular options have not been explored in a long-term planning and climate change scenario context. Certain options, such as new water pricing regimes, water banks, or purchases of water rights (Bruce *et al.*, 2000; Miller, 2000, Mote *et al.,* 2003) are being considered and tested in areas in the U.S. facing water shortages now (e.g. California, Idaho). Another example is a 'new regional governance model' for river stewardship in southern Oregon, proposed in the aftermath of the 2001 drought (Slaughter *et al.*, 2002). However, it is not clear how these or other options would perform under a particular scenario of regional development (e.g. conversion of pasture to high intensity horticulture, urban growth, tourism growth, demands from the Columbia system) or a different climatic and hydrologic regime (e.g. longer warmer growing season, higher summer demand for electricity, changing winter/spring flood regime, changing fire and disease risks).

Coupled with the impacts and adaptation challenges being faced by the Okanagan and Columbia watersheds, there is also an important methodological concern - bringing regional aspects of climate change into a global-scale research and policy environment. Analyses within natural and social sciences have long been faced with the trade-off of choosing between the difficulties of accounting for complex regional detail, and the ease of simpler aggregation accompanied by unrealistic assumptions about natural processes and human behaviour. National and global model-based impacts studies are, by necessity, highly aggregated. These incorporate assumptions about adaptation choices, and their acceptance into practice. Damage costs and adaptation costs and benefits have been estimated for the U.S. using these kinds of assumptions (Mendelsohn and Neumann, 1999). Results can be quite sensitive to what is assumed about levels of shoreline protection, choice of tree species for planting, etc., and how widespread these practices would become during the scenario time period.

If we're going to estimate the costs of climate change impacts, and the value of any adaptation investments, there needs to be more attention given to the development of adaptation scenarios that could reflect regional opportunities and constraints associated with any options that might be considered. Just because a growing season may become longer doesn't mean that all decision makers will be able or willing to adjust to this in the same way or at the same pace. What would stakeholders really do in the face of such changes? How would governments, communities and the private sector incorporate uncertain scenarios of climatic change into their planning? This suggests that dialogue with stakeholders needs to be an explicit part of the process of framing research questions and carrying out impact and adaptation assessments.

1.2 Previous Work, 2000-01

This study of Okanagan water resources and climate change implications builds on two studies conducted during 2000-01. One of these focused on hydrologic aspects while the other was oriented towards irrigated agriculture, the largest consumer of water in the region. The hydrologic study (Cohen and Kulkarni, 2001) had two main goals:

1. To identify climate change impacts on regional hydrology, and possible adaptation strategies for the Okanagan region, and
2. To test an approach for engaging resource managers and regional stakeholders as collaborators in research and dialogue on climate change impacts and adaptation.

Figure 1.1 illustrates how the 2001 study was organized. The relatively short duration of available time for this study (one year) precluded consideration of a major effort at modeling all natural and human processes relevant to climate and water. Rather than developing an all-inclusive model of water resources, in which the connections to climate and management decisions are mathematically expressed, the approach here was to use dialogue to complement mathematical models. This enables the inclusion of issues that may be difficult to model in such terms. Mathematical models were used strategically to generate information on known environmental indicators and processes (temperature, precipitation, snow pack, runoff, streamflow). Dialogue was used for those indicators and processes that include a human component (irrigation, land use, forestry, fisheries, and institutional arrangements).

Climatic change scenarios, obtained from simulations from three climate models, indicated a temperature increase of 1.0-2.5°C from the 1961-1990 base period to the 2020s, and 3-5°C by the 2080s. Higher precipitation was projected for winter, but the climate model simulations did not agree on the direction of change for summer. Results for the climate scenarios for six unregulated creeks within the Okanagan Basin indicated earlier onset of spring peak flows, by as much as 4-6 weeks. The peak was generally lower than

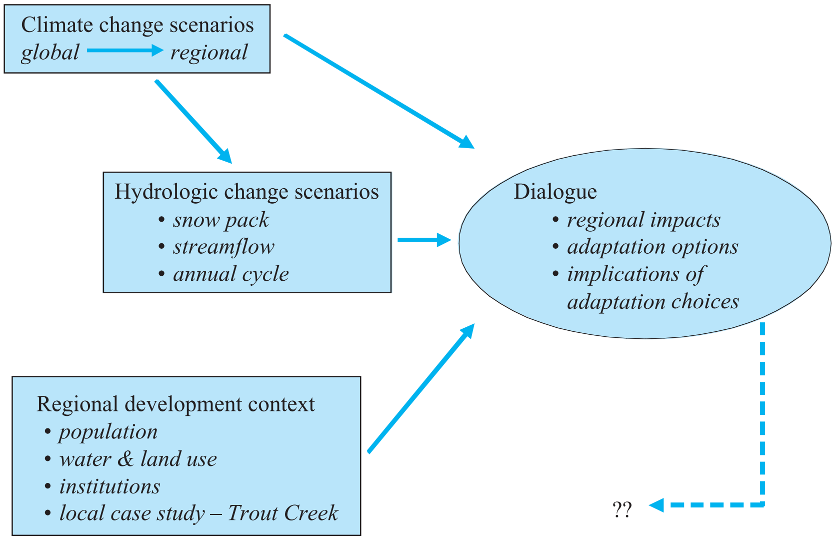

FIGURE 1.1:

Okanagan Climate and Water Resource Impacts Study Framework (Cohen and Kulkarni, 2001).

current peak flows. All areas showed loss of snowpack, with the highest elevation creeks showing the smallest loss. Winter flow would increase, while summer flow would decrease. There was no consensus on scenario changes to total annual flow.

The above analyses were followed by a dialogue process consisting of focus group exercises designed to elicit views on impacts, adaptation, and implications of adaptation choices. Participants identified impacts for forestry, agriculture, fisheries, infrastructure, health and ecosystems. Subsequent consideration of adaptation options resulted in a preference for structural measures, particularly intervention to prevent impacts (e.g. snow making, dams at high elevations, controls on land use and irrigation). Other popular alternatives were developing alternative uses for resources (e.g. alternative energy, grey water) and changing land use plans (e.g. densification of urban land). Participants were then asked to consider implications of adaptation choices. Considerable attention was given to water licensing, flow regulation through dams, and potential restrictions on development. Many comments indicated a need for additional research and outreach activities or changes in consultative processes associated with a particular option.

The study on irrigated agriculture (Neilsen *et al.*, 2001) addressed potential impacts on crop water use under climate change scenarios during the next 100 years. The objectives of the study were to develop methodology to determine crop water requirements under current climate and climate change scenarios and to compare predicted demand with reported current water use and water supply. Methods were developed to integrate crop water use data with spatial climate and land use data. For various crops, equations for estimating crop water use were derived from measured water balances and relationships between maximum, daily temperature and estimated potential evapotranspiration. Land use data were acquired from a variety of sources and incorporated into a GIS. The complex terrain in the Okanagan basin and its potential effect on daily temperature regimes and hence crop water use, required the use of techniques to downscale climate data spatially through PRISM (Parameter-elevation Regressions on Independent Slopes Model) to a 4km x 4km grid (Daly *et al.* 1994). This grid was overlain on the land use data in the GIS to create unique polygons. Calculations of crop water demand were performed for each polygon in a database program. Boundaries of areas supplied by the major water purveyors in the basin (Irrigation Districts) were digitized and added to the GIS. Crop water demand was then totalled on a region and Irrigation District basis.

Overall average predicted water use for present day conditions was compared with values of expected water use provided by B.C. Ministry of Agriculture Fisheries and Food for sites within the region in order to test the crop water demand model. Predicted values were slightly lower than the BCMAFF values (745 mm/year vs. 820-1000 mm/year), which was likely the result of under-estimation of temperatures by PRISM. This was attributed to the coarseness of the PRISM grid, which resulted in large elevation changes within cells. Total annual water consumption for the period 1996-1999, reported by the major Irrigation Districts within the region, was reasonably similar to that predicted by the model (46.9 m^3x 106 vs. 51.8 m^3 x 10^6). Thus the model was considered adequate for assessing effects of climate change. For the region as a whole, estimated crop water demand increased by 37%, from 745 to 1021 mm/year (80 to 110 m^3x 10^6) between the present day and a 2070-2099 scenario. Analysis of water allocations to the 10 major Irrigation Districts indicated that those drawing water from the main channel and lake system would likely have sufficient water to meet increased demand, but some districts using tributary water may not. A major limitation in this study was the availability of data from only one GCM scenario downscaled through PRISM. In the current study, data from a range of models and scenarios will be used to capture the uncertainty associated with GCM experiments.

1.3 Study Objectives

The research activity described in this report aims to be a comprehensive regional assessment of the impacts of climate change on water resources and options for adaptation in the Okanagan Basin. The assessment is a collaborative, interdisciplinary effort involving researchers from Environment Canada, Agriculture and Agri-Food Canada, and the University of British Columbia, and local practitioners and planners from the BC Ministry of Water, Land and Air Protection, the District of Summerland, municipal and regional agencies, and a number of user-based and community-based water interests.

The ultimate goal of the project is to develop integrated climate change and water resource scenarios in order to stimulate a multi-stakeholder discussion on the implications of climate change for water management in the region. The study team hopes to achieve two main objectives: a) providing a set of research products that will be of interest to regional interests in the Okanagan, and b) establishing a methodology for participatory integrated assessment of regional climate change impacts and adaptation that could be applied to climate-related concerns in Canada and other countries. This focus on integrated study at the regional scale offers many learning opportunities, including consideration of region-specific resource concerns, vulnerabilities, management priorities and adaptation options, and could advance the assessment and implementation of adaptation options by promoting sustained relationships with local experts, decision makers and user groups (Parson *et al.,* 2003).

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chapter 2

Study Framework

Stewart Cohen

The overarching framework for the various components of this study is an interdisciplinary approach which uses participatory processes as part of knowledge gathering and partnership building, and not just for the purposes of outreach. Participatory integrated assessment (PIA) is flexible, and does not lock the study team into a particular mode or format of information or data exchange. Each individual component has its own data requirements of course (e.g. climate, land cover characteristics, etc.), and this creates some challenges, but the main requirement for the dialogue component is information that can be understood by an audience of mixed backgrounds, regardless of whether this information originates from natural or social sciences research, or from practitioners' experience.

2.1 Components of Participatory Integrated Assessment

The primary research method chosen for the Okanagan project is a participatory approach to integrated assessment of climate change impacts and adaptation. Rotmans and van Asselt (1996) have described integrated assessment as a process that can promote active dialogue and knowledge sharing between scientists, in the form of interdisciplinary research, and local knowledge holders, who use their experiences and judgements to help frame research questions and express response options that satisfy the region's interests. A participatory approach can complement research produced through quantitative models and fieldwork (Hisschemöller *et al.*, 2001).

This study comprises five key components:

1. **Climate change scenarios:** downscaling global climate change scenarios to the regional level;
2. **Hydrological scenarios:** determining impacts of climate change on basin hydrology;
3. **Water demand scenarios:** developing future demand scenarios particularly for municipalities and irrigated agriculture, factoring in socio-economic trends;
4. **Adaptation options:** exploring previous management experiences and potential future approaches for augmenting water supply and/or reducing water consumption; and
5. **Adaptation dialogue with stakeholders:** learning about regional perspectives on adapting to climate change.

Figure 2.1 illustrates the main components of the project. Climate and hydrologic scenarios provide inputs to the other components, and help to establish the "what if" context for this exercise. Population scenarios are also used, as inputs to estimating future water demand. In the Okanagan study, local knowledge from water managers, user groups and other stakeholders are integral parts of the water demand, land use change and adaptation components. Note that the adaptation options component consists of several elements: institutions, previous experiences, and costs. The dialogue component builds on the options work, and also provides a forum for outreach. The team approach and local partnerships build on previous work in the region (Cohen *et al.*, 2000; Cohen and Kulkarni, 2001; Neilsen *et al.*, 2001).

2.2 Role of Participatory Processes

Participatory methods are being increasingly used in studies of complex issues, such as climate change impacts and adaptation, because of the tangled web of related problems that is inherent within any particular

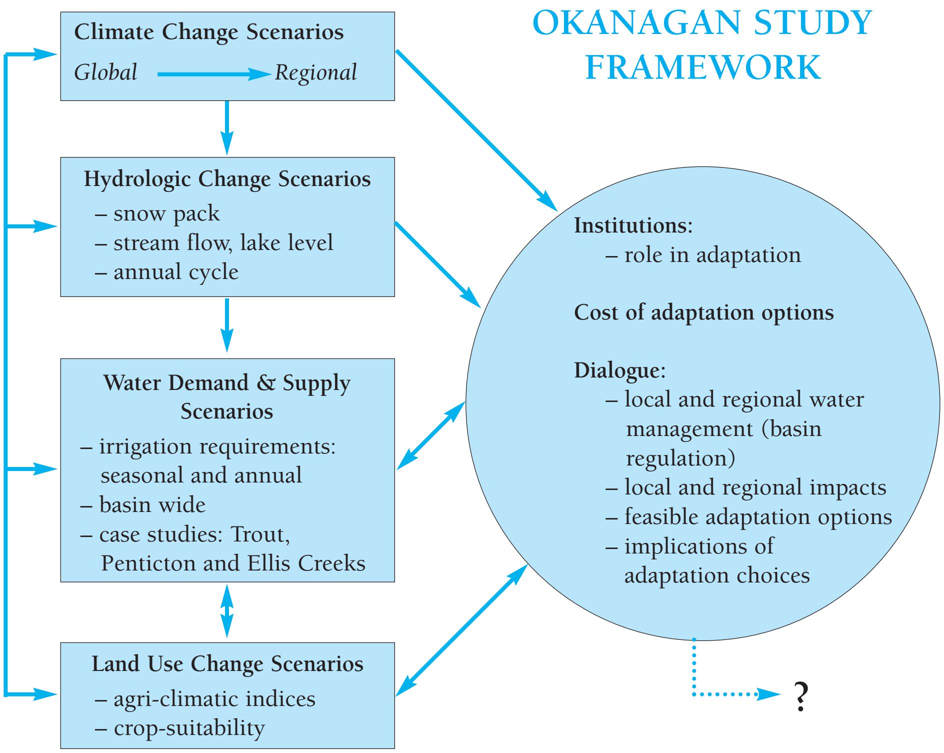

FIGURE 2.1

Framework for study on climate change and water management in the Okanagan region.

case study region or climate-sensitive resource. No one discipline or institution has a monopoly of knowledge, and there is a range of theoretical and practical experiences to draw on which could improve the quality of the research. However, there are a number of different goals that could be achieved by incorporating such methods into a study like this one. Stakeholder empowerment in the research process (i.e. making it more open and democratic) is part of this, but there is also the desire to use research to anticipate emerging problems and contribute to addressing them in a proactive manner. This does not mean that a PIA exclusively aims for building consensus around problem definition or solution. It can pursue consensus building as a goal, but it can also seek to map out a range of possibilities which could provide valuable opportunities for shared learning and ownership of both the problem definition and solution. This has been referred to as “mapping out diversity” (van Asselt and Rijkens-Klomp, 2002).

Dialogue is an important component of participatory methods. This can happen in one-on-one situations (e.g. interviews, surveys), and group settings (e.g. workshops, focus groups). These methods have different objectives, and it is possible to consider using several of these in the same study, to complement other study components (e.g. models), in order to achieve an overall learning objective. For a dialogue process to be meaningful for the adaptation component of this study, there needs to be a number of elements in place:

1. A clear sense of what the dialogue’s objectives are,
2. An understanding of the regional context, and
3. A gradual build-up of trust through shared learning.

Previous outreach activities (Cohen and Kulkarni, 2001) have been instrumental in helping the research team achieve ‘1’ and ‘3’, to some degree, but outreach on its own provides only a limited sense of the management context in which water-related decisions have been made in the past, as well as any trends or recent developments that may affect this context in the future. It is desirable for research to help in relating theoretical issues to matters of operational practice for which local knowledge can be applied most effectively. In order for theoretical notions of proactive adaptation to be translated into practical terms, there needs to be concrete examples of how this has been done, regardless of whether or not the particular case was explicitly addressing climate change. Such cases also complement scenario studies in that there can be important lessons learned that may be applicable to the scenarios being addressed.

Our earlier study also used stakeholder dialogue to identify adaptation options. Implications were touched on but not thoroughly examined. What still needs to be fleshed out is a mock, but plausible, action plan: a discussion of the steps needed to be taken to prepare the ground for change. It is not only a question of how do we act, but who should act and what is required for action to take place, such as a new regulation, resources, expertise, or better planning. In other words, what factors would help facilitate change?

In this study, one of the key elements in learning about regional management context, as well as regional approaches to adaptation, is the set of early adopters cases (Shepherd, Chapter 10). These cases, which are part of the local management/institutions component, enable both the research team and prospective stakeholder participants to see regional examples of proactive adaptation to challenges that can be analogous to the climate change scenarios being considered. Each of the cases deals with a potential near-term shortage in water quantity for major user groups (municipal, irrigation). Insights into the decision making process and the options selected provide valuable information about institutions, resource constraints, technological applications, economic considerations, and local perceptions and attitudes. It enables the research team to know the people, appreciate local history, and observe the effectiveness of these measures.

The results of these historical case studies indicate some of the complex issues that might arise from implementation of certain adaptation options e.g. grower perceptions of metering, as well as some of the solutions to barriers to change. A discussion, not only of the implications (potential barriers) of a specific adaptation option, but of strategies that would help overcome hurdles, would be a rich, rewarding and useful exercise. When these are combined with scenario-based assessments, a forward-looking 'what if' dialogue can be generated. This dialogue would address future vulnerabilities and risks, building on both the scenario-based assessments and the contextual knowledge gained from the early adopters cases and previous regional studies.

Since 1997, various members of the research team have been engaged in research and awareness raising on climate change, climate impacts, and adaptation within the Okanagan region, through research reports (Cohen *et al.,* 2000; Neilsen *et al.,* 2001; Cohen and Kulkarni, 2001) and presentations at various regional fora (e.g. British Columbia Water Supply Association, British Columbia Tree Fruit Growers Association, Canadian Water Resources Association, Okanagan Basin Water Board). This has also attracted regional media attention (e.g. Squire, 2000; Steeves, 2001).

By orienting this dialogue towards addressing future climate-related challenges, participants would not be ignoring current vulnerabilities or recent experiences with climate events. The Okanagan has certainly had its share of extremes in recent years, including the 2001 drought, and 2003 drought and fires. The latter has led to a public inquiry which focused on fire fighting and emergency response measures (Filmon, 2004). These droughts have raised local awareness about the implications of climate events, and are already contributing to dialogue on drought management (Matthews, 2004) which include long term implications of climate change. Rather than overlapping or duplicating assessments that focus on current vulnerabilities, the futures focus of scenario-based adaptation research creates a dialogue on long-term planning that would consider climate change impacts in the context of regional development challenges, thereby serving to complement ongoing efforts that assess current vulnerabilities to extreme events. This is what our study aims to do.

There are a number of incentives for stakeholders to participate as partners in scenario-based research, such as the potential for long-term problem solving, and an opportunity to consider new technical information. However, it also offers stakeholders an important incentive to participate in this dialogue - respect for local experience, which helps to achieve trust and reduce tensions that could lead to conflicts around sensitive issues.

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chapter 3

Water Management

(from the 2003 Interim Report)*

Philippa Shepherd, Tina Neale, Stewart Cohen

3.1 Institutional Framework for Water Management

There are three primary features of the Okanagan watershed which emphasise the complex, convoluted and multi-scale structure of interacting organisations and institutions involved in water management decisions:

- The water system crosses an international border
- Multiple levels of government
- Multiple in-stream and out-of-stream water uses meaning many advocacy organisations at different scales

The Okanagan Basin adjoins the Columbia Basin at the Canada-US border, which crosses Osoyoos Lake. Two organisations are concerned with cross-border relationships regarding water resources and the environment. The International Joint Commission (IJC) is an independent bi-national organization, which was established by the Federal Boundary Waters Treaty of 1909. This treaty set the basic principles for guiding boundary water relations between Canada and the US. To assist it with supervision, monitoring and research functions, the IJC created bilateral boards of which the Osoyoos Lake Board of Control was one. It was established to supervise the operation of the upgraded Zosel Dam (completed in 1987), which controls the level of Osoyoos Lake, and to ensure compliance with the IJC's Order of Approval. The Environmental Co-operation Agreement of 1992 established the BC/Washington Environmental Cooperation Council to ensure coordinated action and information sharing on critical cross-border environmental issues.

Governance and regulation of water supply, quality and demand in the Okanagan Basin is divided amongst four levels: federal, provincial, regional and local. Division of responsibilities for water between federal and provincial agencies is complex and often shared. Under the Constitution Act 1867, provinces own both surface and groundwater resources, while water on federal lands (e.g. National Parks), in the territories and on Indian Reserves falls under federal jurisdiction. The federal government also has responsibility for boundary and transboundary waters under the International River Improvements Act, which controls activities that may affect the flow of rivers entering the US. Provincial ministries are the key regulatory bodies governing a wide-range of water-related issues: pollution, flow regulation, watershed management, etc. Federal responsibilities, on the other hand, primarily cover areas that have the potential for significant national economic impact such as navigation and fisheries. The key federal agencies and provincial ministries directly and indirectly involved in regulation of water quantity and quality are:

Federal

- Environment Canada (EC)
- Fisheries and Oceans Canada (FOC)
- Agriculture and Agri-Food Canada (AFFC)

Provincial

- Ministry of Sustainable Resource Management (MSRM)
- Land and Water BC (LWBC)
- Ministry of Water, Land and Air Protection (MWLAP)
- Ministry of Health Services (MHS)
- Ministry of Forestry (MF)
- Ministry of Agriculture, Food and Fisheries (MAFF)

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* *The information contained in this chapter represents the regulatory framework that was in place up until spring 2003.*

The degree to which responsibilities are shared between federal and provincial bodies varies from year to year, and includes interprovincial water issues, agriculture, significant national water issues, and health. The Canada Water Act defines provisions for formal consultation and agreements with the provinces "to provide for management of the water resources of Canada, including research and the planning and implementation of programs relating to the conservation, development and utilization of water resources."

The Local Government Act RSBC 1996, c. 224 administered by the BC Ministry of Community, Aboriginal and Women's Services, sets out the framework for the local government system in British Columbia. It defines the creation, structure and operation of the three types of local government: regional districts, municipalities and improvement districts, as well as their powers and responsibilities, which differ between the three. The Okanagan is split into three regional districts, 11 municipalities and 40 improvement districts. Regional districts are the latest form of local governance, being established in the Okanagan in the mid-1960s to provide basic services, such as water, to residents of unincorporated areas. Municipalities generally provide multiple services to an urban customer base, while improvement districts were established to deliver one or more public services to a community, such as water, fire protection, street lighting, dyking, drainage, garbage collection and parks. The smallest bodies providing water are Water User Communities – public corporate bodies incorporated under the Water Act RSBC 1996, c. 483. Six or more different licensees, each of whom hold their own license(s), can form a Water User Community.

Water on Indian Reserves is under federal jurisdiction. The Okanagan Nation Alliance is the Tribal Council representing the people of the Okanagan Nation, which is comprised of seven Indian Band Reserves (ONA, 2000a). The Bands participate in the Okanagan Nation Fisheries Commission (ONFC), which was established in 1995. "The goal and mandate of the ONFC is the conservation, protection, restoration, and enhancement of indigenous fisheries (anadromous and resident) and aquatic resources within Okanagan Nation territory. The ONFC provides technical assistance to the member Bands and also acts as a liaison with federal and provincial agencies" (ONA, 2000b).

There is one key inter-regional body in the Okanagan region - the Okanagan Basin Water Board (OBWB). The Board was established after the completion of the Okanagan Basin Agreement study in 1974 as a first step to creating a body responsible for valley-wide water resource issues. Until now activities have focused on control of Eurasian water milfoil and funding of liquid waste treatment projects in partnership with the provincial government. As the OBWB has achieved its main objectives of reducing phosphorus loading to the lake and controlling milfoil, the role of the OBWB is being questioned and is currently under review. The Okanagan Basin Technical Working Group is a tripartite body with representatives from DFO, MWLAP, and ONFC. General objectives for this group are to identify and 'steer' initiatives designed to rebuild fish stocks, including salmon, in the Okanagan River basin in Canada.

In addition to the legally mandated organisations party to water management in the Okanagan Basin, there are several significant non-governmental players at the regional level. These can be divided into four primary topics: protection of fisheries and their habitats, watershed stewardship, supporting the local agricultural community and aiding better local water management practices. Some of the most predominant groups include:

Fisheries	• Okanagan Similkameen Boundary Fisheries Partnership
Watersheds	• Community Watershed Round Tables
Agriculture	• BC Fruit Growers' Association • Okanagan Valley Tree Fruit Authority.
Water Management	• Water Supply Association • BC Water and Waste Association

Appendix A provides a brief description of the key institutions involved in water management in the Okanagan.

3.2 Regulatory Framework

This section outlines the provincial and federal regulatory framework for water supply, quality, use and ecosystem health. Due to ongoing changes to the regulatory framework, the information in this section is considered current as of April 1, 2003.

3.2.1 Water Allocation and Licensing

British Columbia's water allocation and licensing system evolved in the context of settlement patterns and associated land uses during the latter half of the

1800s (Wilson, 1989). The early importance of irrigation for agriculture and water supplies for gold mining in the BC interior favoured a system of water rights allowing use of water on non-riparian lands. Under English Common Law, only riparian landowners had the right to use water flowing through or adjacent to their lands. This was found to be restrictive to the development of agriculture and mining because riparian rights did not allow use of water on non-riparian lands or grant water rights to non-riparian landowners. To overcome these restrictions, a system based on appropriative rights, became the dominant water rights system in British Columbia.

The appropriative system, which evolved during the European settlement of the western United States, has two characteristics that remain central to British Columbia's system of water rights: beneficial use and prior appropriation (Scott, 1991). Prior appropriation grants the right to use water on a "first come, first served" basis, giving priority access to the water resource to the earliest license holder. In drought conditions, holders of the earliest licenses issued on a source have the right to use their entire allotment before holders of later licenses. The concept of beneficial use is designed to ensure that efficient use is being made of scarce water resources. Under the appropriative system, a license holder who does not demonstrate beneficial use of water forfeits the water right, regardless of the priority of the right. British Columbia's current water rights law retains the principles of beneficial use and prior appropriation.

An examination of the regulatory framework for water rights in British Columbia must begin with the Canadian Constitution, the supreme law of Canada. The Constitution Act 1867 divides legislative powers between the Canadian parliament and the provincial legislatures. Section 92.13 gives the provinces legislative authority over "Property and Civil rights in the Province" and is most relevant to a discussion of water rights in British Columbia. Section 92.16 is also important, allowing provinces to legislate in "Generally all Matters of a merely local or private Nature in the Province." Other sections of the Constitution Act apply more generally to water management. These include s. 91.12 giving the Parliament of Canada legislative authority over "Sea Coast and Inland Fisheries" and s. 95 stating that the Parliament of Canada and the provincial legislatures have concurrent authority to legislate in matters pertaining to agriculture.

Following from s. 92.13 of the Constitution Act, the Province of British Columbia has the power to make legislation regarding property rights, including water rights, in the province. In British Columbia, water rights are governed primarily by the Water Act RSBC 1996 c. 483. Section 2(1) of the Water Act vests ownership of all surface water resources in the government of British Columbia. The province uses a water licensing system, also defined in the Water Act, to "allow users to occupy the Crown's own water rights" (Scott, 1991, p.356). Water licenses, therefore, give the license holder a legal right to use water, but not ownership of the water resource.

The Water Act, and the associated system of water rights, applies only to surface waters in British Columbia.[1] Section 3 of the Water Act states that the Lieutenant Governor in Council may develop regulations to apply the Act to groundwater, however this has not occurred to date. While there are several statutes, regulations and guidelines that affect groundwater use in British Columbia , there are no laws specifically pertaining to management of groundwater or allocation of rights to use groundwater (Foweraker et. al., no date). Unlike surface water, groundwater sources may be developed without a water license.

The Water Act states that water licenses issued after June 21, 1995 must specify the date of precedence, the purposes for which the water will be used and the land or undertaking to which the license is appurtenant. The date of precedence is the feature of water licenses that allows prior appropriation rules to be applied. Section 15 describes how the date of precedence is used, giving priority to licenses with the earliest precedence dates. For licenses with the same date of precedence on the same source, priority of purposes is used to determine precedence of the water right. Water licenses may specify up to three purposes such as domestic, irrigation, stock watering, electrical generation, etc. The Water Act ranks these purposes in priority order, with domestic uses ranked as the highest priority over other purposes. Specification of purposes for which water will be used also supports the concept of beneficial use. Section 23(2)(a) of the Water Act allows a water license to be suspended or revoked if the licensee does not make beneficial use of the water as outlined in the terms of the license. Beneficial use is not defined in the Water Act; however, s. 39 (1)(c) gives "engineers and officers" employed by the government the power to determine what constitutes beneficial use.

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[1] *These include the Waste Management Act, Health Act and the Environment Management Act.*

The British Columbia Ministry of Sustainable Resource Management (MSRM) is responsible for administering the water allocation functions indicated in the Water Act. MSRM has delegated certain functions, such as the administration of water license applications, to Land and Water BC, a provincial crown corporation.

The availability of water for allocation is determined using stream flow measurements averaged over five years as well as an analysis of the probability that enough water will be available to supply new and existing water rights in a specified number of years (probability of occurrence) (Mike Collette and Neil Banera, pers. comm.). A variety of legal persons, such as government agencies, owners or administrators of lands or undertakings (eg. mines), water utilities, etc., may apply for water licenses. The water license application must specify the purpose(s) for which the water will be used, the quantity to be used for each purpose, any constructed works required to make use of the water, the source (eg. creek, lake, spring, etc.) and the point of diversion. If the application is approved, this information is incorporated into the terms of the license along with any conditions that the comptroller deems necessary. Conditions may specify a date for completion of works, a date from which beneficial use of the water must be made, requirements for installation of monitoring equipment, such as meters, or requirements for storage.

Water rights issued with a license are perpetual; they do not expire or require renewal. Licenses are transferred or divided when the land or undertaking to which they are appurtenant is sold, subdivided or otherwise transferred. The date of precedence does not change with transfer or division of a water license therefore the priority of the water license on the source remains constant.

In general, the Ministry of Sustainable Resource Management and Land and Water BC appear to carry out little active management of water licenses beyond the processing of applications and approvals. The Ministry does not monitor actual consumption or beneficial use on a regular basis (Mike Collette, pers. comm.), however it may take these into consideration when evaluating new license applications (Neil Banera, pers. comm.). The Water Act provides for a reporting system in Section 22.01, stating that licensees are required to submit signed declarations that water has been used beneficially in accordance with the terms of the license, however it is unclear whether these provisions are used in practice. Determining the relationship between the quantities of water allocated in water licenses and the amount used is therefore a challenging task. Outside of the more sophisticated water utilities that use monitoring equipment such as water meters, information on actual consumption may not be readily available.

The Okanagan Basin presents an interesting forum for exploring water allocation and licensing given its semi-arid climate, its growing population and the importance of irrigation to the regional economy. As of July 2002, there were approximately 4130 active water licenses in the Okanagan Basin listed in the Water License Query database maintained by Land and Water BC (Land and Water BC, no date). These licenses represent approximately 1.05 billion cubic meters of allocated water on 980 streams for both consumptive and in stream uses. Sixty-six water license applications were also listed requesting a further 209 million cubic meters. Of the 1.05 billion m^3 of water allocated in the Okanagan, 476.8 million m^3 is allocated for consumptive purposes, where water is removed form the source. Of this licensed quantity, approximately 67% is allocated for the purposes of “Irrigation” and “Irrigation Local Auth,” 31% for “Waterworks Local Auth” and “Waterworks (Other)” and the remaining 2% for other purposes including “Watering,” “Domestic” and “Enterprise”[2] (see Figure 3.1).

Given the lack of information on actual water consumption in the Okanagan Basin, it is difficult to determine how licensed quantity relates to water demand in the region. However, management practices do appear to make the assumption that licensed quantity and actual use are approximately the same. Unlike riparian rights systems in which the rights of downstream riparians with respect to water quality and quantity must be considered, the prior appropriation system allows the allocation of more water than actually exists in a particular source. Management of water rights in British Columbia appears to have incorporated procedures to limit this occurrence and to consider the impact of new allocations on existing licensees and other parties. One example of this is the use of five-year stream flow averages and probability of occurrence analyses mentioned above to ensure that water is available for allocation. The water license application procedure also requires that other agencies be notified of new allocations and may require that

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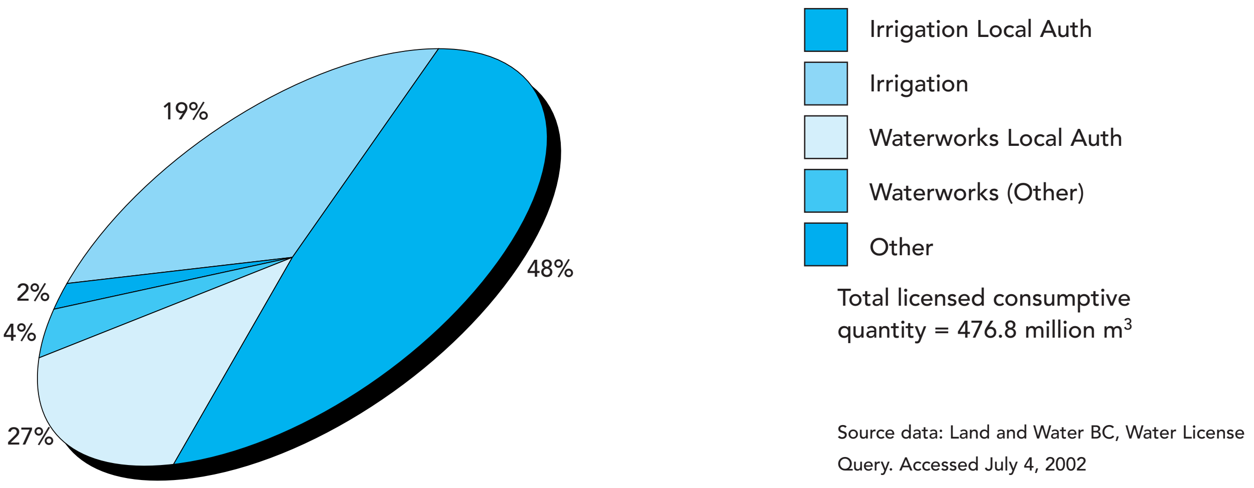
[2] *For full descriptions of the water license purposes, refer to http://www.elp.gov.bc.ca:8000/wat/wrs/fs3fees2.doc*



OKANAGAN BASIN LICENSED CONSUMPTIVE QUANTITY BY PURPOSE

Total licensed consumptive quantity = 476.8 million m^3

Source data: Land and Water BC, Water License Query. Accessed July 4, 2002

FIGURE 3.1

Licensed consumptive quantity in the Okanagan Basin by purpose

downstream licensees and landowners whose land may be affected by the construction of works be given an opportunity to comment (Neil Banera, pers. comm.).

Another management tool is the maintenance of a List of Stream Restrictions and Water Reserves. Approximately 300 streams in the Okanagan were listed in the July 17, 2002, version of this document published on the Land and Water BC website (Land and Water BC, 2002). 235 of the streams on this list are designated as “fully recorded” (insufficient water to grant further licenses), fully recorded with some limited use (eg. small domestic withdrawals or new uses supported by storage) or “refused no water” implying the stream is fully recorded and license applications have been rejected. 39 streams have the designation “possible water shortage” and the remaining streams are either designated as reserves or are restricted in use (eg. during spring freshet only).

Given the proportion of streams that are fully recorded or have possible water shortages, it is not surprising that conflicts between water users can arise during low flow periods. Under strict prior appropriation rules, the highest priority licenses would have first access to any water in these situations. While prior appropriation is practiced, other options, such as cooperative agreements among licensees are also used regularly (eg. all licensees agree to use 10% less water) (Neil Banera, pers. comm.). The principle of beneficial use has been applied much less frequently to resolve water shortage situations. Only one example of the application of beneficial use has been found during this investigation. In this case, an irrigation district’s application for a water license to develop a new source was refused on the basis that the district had not proved it was using its existing supply efficiently (Neil Banera, pers. comm.).

Ecological considerations, such as ensuring sufficient water for fish habitat, are not explicitly considered in the Water Act. Under the licensing system laid out in the Act, the entire flow (or more) of a stream can be allocated for consumptive uses without consideration of the stream’s ecological functions. In 1985/6 the Deputy Minister of Environment, Lands and Parks enacted a policy giving the managers of the water licensing system the power to refuse water license applications which would have a “significant and adverse impact” on fish populations, or include conditions in the license for the benefit of fish habitat (eg. requirements for fish screens on intakes, reductions in consumptive use during low flow periods) (Neil Banera, pers. comm.). While there have been challenges in implementing fish flow requirements, water licensing decisions currently incorporate a fish flow reserve of 10% of mean annual stream flow (see section 3.2.4 Fish and Habitat Management).

3.2.2 Water Quality Regulation

3.2.2.1 Drinking water: regulation, monitoring and assessment

Federal

Water quality management is primarily a provincial responsibility. However, the Canada Water Act R.S., c.5(1st Supp.), s.1 (Part II) specifies the prohibition of polluting any waters that have been designated a water quality management area either through a federal-provincial agreement where water assessment is deemed of federal interest, or "where the water quality management of any inter-jurisdictional waters has become a matter of urgent national concern." Water quality concerns on federal lands e.g. Indian Reserves and National Parks, are the jurisdiction and responsibility of the Federal Government.

Health Canada has published Guidelines for Canadian Drinking Water Quality (GCDWQ) since 1968, which apply to most, if not all, provinces (Federal-Provincial-Territorial Committee on Drinking Water, 2002). The Federal-Provincial Subcommittee on Drinking Water prepares the guidelines. The Subcommittee is made up of representatives from each province and territory, as well as from Health Canada. Health Canada also produces Guidelines on Recreational Water Quality.

In 2002, the Federal-Provincial-Territorial Committee on Drinking Water and the Water Quality Task Group of the Canadian Council of Ministers of the Environment (CCME) published a position paper advocating a multi-barrier approach to protecting water quality including source water protection, drinking water treatment, and distribution systems[3].

Provincial

Currently, the only proclaimed drinking water regulation in BC is the Safe Drinking Water Regulation, B.C. Reg. 230/92, (SDWR) adopted under the Health Act RSBC 1996, c. 178. It deals only with the presence of fecal coliform, E. coli and total coliform presence, and under section 5 specifies that the water purveyor has the responsibility to provide potable ("water that meets the standards established by Schedule A, *Microbiological Standards*, and is safe to drink and fit for domestic purposes without further treatment") water to all users served by a water works system. Under section 5 of the SDWR, a water purveyor must ensure that water samples are collected from locations at a minimum frequency and shipped to a laboratory in accordance with procedures established by the medical health officer or public health inspector.

Due to deteriorating water quality in B.C., decreased tolerance of colour, greater public concern over water quality and disinfection by-products, and the death of seven people in Walkerton, Ontario caused by unsafe levels of E.coli bacteria in the town water supply, the provincial (New Democratic Party) government enacted the Drinking Water Protection Act, Bill 20, in 2001 prior to the provincial election. The Act attempts to integrate the current mix of legislation dealing with drinking water quality concerns as well as strengthen water quality standards. Groundwater legislation was proposed at the same time. In September 2001, the new (Liberal Party) government appointed a nine-member Drinking Water Review Panel to review the Drinking Water Protection Act and new groundwater provisions. The Panel released its final report on February 13, 2002 and recommended the Act be brought into force together with a relatively limited number of amendments (Drinking Water Review Panel, 2002). The government is currently reviewing the Panel's recommendations. One major re-emphasis is the need to protect the water source, which is not covered in the Safe Drinking Water Regulation (although monitoring is partially covered in the Environment Management Act RSBC 1996, c. 118).

The Ministry of Health Planning is now the lead ministry for ensuring drinking water quality standards. Within the Ministry, the Public Health Protection Branch administers the Drinking Water Program, under which the new government has developed a Drinking Water Protection Plan – a comprehensive framework for the protection of drinking water. The plan has eight main principles (Ministries of Health Planning and Services, 2002):

- The safety of drinking water is a health issue
- Prevention and source protection are a critical part of drinking water protection.
- Providing safe drinking water requires an integrated approach.

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[3] *See CCME's website at http://www.ccme.ca/assets/pdf/mba_eng.pdf*

- All water systems need to be thoroughly assessed to determine risks.
- Proper treatment and water distribution system integrity are important to protect human health.
- Tap water must meet acceptable safety standards and be monitored.
- Small systems require a flexible system with safeguards.
- Safe drinking water should be affordable, with users paying appropriate costs.

The government has established various advisory boards and committees to review BC water regulation: an inter-ministry committee to identify emerging issues and develop integrated policy if required; a Groundwater Advisory Board to advise on drinking water standards and protection of groundwater sources, and a Drinking Water Advisory Committee to provide technical expertise on standards for tap water (Ministry of Health Services, 2002). The following ministries are also involved in ensuring high water quality standards:

- Ministry of Water, Land and Air and Protection (MWLAP) in collaboration with the Ministry of Health Planning is responsible for developing an action plan to improve the protection of drinking water at groundwater sources (MWLAP, 2002).
- Ministry of Agriculture, Food and Fisheries (MAFF) is responsible for farm management relating to the environment and ensuring that land-use planning takes into consideration drinking water protection plans.
- Ministry of Sustainable Resource Management (MSRM) is responsible for ensuring that land use plans consider drinking water issues (MSRM, 2001).
- Ministry of Forests (MF) will ensure through the amended Forest Practices Code Act of BC (to be the Forests Practices and Range Act in 2005) that drinking water sources aren't impacted by forestry activities (see below).

The Canada-BC Infrastructure Program (administered by the Ministry of Community Services, Aborigines and Women) is the primary source of funding for local improvement projects, including water treatment and infrastructure needs. In 2002, the provincial government approved 92 water-related improvement projects worth $239 million to be funded through the program. The government is also increasing funding for water quality monitoring by $1.5 million a year for the next three years.

3.2.2.2 Ambient water quality: regulation, monitoring and assessment

Federal

Environment Canada plays a significant part in water quality issues regarding source quality. Its role is to aid the protection of water sources (as part of the 'environment') through establishing nationally consistent standards of ambient water quality, and restrictions on pollution discharges. In 1999, the federal government passed the Canadian Environmental Protection Act, 1999, "respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development". Specifically applicable to water management issues, the Act stipulates the federal government's role in monitoring air, land and water pollution; establishment of pollution prevention plans for specific substances if deemed necessary, and preventing pollution of international (i.e. non-Canadian) waters from Canadian sources.

The Canadian Council of Ministers of the Environment (CCME) is an important forum for facilitating federal, provincial and territorial collaboration on environmental priorities of national concern, including water quality. Its Water Quality Task Group is responsible for establishing national ambient environmental quality guidelines for specific substances published in the Canadian Environmental Quality Guidelines.

Provincial

The primary ministry responsible for protecting, monitoring and assessing water quality in BC is the Ministry of Water, Land and Air Protection (MWLAP). The Water Protection Branch of MWLAP is responsible for developing water quality guidelines based on the CCME criteria (MWLAP, 1998). Water quality criteria specify the "safe" concentrations of specific contaminants for five water classes (Dorcey & Griggs, 1991):

- Drinking, public water supply and food processing;
- Aquatic life and wildlife
- Agriculture
- Recreation and aesthetics
- Industrial

MWLAP is specifically responsible for the health of water sources with respect to drinking water and in terms of maintaining the health of aquatic ecosystems.

As part of the Drinking Water Action Plan, the Ministry is responsible for establishing standards and monitoring, and ensuring compliance and enforcement to protect surface and ground water quality. The Environment Management Act RSBC 1996, c.118 specifies that the duty of the Minister is the management, protection and enhancement of the environment including, amongst other activities, "the preparation and publication of policies, strategies, objectives and standards for the protection and management of the environment." MSRM administers the Environmental Assessment Act RSBC 2002, c.43, which provides the framework for managing specific projects that might have a detrimental impact on the environment, including water sources. The Water Regulation B.C. Reg. 204/88 under the Water Act, Part 7 - Changes in and about a stream, covers water quality protection in the case of modification to a stream.

The Water and Air Monitoring and Reporting Section (WAMR) of the Water, Air and Climate Change Branch (WACB) within the Environmental Protection Division of MWLAP is responsible for water monitoring. The Branch develops legislation and policies to protect air, water and land. It sets standards for, and monitors and reports on, ambient air and water quality. The WAMR Section is responsible for monitoring, auditing and reporting on the quality of the province's water and air. It operates BC's ambient water and air monitoring network. Administration is split into seven regional offices, including the Thompson-Okanagan office of the Southern-Interior Region.

The designation of Community Watersheds in the *Forest Practices Code of BC Act* RSBC 1996 c.159 (FPCA) further ensures the protection of water quality (and ecosystem health) in BC. The general definition being any natural watershed area on which a community holds a valid water license issued under the Water Act by the Comptroller of Water Rights (defined in s.41 (8) of the FPCA). A forest licensee operating within a community watershed is required to submit a long-term forest development plan for that portion of the area. The designation of Community Watersheds, which is based on character criteria, such as drainage area of less than 500 km^2, is carried out by the Ministry of Forests regional manager and the designated environment official (i.e. regional water manager as defined in the Operational Planning Regulation B.C. Reg. 107/98 under the FPCA). The FPCA brings into effect restrictions on forestry and range practices in community watersheds of which there are 450 in British Columbia. There are 64 such Community Watersheds in the Okanagan Basin (Vernon and Penticton Forest Districts). The Ministry of Forests administers the Forest Practises Code, other than the designation of community watersheds which is under the authority of the Ministry of Sustainable Resource Management.

On December 17, 2002, streamlining amendments to the Forest Practices Code of British Columbia Act and regulations came into effect. These amendments give licensees immediate relief from regulatory burden, during the two-year transition period until the new Forest and Range Practices Act (Bill 74-2002) is fully implemented in April 2005[4]. Under the new Forest and Range Practices Act, Part 9, Section 150 the Lieutenant Governor in Council may make regulations to designate extended land as a community watershed, a domestic watershed or fisheries sensitive watershed and prescribe requirements thereof.

Riparian management is also defined in the Operational Planning Regulation BC Reg. 107/98. Depending on the status, character and size of the stream, wetland or lake a riparian reserve zone, a riparian management zone and a riparian management area are designated. The designation of riparian buffers is primarily to minimize the impacts of forest and range use on stream and lake water quality and maintain stream channel stability. The Riparian Management Area Guidebook provides details on riparian management issues.

3.2.3 Water conservation

3.2.3.1 Federal

One of the goal's of Canada's 1987 Federal Water Policy is "to promote the wise and efficient management and use of water" (Environment Canada, 1987). Section 7 of the Agricultural and Rural Development Act (ARDA) R.S. 1985, c.A-3 stipulates that programs of research can be initiated for "the development and conservation of water supplies and for soil improvement and conservation in the province". In mid-1994, the Canadian Council of Ministers of the Environment (CCME) formed a national task force to develop a National Action Plan to encourage Municipal Water Use Efficiency. The goal of this action plan "is to achieve more efficient use of water in Canadian municipalities in order to save money and energy, delay or reduce expansion of existing water and wastewater systems, and conserve water" (CCME, 1994). In 1999, Environment Canada in co-operation with the

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[4] *see http://www.for.gov.bc.ca/code/*

Canadian Water and Wastewater Association (CWWA) developed a Municipal Water Use Database along with a Water Efficiency Experiences Database.

3.2.3.2 Provincial

The BC Provincial Water Conservation Working Group was appointed in July 1997 to develop a Strategy Document on water conservation. A merger of this Working Group with the BCWWA Committee resulted in the creation of an interagency working group – the Water Conservation Strategy Working Group[5]. The Working Group represented federal and provincial agencies, local governments, utilities, water managers, professional associations and special water use interests. In the fall of 1997, the Ministry of Environment, Lands and Parks (now MWLAP) finalised a Water Conservation Strategy for British Columbia. The objectives of the strategy are (MWLAP, 1997a):

- to demonstrate the need for and benefits of improved water use efficiency measures;
- to reinforce the value of British Columbia's water resource;
- to present a menu of water use efficiency tools and techniques;
- to identify, acknowledge and learn from water use efficiency initiatives in British Columbia;
- to guide the development of provincial and local legislation, policies, guidelines and standards to improve water use efficiency;
- to engage community leaders, water managers, government agencies, water utilities, suppliers and the public in addressing water supply issues through creative partnerships; and
- to recommend next steps for advancing water use efficiency in British Columbia.

As part of the Strategy, water use efficiency measures and tools were collected at the level of senior government, regional and municipal local authorities and irrigation/improvement districts. Table 3.1 highlights some key federal and provincial initiatives in the area of water conservation as stated in the Water Use Efficiency Catalogue of BC (MWLAP, 1997b).

TABLE 3.1

Major federal and provincial initiatives in the area of water conservation selected from the 1997 Water Use Efficiency Catalogue of BC

HARD CONSERVATION MEASURES
Legal Tools
The Fish Protection Act (1997) administered in conjunction with the Water Act, can provide for water conservation to be licensed specifically. (MWLAP)
In 1993 the Union of BC Municipalities (UBCM) passed a resolution in response to *"continuing growth and increased per capita consumption of water"* which requested that the Building Standards Branch (MMA) amend the BC Building and Plumbing Code to require the use of water conservation devices in all new construction. (MWACS)
The proposed "Municipal Sewage Regulations" are encouraging the use of reclaimed water to address the issues of water shortages, the use of reclaimed water will decrease supply needs from, and discharges to fish bearing streams. (Municipal Water Reduction Branch)
Economic and Financial Tools
The Ministry of Municipal Affairs and Housing adopted a water conservation policy in 1992. The policy states: *"The Ministry encourages water conservation initiatives, and supports consumption-based water rates. For new water supply or treatment projects it is important that water conservation be part of project planning. As funding is limited, priority will be given where water conservation measures and universal metering are in place."*
Presently, municipalities applying for infrastructure grants may be required to demonstrate that the proposed project uses water efficiently; and that a water audit and leak detection programs have been implemented.

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[5] *see the 1997 Water Use Efficiency Catalogue http://wlapwww.gov.bc.ca/wat/wamr/wat_use_catalogue/toc.html*

Operations and Management Tools

1989, The Okanagan Valley Water Supply and Demand Management Study (MAFF)

In spring 1997 the British Columbia Buildings Corporation adopted technical standards which require increased efficiencies in irrigation and landscaping for all BCBC owned and operated buildings.

Fraser River Action Plan (FRAP) (Federal Government)

The BC Building and Plumbing Code was amended to include low-flow fixtures and maximum flush flows (Mowers)

“Municipal Sewage Regulations” are encouraging the use of reclaimed water to address the issues of water shortages (Municipal Water Reduction Branch)

SOFT CONSERVATION MEASURES

1997 Fraser River Action Plan (FRAP): An Action Plan was developed for implementation over a 3-year period to facilitate a Province-wide Partnership Agreement regarding municipal water-use efficiency (Water Use Efficiency Committee) + a 3-year program of Annual Seminars

The Water Use Efficiency committee organized Technology Transfer Seminars in conjunction with the 1993 and 1994 Annual BCWWA Conferences. The themes of the seminars were "Water Conservation Strategies and Experiences", and "Planning and Implementing Water Conservation".

The Know H_20! eco-education project was developed by the Ministry in partnership with Alliance Professional Services and the BC Water and Waste Association. The project is being designed to inform local government administrators and elected officials about water-related issues; regulatory and non-regulatory management tools; and opportunities to maintain and enhance water management efforts at the local level.

The Ministry of Agriculture, Food and Fisheries is actively involved in encouraging water conservation through participation in water conservation projects and publication of relevant material e.g. *B.C. Trickle Irrigation Manual*. Currently a series of Environmental Farm Plans are being developed by MAFF. The objective of the water management component of the Plans is to inform and guide farmers on water efficient management methods and options, such as irrigation scheduling (Janine Nyvall, MAFF, pers. comm.).

3.2.4 Fish and Habitat Management

3.2.4.1 Federal government

Fisheries and Oceans Canada has a clear, legislative mandate for the protection of fish habitat. The Fisheries Act R.S. 1985, c. F-14 gives the Minister of Fisheries and Oceans the responsibility to protect fish and fish habitat from destructive activities in marine and inland waters. The main provision under the Fisheries Act dealing with the protection of fish habitat is s. 35. Subsection 35(1) states “No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.” However, subsection 35(2) qualifies this prohibition, in that it allows for the authorization by the Minister of Fisheries and Oceans, or through regulation, of the alteration, disruption or destruction of fish habitat. Operationally, decisions on whether subsection 35(2) authorizations are issued are made by regional habitat staff within the Fisheries and Oceans Canada.

In 1986, the Federal Government published their Policy for the Management of Fish Habitat. This provided the framework for ensuring the protection of fish habitat including engaging and actively involving Canadians in stewardship activities. Fisheries and Oceans Sustainable Development Strategy (2002) is an update of the department’s policy concerning management of marine and freshwater fish resources in Canada. The main program managing fish habitat, is the Fish Habitat Management Program. Its mandate is to: protect and conserve fish habitat in support of Canada's coastal and inland fisheries resources; and conduct environmental assessments under the Canadian Environmental Assessment Act.

Fisheries and Oceans Canada is now developing a detailed national action plan for Fish Habitat Stewardship. The Action Plan will ensure that Fisheries and Oceans Canada is directly involved in stewardship activities across Canada and is applying the proactive strategies outlined in the Policy. The Action Plan will also strive to build partnerships with industry, developers, NGO’s, governments and community groups to advocate the benefit of protecting fish habitat so they too can contribute to the net gain of this habitat. The Habitat Conservation and Stewardship Program in British Columbia and the Yukon is an example of such stewardship activities. Up until March 2003, Fisheries and Oceans Canada funded a full-time Stewardship Co-ordinator for the Okanagan, Similkameen and Boundary areas as part of their Habitat Conservation and Stewardship Co-ordinator Program across Canada.

Habitat Restoration and Salmon Enhancement Program (HRSEP) was established in 1996-1997 to complement the Pacific Salmon Revitalisation Strategy. The main objective of the federally funded HRSEP is to revitalise salmon populations in the Pacific Region through habitat restoration, stock rebuilding, and resource and watershed stewardship. Other important goals are to develop and strengthen partnerships at the community level and (where feasible) train/employ displaced fishery workers. The projects are run by a variety of community groups and agencies.

The Pacific Region is the operational unit of Fisheries and Oceans Canada that covers fish issues in British Columbia. The Habitat and Enhancement Branch (HEB) of BC and the Yukon is responsible for:

- The protection and restoration of fish habitat
- Salmonid Enhancement Programs (SEP)
- Integrated resource management planning
- Community involvement programs and public education.

In 1999 Canada and the United States reached a comprehensive agreement under the Pacific Salmon Treaty. The agreement signals a cooperative, conservation-based approach to the management of Pacific salmon fisheries, and a more equitable sharing of salmon catches between Canada and the United States.

3.2.4.2 Province

Commercial fisheries

The Fisheries Act RSBC 1996, c.149 covers licensing and regulatory control of activities associated with commercial fisheries and aquaculture operations. Currently, there are 129 commercial freshwater fish farms and hatcheries. MAFF is responsible for the management of commercial fisheries and the administration of the Act. A new Aquaculture Regulation which came into force in 2002 strengthens the environmental controls related to aquaculture activities e.g. fish escape and pollution.

Fish habitat protection and minimum fish flows

In 1997, the then BC government proposed a Fish Protection Act RSBC 1997, c.21(FPA). Its four major objectives are: ensuring sufficient water for fish; protecting and restoring fish habitat; improved riparian protection and enhancement; and stronger local government powers in environmental planning. The Act would allow managers to issue orders to temporarily reduce water use during droughts, grant licenses to protect in stream flow, and to reduce licensed allocations. Sections 8 to 11 of the Fish Protection Act that would allow these actions have not yet been proclaimed into force, so it remains to be seen how application of these sections would be applied in the Okanagan.

MSRM is responsible for the general administration of the Fish Protection Act. In addition, the Ministry administers the Sensitive Streams Designation and Licensing Regulation (B.C. Reg. 89/2000) under the FPA. A general streams regulation, to ensure consideration of potential impacts on fish and fish habitat in water allocation decisions or approvals for changes in or about streams, is also under consideration.

The Resource Management Division is responsible for developing Land Resource Management Plans, which include policy on fish concerns. The Aquatic Information Branch within the Registries and Resource Information Division of MSRM manages the Fisheries Information Program involving the provision of inventory data and documents. This program includes the BC Fisheries Data Warehouse (eg. the FishWizard), Fisheries Project Registry and the Fisheries Inventory, created under the Canada-BC Agreement on the Management of Pacific Salmon Fishery Issues.

MWLAP is responsible for the administration of the Fish Protection Act Section 12 concerning streamside protection, which is enforced through the Streamside Protection Regulation (B.C. Reg. 89/2000). The Regulation calls on local governments to establish streamside protection and enhancement areas in residential, commercial and industrial zones and to identify these areas through their land use plans and regulations by the year 2006. Only 12 such sites have thus far been designated (Niel Banera, Ministry of Sustainable Resource Management, pers. comm.). The SPR is currently undergoing a review to determine what revisions to the regulation, guidelines or implementation strategy might be necessary to ensure protection of fish while respecting private property interests.

MWLAP has various responsibilities related to fish management including:

- Species at Risk — Identify, protect and restore species at risk and their habitat e.g. Sockeye has yellow status;

- Wildlife and Wild Fish — Manage and protect fish, wildlife and their habitat e.g. Sockeye, Kokanee, Chum, Chinook, Trout and many introduced fish species inhabit the Okanagan Watershed;
- Habitat Conservation — Manage conservation in parks and protected areas system;
- Sport fishing management;
- Non-commercial freshwater aquaculture management;
- Water quality monitoring.

The department responsible in MWLAP for fish issues is the Environmental Stewardship Division (ESD). The BC Biodiversity Branch deals exclusively with biodiversity issues, while the Fisheries Branch administers projects concerned with freshwater fish species and habitat management. A Recreation Stewardship Panel was named in spring 2002 to make recommendations for a new management model for angling, hatcheries, hunting and park recreation that connects fees with services and opportunities and allows greater public involvement in decision making.

The Thompson-Okanagan Region Office of the ESD supervises the Okanagan Lake Action Plan (OLAP). Public and government concern for the future of Okanagan Lake kokanee during the early 1900s led to formation of a proactive plan in 1996. This forward-looking plan with a twenty-year time horizon attempts to address all of the physical and biological factors that influence Okanagan Lake and the kokanee populations that inhabit it.

Fish and Forests

The Forest Practices Code of BC Act outlines the protection of community watersheds (drinking water) and riparian zones (habitat and surface water quality protection through prevention of erosion) on crown lands. Resource management planning including watersheds is now the administrative responsibility of MSRM rather than MF (see section on water quality).

Inter-departmental projects

The government is committed to developing a Living Rivers Strategy to protect and improve the province's river systems through watershed management, and enhancements and restoration of fish habitat (MWLAP, 2002a). Working with the Ministry of Sustainable Resource Management, MWLAP has begun to analyze and review options and prepare recommendations for public review during 2002, targeting implementation of an integrated strategy by 2004. MWLAP has created the Living Rivers Section within the Biodiversity Branch to lead the initiative. This takes over activities from the Fisheries Renewal BC and Watershed Restoration Program from the previous government. A $2-million trust fund to protect and restore B.C.'s rivers as been established as the first step in developing the Strategy (MWLAP, 2002b).

Under the Resource Management Branch, is a joint initiative between MAFF, MWLAP (previously MELP) and the B.C. Agriculture Council – The Partnership on Agriculture and the Environment. The initiative involves a 10-Point Action Plan to integrate agriculture and environment ministry activities. The Agricultural Watercourse Maintenance Policy was established under this partnership to minimize the impact of agricultural runoff (from ditches) on fish. MAFF also produces various guidance documents on farming practices, and partners in (provides resource to) various projects, to reduce agricultural environmental impact and conserve resources e.g. irrigation, water storage, wastewater runoff, nutrient use, etc.

3.3 Regulation and Regional Vulnerability

In the context of adaptation to climate change in the Okanagan, British Columbia's regulatory system provides several challenges. Rising water demands due to population growth and changes in water supply and demand due to climate change may result in increased activation of the prior appropriation principle, resulting in increased conflict. Even though conflict is often resolved in the field through more informal methods, increased water stress makes the situation more vulnerable (Neil Banera, Ministry of Sustainable Resource Management, pers. comm.). Under the same conditions, the beneficial use principle could become a more significant requirement in divvying out licenses as water sources become saturated. The perpetual nature of water licenses and the limited ability of managers to modify water rights e.g. transferability and conditionalities, may become restrictive in the face of increasing demands to manage water for multiple objectives (which may or may not be subject to water licensing). Balancing in-stream e.g. fish, and out-of-stream uses e.g. domestic, could become an increasingly difficult under a climate change scenario. The failure to proclaim the Fisheries Protection Act and to define acceptable minimum fish flows adds to this difficulty.

Although improved water quality standards under the impending Drinking Water Quality Act are essential in providing clean and acceptable potable water to users, the challenge in the Okanagan (and other regions) will be the cost of implementation. Currently, the Canada-British Columbia Infrastructure Program, launched in

January 2001 provides grants to local government. The agreement calls for the investment of more than $800 million over six years to improve urban and rural local government infrastructure in British Columbia. The two governments each agreed to contribute $268 million towards the program, with the remaining amount coming from municipal governments and other project proponents. The program's first priority is green local government infrastructure.

The challenge will be providing potable water to rural communities in the Okanagan. Under the Local Government Grants Act, irrigation districts are still not eligible for unconditional funding, unlike municipalities. It is often cited that access to funding is used as leverage for the province's agenda of regionalisation i.e. move from local to regional administration of services (Erik Karlsen, pers. comm.).

Although water efficiency is a priority both in the federal and provincial governments the question of who should bear the cost is again pertinent. MAFF is actively involved in encouraging farmers to move toward more efficient means of irrigation (Janine Nyvall, pers. com.). The 'green' priority of the Canada-BC Infrastructure means that local authority water efficiency programs (amongst other things) will take precedence. Significant steps toward greater efficiency are taking place in local authorities throughout the Okanagan, as well as some Irrigation Districts. Increased efficiency will alleviate initial strains from the many factors that stress water resources in the Okanagan, including climate change, the question is at what point will it not be enough.

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chapter 4

Climate

Bill Taylor and Mark Barton

This chapter aims to develop an understanding of the past and current Okanagan Basin climate at a range of spatial and temporal scales. The main body of this chapter includes an analysis of trends in a number of important climatic variables for this region, and a discussion of natural climatic variability due to El Nino/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). We also discuss drought indices, a history of drought in the Okanagan, and a review of the summer 2003 drought. Space and time limit this chapter to an initial assessment of some measures of the hugely complex climate system. Climate records with their limited length and/or quality significantly limit the range of analyses that are statistically and climatologically significant (Okanagan Valley Tree Fruit Authority, 1995). This limitation is overwhelming at high elevations (>1,200 m), where snow accumulation and runoff are important controls on the water supply.

4.1 Climate Overview

4.1.1 Geography and topography

The 8,200 km^2 Okanagan valley is a long narrow basin stretching 182 km from the Vernon area in the north to the Washington state border near Osoyoos in the south. The basin's southern interior location gives the area its mild continental dry climate. Mountain ranges to the west dry the air masses originating over the Pacific Ocean and give the region a dry mild winter and hot dry summer climate. Very cold arctic air masses enter the region occasionally. They are the main cause of severe vine and fruit tree damage in the valley (Okanagan Valley Tree Fruit Authority, 1995).

The main features of the basin are Okanagan Lake, with a surface area of 350 km^2, and five smaller main stem lakes of Okanagan River with a combined surface area of approximately 87 km^2. These lakes greatly impact the basin hydrology through evaporation from the lake and interactions between surface and groundwater systems. The mountain crests around the valley are at about 1,600 to 2,000 m elevation and the mean basin elevation is about 1,100 m. Most of the hydrologically important runoff occurs at or above 1,200 m elevation with little or none below this level (Obedkoff, 1973).

4.1.2 The climate of the Okanagan

Okanagan Basin climate ranges from arid in the southern valley bottom around Osoyoos, to moist near the high elevation forested basin boundary above McCulloch in the northeast and Peachland Brenda Mines in the west. Semi-arid conditions characterize much of the valley bottom and the lower bench agricultural and municipal areas throughout the valley. Winters are typically described as mild continental. In summer, weather conditions are among the hottest and driest in British Columbia. Mean annual precipitation ranges from less than 300 mm at the southern end of the valley to at least 700 mm in the sub-alpine areas.

The dry and reliably sunny summer Okanagan climate is the key reason that the tourism and agriculture industries are the mainstays of the valley economy. Wine and tree fruit production are significant components in both tourism and agriculture sectors, largely due to the near ideal climatic conditions. An extensive range of microclimates are exploited by these rapidly modernizing industries.

Agricultural and municipal development in many parts of the valley is only possible because of the irrigation water from about fifty high elevation reservoirs throughout the valley. Okanagan Lake along the valley bottom is by far the largest reservoir. It supplies water for many of the municipalities and is exploited for its recreational and fish rearing potential.

The two large communities of Kelowna (pop. 96,000) and Penticton (pop. 31,000) rely in part on the lake for their municipal water supplies and the tourism industry depends on the lake for its recreational and aesthetic appeal (Statistics Canada 2001 Census data). Between 1971 and 2003 the population of British Columbia's Okanagan basin has more than doubled. This is the fastest growth rate among the 23 major river basins in Canada (Statistics Canada 2003). However, this scenic region in the British Columbia interior also has one of Canada's lowest renewable supplies of fresh water (Statistics Canada 2003). The Okanagan-Similkameen basin has only 0.1% of the country's renewable supply of fresh water. In comparison the Pacific Coastal basin has 15.8% of the renewable supply of fresh water, (Statistics Canada 2003). The current population of the Okanagan-Similkameen basin is about 290,000. In 2001, the Okanagan-Similkameen river basin ranked first in Canada in terms of the number of people for each square km of surface water, and second only to the Great Lakes-St. Lawrence river basin in terms of population density for every square km of land (Statistics Canada 2003). The Okanagan-Similkameen river basin has nearly 439 people for every square km of surface water (Statistics Canada 2003). British Columbia's Fraser River valley has 224 (Statistics Canada 2003). This rapidly expanding population is increasingly placing demands on the available water supply.

4.1.3 Natural variability – PDO and ENSO

Natural climatic variability occurs on many different time scales. El Niño/Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) are two predominant modes of natural variability affecting the climate of Western Canada occurring on inter-annual and inter-decadal time-scales, respectively (Wallace and Gutzler, 1981; Trenberth and Hurrell, 1994; Mantua et al, 1997). Understanding these sources of natural variability is important in detecting climate change since the natural variability can mask gradual changes in climate due to greenhouse warming.

ENSO and PDO are characterized by periods of anomalous warming and cooling of the Pacific Ocean accompanied by characteristic changes in atmospheric circulation. El Nino is distinguished by a warming of the tropical waters of the central Pacific with a corresponding decrease in the strength of the easterly trade winds. During La Niña, the opposite phase of ENSO, the central tropical Pacific cools and the trade winds become stronger.

Like ENSO, the PDO also involves anomalous warming and cooling of the Pacific Ocean, however, there are differences in the timescale over which these phases are observed and the part of the ocean where they occur. PDO changes phase less frequently, and it is observed in the North Pacific rather than the tropics. During the positive phase of PDO, much of the North Pacific is cooler than usual, except for the waters along the middle latitudes of coastal North America which show a characteristic warming. When PDO is negative, the North Pacific is anomalously warm with cooler waters along the coast of Canada and the Gulf of Alaska.

During the warm phases of both ENSO (El Nino) and PDO, there is a corresponding change in the winter-time atmospheric circulation over the North Pacific which Wallace and Gutzler (1981) termed the Pacific North American (PNA) pattern. During the PNA, the Aleutian Low deepens, an amplified ridge of high pressure forms over the coast of North America, and the storm track is directed northward into the Gulf of Alaska. This results in an increase in the south-westerly flow of warm air into the Pacific Northwest US and Western Canada from November to March. Shabbar and Khandekar (1996) and Shabbar et al (1997) found winters in Western Canada to be much milder and drier during El Niño. Snowfall is generally less during the PNA, likely due to a reduction in the fraction of precipitation falling as snow as a result of higher temperatures. During the cold phases (i.e. La Niña and PDO negative), the flow becomes more westerly and winters in Western Canada are typically cooler and snowier.

In recent years, there have been several particularly strong El Niños in the winters of 1982-83, 1986-87 and 1997-98. The PDO has undergone at least four phase changes during the 20th Century: 1900-1925 (cold), 1926-1946 (warm), 1947-1976 (cold), and 1977- late-1990s (warm). There is some evidence to suggest that the PDO changed phase in the late 1990s to the cool phase, however, there are insufficient data to determine this unequivocally. An abrupt change in sea surface temperatures in the North Pacific in 1977 to the warm phase of PDO is well documented (Trenberth, 1990).

4.2 Data and Methods

4.2.1 Climate stations and records

Environment Canada began monitoring climate in the valley over a century ago. Vernon Coldstream Ranch was the first station to measure temperature and precipitation at daily intervals, from 1 April 1900. Currently there are 21 active weather station locations in the Okanagan and 71 listed as inactive. All but one of the active stations are low elevation valley bottom and lower bench stations. Osoyoos is the lowest at 283 m elevation and Joe Rich Creek is the only mid-elevation station at 875 m in the Mission Creek watershed east of Kelowna. A map showing the locations of climate stations used in this study are shown on the map in Figure 4.1.

FIGURE 4.1

Map of Okanagan showing climate stations.

Climate data for annual, monthly, daily and hourly time periods are used in many aspects of this study. Annual and monthly data are used to develop an understanding of long term climate trends and seasonal climate variation over the period of record. Daily temperature and precipitation data for the 1961-1990 climate normal period are extensively utilized in the hydrology modeling aspects of the study. These data are the baseline upon which climate scenarios are developed for the 2020's, 2050's and 2080's (see Chapter 5). Hourly temperature data from the Hobo network in Summerland and Naramata orchards and vineyards allows an assessment of microclimatic crop growing conditions.

Climate stations operated by and for Environment Canada have existed at about one hundred locations throughout the valley. Of these, only two stations, Vernon Coldstream Ranch and Summerland, have a long (~100 yr) and almost continuous record of temperature and precipitation. Station automation in the mid 1990's introduced serious gaps in the precipitation records at the Vernon and Summerland stations. It is quite common, throughout Canada, for auto-stations to have as much as 50% of the precipitation readings missing due to equipment problems.

Station moves and changes in the climate variables measured have occurred quite frequently, even at Vernon Coldstream Ranch and at Summerland. Such changes usually create steps in temperature and other climate records that are due to microclimate and instrument effects rather than purely due to climate variability and climate change. Therefore, the data often require adjustments so that the climate datasets are, in effect, what would have been recorded by perfectly maintained instruments at a single location for the entire period of record. This adjustment process is referred to as data homogenization. Almost one hundred years of temperature and precipitation data have been homogenized for Vernon Coldstream Ranch and Summerland. Homogenized (rehabilitated) precipitation data also exist for several other stations in the Okanagan including Penticton, where data for the Penticton town and airport stations were joined. Due to the enormity of the homogenization task, examination of long term trends was limited mostly to the few weather stations for which homogenized data were available. Data homogenization complexities are well explained for the Canadian datasets used here (Mekis and Hogg 1999, Vincent and Gullett 1999). Trends have also been calculated for shorter periods for many non-homogenized datasets where there was no alternative. Analyses of trends in such data are labeled with the appropriate caveats.

At stations with short records, the existence of trends in climate data may be masked by decadal scale variability such as the Pacific Decadal Oscillation. Stations with histories going back only 50 years contain records that began during the cold phase of PDO (1947-1976) and end during the warm phase (1977- mid-1990s). Temperature trends during this period will be very strongly influenced by this decadal cycle from the cold PDO to warm PDO. Thus, an effort was made to use climate records with sufficiently long histories (e.g. 100 years) to minimize the influence of decadal-scale cycles. The impacts of record length and record start-dates on trends in this region are well described by Mote (2003).

The hydrology of the Okanagan Basin is snow-melt dominated, so the accumulation of winter precipitation largely determines the amount of water available for the coming growing season. The snow pack reaches its maximum depth around April 1, and the snow water equivalent (SWE) at that time is a good estimate of the water supply for the remainder of the year. The provincial Ministry of Water, Land and Air Protection operates a snow survey network as part of its River Forecast Program. Manual snow course data and automatic snow pillow data are available from the River Forecast Centre website at **http://wlapwww.gov.bc.ca/rfc/index.htm**

There are only a few snow courses dating back to the 1930s in the Okanagan Basin, and with the majority of stations established in the 1960s and 1970s. To identify trends, we sought the largest possible number of stations with the longest set of overlapping records, including several stations from the Thompson Basin to the north. The inclusion of these stations outside the Okanagan valley is justified on the basis of a cluster analysis done by Moore and McKendry (1996) who found the snowpack of the Okanagan and Thompson regions to be relatively homogeneous. Thirteen stations from the Thompson and Okanagan Basins with reasonably complete records from 1950 to 2003 were found. Because the amount of snow that falls and accumulates is very dependent on elevation, it is not meaningful to calculate an average SWE for the entire region. Rather, we calculated a standardized SWE at each site by subtracting the mean from each station and dividing by its standard deviation. The standardized SWE was then averaged over the 13 sites to obtain a basin-wide standardized SWE.

In the Okanagan basin solar radiation is measured only at Summerland weather station located about 12 km north of Penticton Airport. Records began in June 1961 and quality controlled data ended July 1995. Most of the data for the 1995-2004 period are currently in raw instrument output format (mV) and will be processed into (MJ m^{-2}) if serial numbers and associated calibrations are found. Data may be permanently lost for 1995-2004. Net (all wave) radiation measurement at Summerland began January 1974 and is available to July 1995. More recent net radiation data is ready for processing and awaits the arrival of calibration information as solar radiation data does.

4.2.2 Statistical methods

Statistical tests were used to detect the presence of trends in the surface climate data, and to test for differences in climate during various phases of ENSO and the PDO. The Mann-Kendall non-parametric test was used to determine the statistical significance of a trend, and Sen's method was used to estimate the magnitude of a trend (Salmi et al, 2002). Non-parametric tests were chosen in this case because they are robust, are less sensitive to non-normal distributions, and are less affected by extreme values or outliers (Zhang et al, 2000). Most meteorological time series are serially correlated. Because serial correlation may result in overstating the statistical significance of trends, the data were first tested for autocorrelation, and then "pre-whitened" based on the amount of autocorrelation found in the time series (Wang and Swail, 2001).

In order to assess the impacts of ENSO on the Okanagan climate, average winter temperatures for each November to March period were classified as one of El Niño, La Niña or Non-ENSO according to the Climate Research Branch of Environment Canada classification **http://www.msc.ec.gc.ca/education/elnino/**. After de-trending the data, El Nino temperatures were compared to non-ENSO temperatures, and the non-parametric Mann-Whitney U test was used to test for differences between means. The same procedure was repeated for La Nina temperatures. Winter precipitation data for seven stations were classified into three ENSO groups and tested for differences between means. Similar procedures were also applied to the standardized April 1 SWE to test for differences between the mean SWE during cold and warm ENSO events and non-ENSO years. Differences in temperature, precipitation and SWE during the positive and negative phases of PDO were also tested.

4.3 Climate Trends and Variability

Our aim in this part of the study is to identify climate trends in the Okanagan Basin for a number of climatological variables and to determine the influence of large scale natural variability on the climate. Climate trends are an important indicator of climate change as they provide a quantitative measure of the rate of change in such variables as temperature and precipitation for a given location. In a stationary climate, annual departures from the mean cancel each other out and are randomly distributed throughout the period of record. However, as the global climate record shows in Figure 4.2, the climate of the 20th Century was not stationary, and in fact shows a warming trend of 0.6 ±0.2 degrees C (IPCC, 2001). This warming trend is not monotonic and includes periods of steep increases in temperature as well as at least one period of slight cooling. The reasons for climate change are varied and complex. The dramatic build-up of

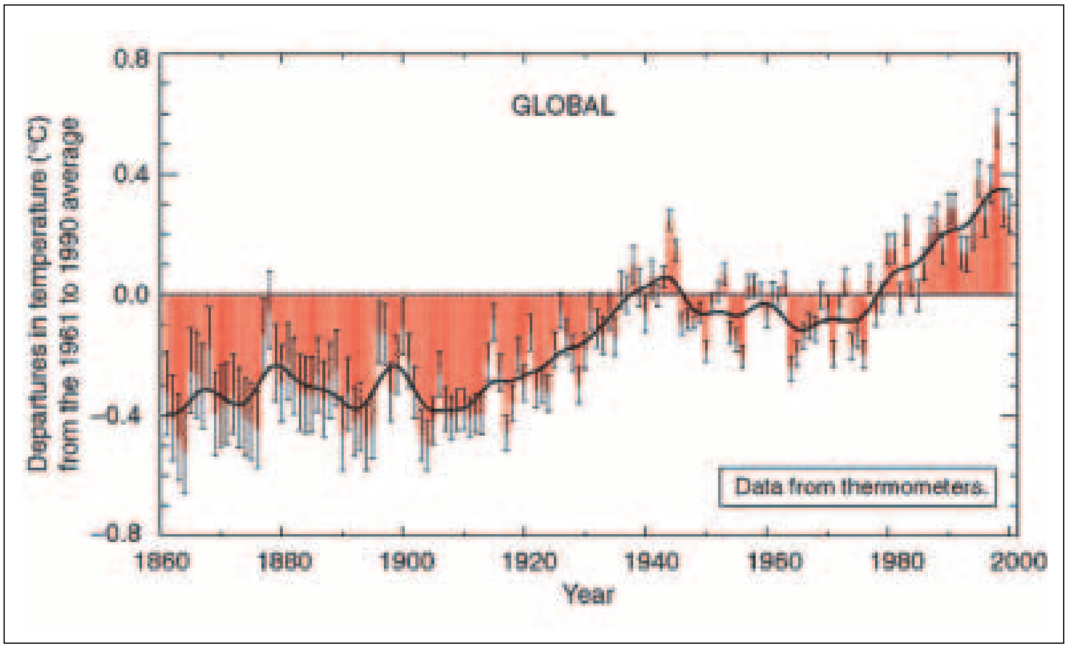

FIGURE 4.2

Time series of global temperatures since 1860 (IPCC, 2001). Vertical lines represent departures from the 1961-90 average temperature. The heavy line smoothes out year-to-year fluctuations.

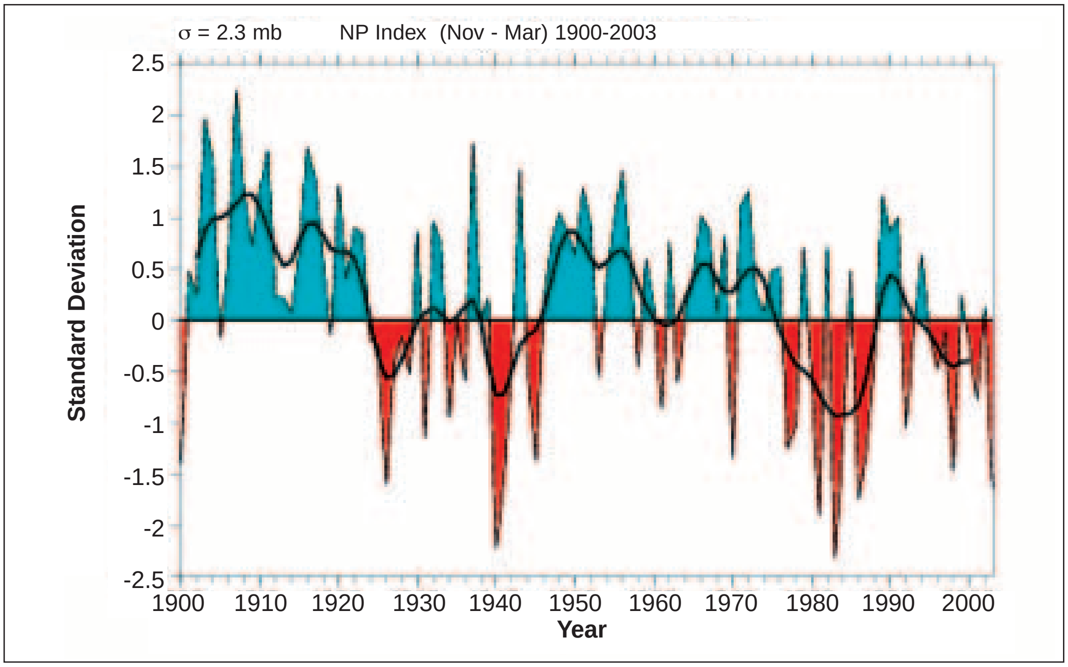

FIGURE 4.3

The North Pacific (NP) Index is the area-weighted standardized November to March sea level pressure anomaly over the region 30N-65N, 160E-140W (Trenberth and Hurrell, 1994).

greenhouse gases in the atmosphere is widely accepted as the primary reason for the rise in temperatures during the last 50 years of the 20th Century (IPCC, 2001). Other sources of climate change include variations in solar output, changes in concentrations of aerosols and volcanic dust (which cools the climate), and changes in land use.

In addition to these external sources of change, the climate has its own natural rhythm of internal variability. A number of indices have been developed to track the state and evolution of ENSO and PDO phases and the PNA. In this study, we use the North Pacific Index (Trenberth and Hurrell, 1994) following the custom of other climate studies in British Columbia and the Pacific Northwest (Moore, 1996; Moore & McKendry, 1996; Mote 2002). The NP Index is based on departures from normal atmospheric pressure over the north-eastern region of the Pacific Ocean. The November to March NPI values since 1900 are plotted in Figure 4.3.

4.3.1 Okanagan climate in the 20th Century

Air temperature and precipitation are the two most commonly measured climate variables in the valley. They are also the most widely studied in climate change projects. Analysis of trends and variability give a good indication of the potential impacts that are likely under current and future conditions. Mean annual temperature and precipitation give a simple overall indication of the rate of change. Seasonal patterns of change through time are studied to illustrate the likely development of water availability issues as longer warmer growing seasons place increasing demands on water supply, and as earlier snowmelt and reduced snowpack place more constraints on supply.

Homogenized temperature records and rehabilitated precipitation records from Environment Canada's Adjusted Historical Canadian Climate Data (AHCCD) data base were examined to detect the presence of trends in temperature and precipitation for each season. These records have been adjusted to remove influences due to changes in instrumentation, station relocation, and changes to observation times and practices. In addition, a number of other meteorological variables including radiation, cloud cover, humidity and barometric pressure were analyzed.

4.3.1.1 Temperature

Homogenized temperature records for daily minimum and daily maximum temperatures were examined for two long-term stations: Summerland CDA and Vernon Coldstream Ranch. Warming is significant at both sites for winter and spring for both daily minimum and maximum temperatures, although trends in daily minimum temperatures are larger than those for the daily maximums. At Summerland, for example, daily maximum temperatures during winter rose 2.4 °C per century, while daily minimums were higher by 3.6 °C. Consequently, there is also a statistically significant decrease in the winter diurnal temperature range. Warming during the other three seasons was generally between one and two degrees per century for the mean daily minimum and daily maximum temperature. The largest trends at both sites were observed for daily minimum temperatures during winter. These results are summarized in Table 4.1. Plots for Summerland for daily minimum and maximum temperature are shown in Figures 4.4a and 4.4b, respectively. These findings are consistent with the trends published by the BC Ministry of Water, Land and Air Protection (BC WLAP, 2002) and as reported by Mote (2003).

TABLE 4.1

Summary of trends in temperature in degrees C per decade. Statistically significant trends are bolded.

SITE	ELEV	YEARS OF RECORD	WINTER	SPRING	SUMMER	AUTUMN
Daily Maximum						
Vernon CSR	482	100	**0.15**	**0.10**	0.03	**0.10**
Summerland	454	94	**0.24**	**0.12**	**0.10**	**0.12**
Daily Minimum						
Vernon CSR	482	100	**0.35**	**0.19**	**0.18**	**0.14**
Summerland	454	94	**0.36**	**0.14**	0.06	0.08

Temperature extremes were also examined to determine the presence of trends. The annual minima, and the second and fifth percentiles of the daily minimum temperatures at Summerland CDA were examined, as well as the annual maxima and the 95th and 98th percentiles of the daily maximum. Trends in extreme minimum temperatures are large and statistically significant, on the order of 4 to 5 degrees C per century, which is greater than the 3.6 °C trend observed for the annual mean daily minimum. Extreme maximum temperatures indicate a more modest increase of roughly 1.5 °C at the 95th and 98th percentiles which is also statistically significant. There is no discernible trend in the annual maximum.

There is a strong relationship between Okanagan winter temperatures and the PNA pattern. When the North

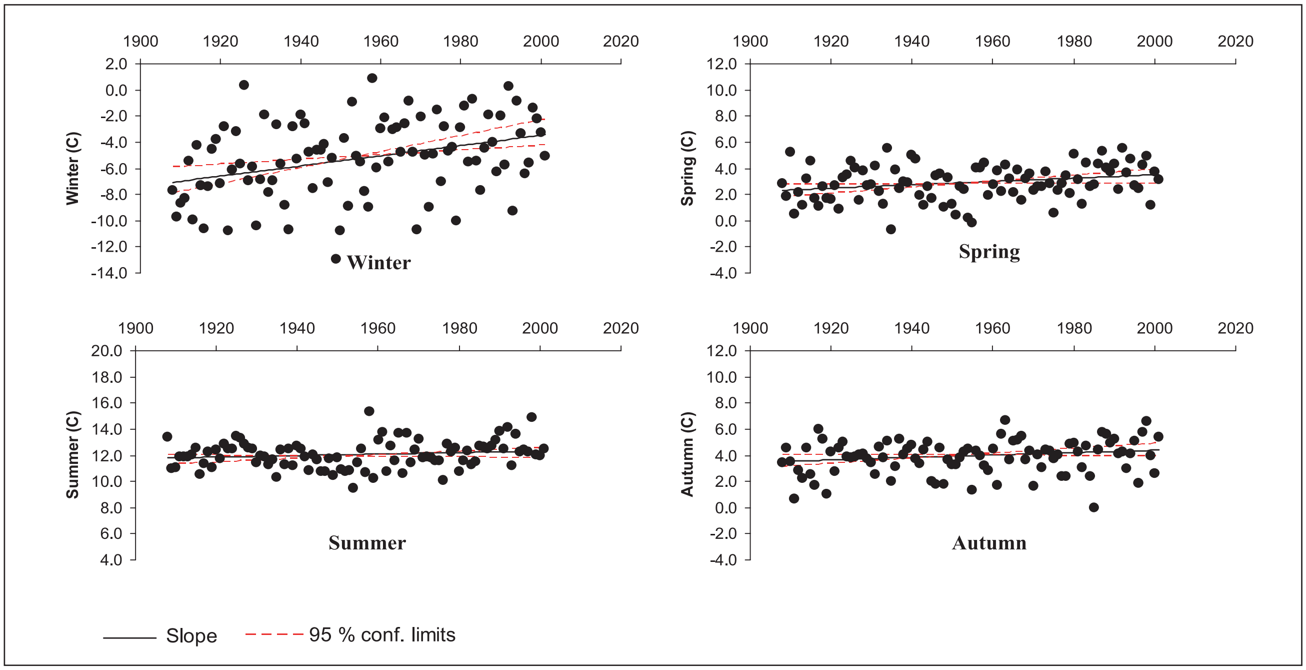

FIGURE 4.4A

Seasonal trends in the annual mean daily minimum temperatures for Summerland. Units are degrees C. Trends are statistically significant (p<.05) for winter and spring.

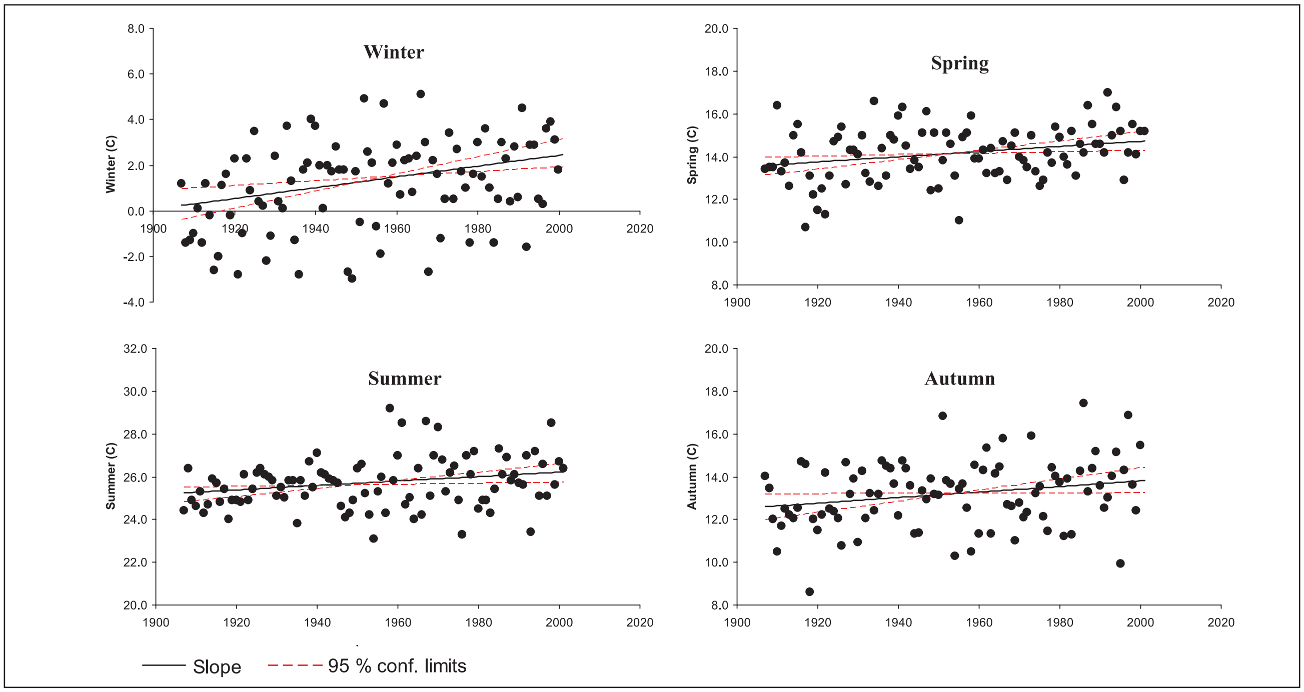

FIGURE 4.4B

As in Figure 4 (a) except daily maximum temperatures. Units are degrees C. Trends are statistically significant (p<.05) for all seasons.

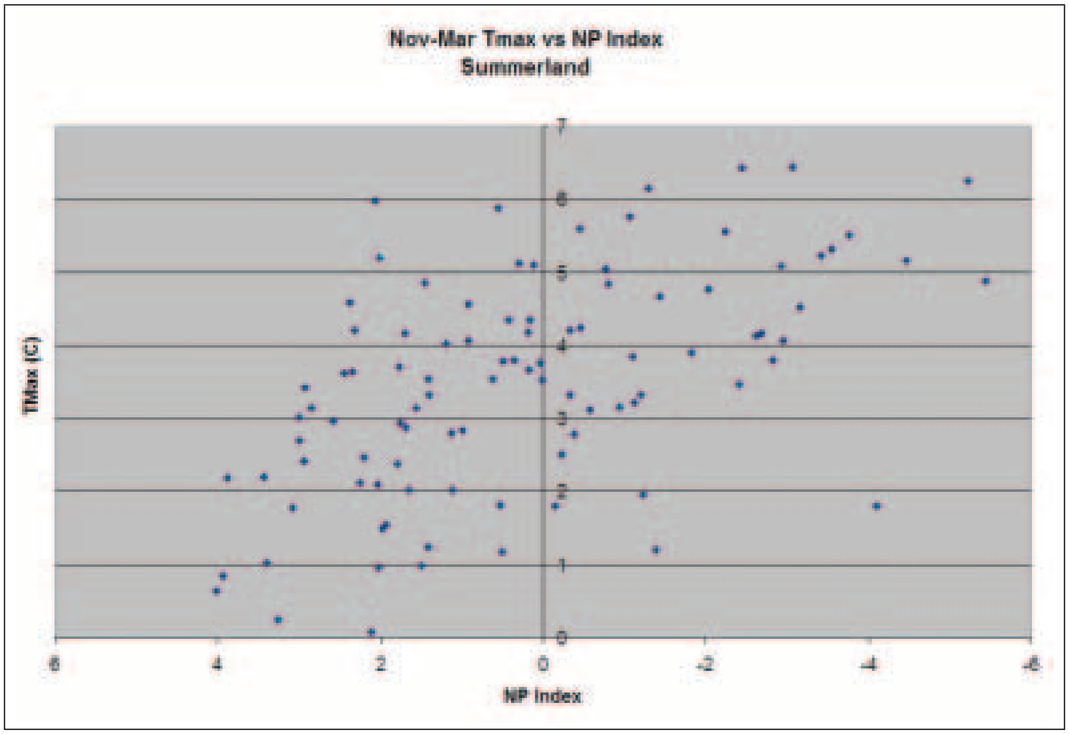

FIGURE 4.5

Relationship between November to March mean daily maximum temperature at Summerland and the NP Index (scale reversed).

Pacific (NP) Index is negative, i.e. a deeper Aleutian Low, November to March temperatures in the Okanagan are significantly higher as shown in Figure 4.5. Such variations in Okanagan temperatures are associated with changes in circulation that increase the southwesterly flow of warm air into the north-eastern Pacific when the Aleutian Low deepens, as in the case of El Nino. Both daily minimum and daily maximum temperatures were found to have a statistically significant correlation (r = ~ -0.6) with the NP Index.

Temperatures during El Niño winters were found to be significantly higher than non-ENSO winters at both valley stations by about one degree Celsius. No significant differences were found for La Niña winter temperatures. We also compared average winter temperatures for successive phases of the PDO and found no significant differences at either of the two valley stations.

4.3.1.2 Precipitation

Rehabilitated precipitation records from six different sites were examined for trend analysis: Kelowna Airport (429 m), Penticton Airport (344 m), Summerland CDA (454 m), Joe Rich Creek (875 m), McCulloch (1250 m) and Vernon Coldstream Ranch (482 m). Statistically significant trends were found at virtually all sites for spring and summer precipitation as shown in Table 4.2. Based on an average of the four valley stations

TABLE 4.2

Summary of trends in precipitation in percent per decade. Statistically significant trends are bolded.

SITE	ELEV	YEARS OF RECORD	WINTER	SPRING	SUMMER	AUTUMN
Vernon CSR	482	91	**3.5**	**3.7**	**3.6**	**2.5**
Kelowna	429	97	0.3	**5.0**	**4.8**	1.1
Penticton	344	94	0.1	**4.9**	**4.2**	1.2
Summerland	454	87	2.7	**4.9**	**4.9**	-0.1
Joe Rich Ck.	875	67	-0.2	**3.4**	**6.7**	3.0
McCulloch	1250	65	1.4	1.0	**5.7**	-2.9

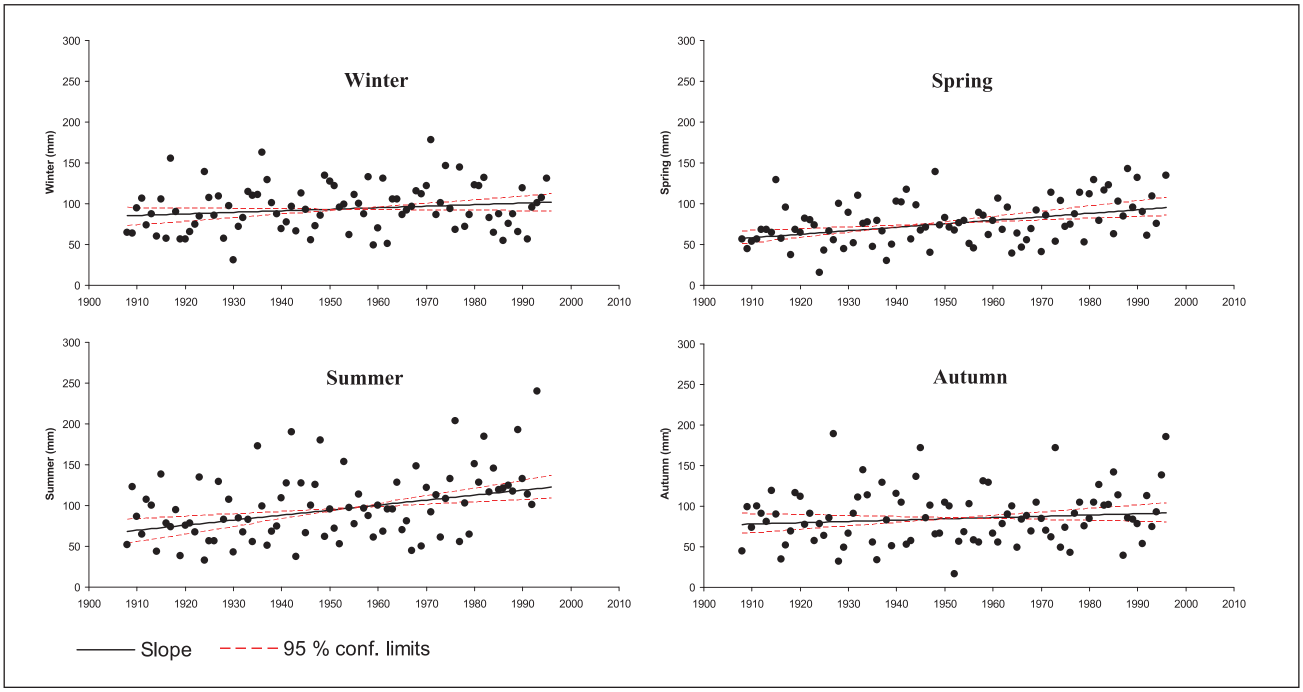

FIGURE 4.6

Seasonal trends in total precipitation based on the average of four valley stations. Units are millimeters. Spring and summer show statistically significant trends (p<.05).

(Figure 4.6), spring-time precipitation increased by 43 mm (55%) over the 20th Century, while summer experienced an increase of 62 mm (62%) over 100 years. No discernible trends in snowfall except at Penticton (Table 4.3). These findings concur with the precipitation trends identified in the provincial Climate Change Indicators report (BC WLAP, 2002).

The November to March NP Index and snowfall are highly correlated (r = 0.3 to 0.6) for all stations in the Okanagan regardless of elevation. Figure 4.7 shows the relationship between snowfall at McCulloch and the November to March NP Index. With the deepening of the Aleutian Low, the storm track is directed into the Gulf of Alaska, freezing levels are higher, and the fraction of precipitation falling as snow is reduced. At all valley stations, the snow fraction has decreased over the 20th Century (Table 4.3). However, there is no evidence of a change in the snow fraction at stations such as McCulloch (1250 m) where temperatures remain generally below freezing during the entire winter, and where the snow fraction averages 92%. A comparison of Penticton and McCulloch snow fractions are shown in Figures 4.8 (a) and (b) to illustrate differences due to elevation.

In general, total winter precipitation during El Niño winters is significantly below that recorded during non-ENSO years at lower elevation stations. Snowfall was found to be significantly reduced during El Niño years at all but one site regardless of elevation. At higher elevations, where most winter precipitation falls as snow, both snowfall and total precipitation were significantly less during El Niño winters. Only one site, Joe Rich Creek (875 m), was found to receive more

TABLE 4.3

Summary of trends in snowfall (cm per decade) and snow fraction (per decade). Statistically significant trends are bolded.

SITE	ELEV	YEARS OF RECORD	SNOWFALL (CM)	SNOW FRACTION CHANGE
Vernon CSR	482	91	1.5	**-0.16**
Kelowna	429	97	-1.4	**-0.13**
Penticton	344	94	**-2.6**	**-0.24**
Summerland	454	87	-1.0	**-0.29**
Joe Rich Ck.	875	67	-1.7	-0.14
McCulloch	1250	65	0.9	-0.02

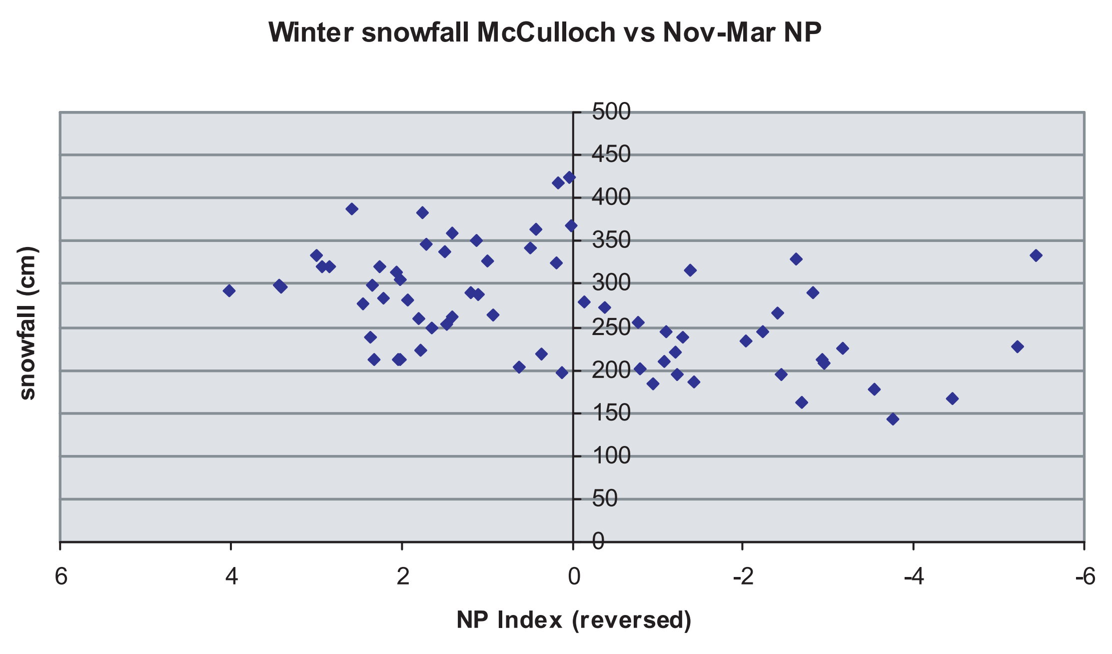

FIGURE 4.7

Relationship between snowfall at McCulloch and the NP Index (scale reversed)

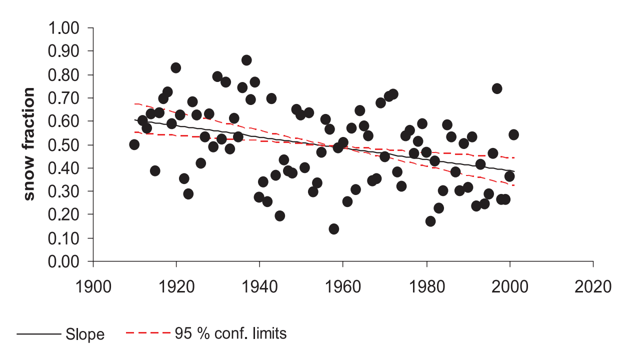

FIGURE 4.8(A)

Trends in snow fraction at Penticton A, a low elevation station (344 m). The trend is statistically significant.

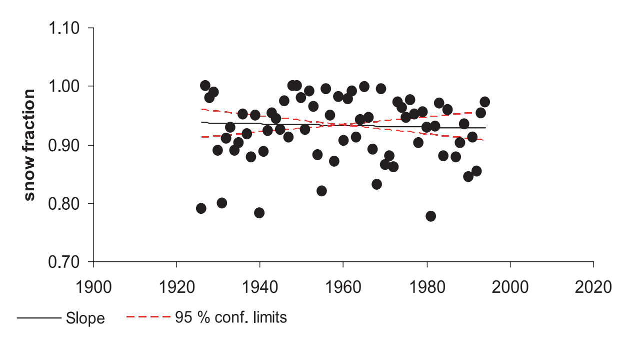

FIGURE 4.8(B)

Trends in snow fraction at McCulloch, a higher elevation station (1250 m). No significant trend.

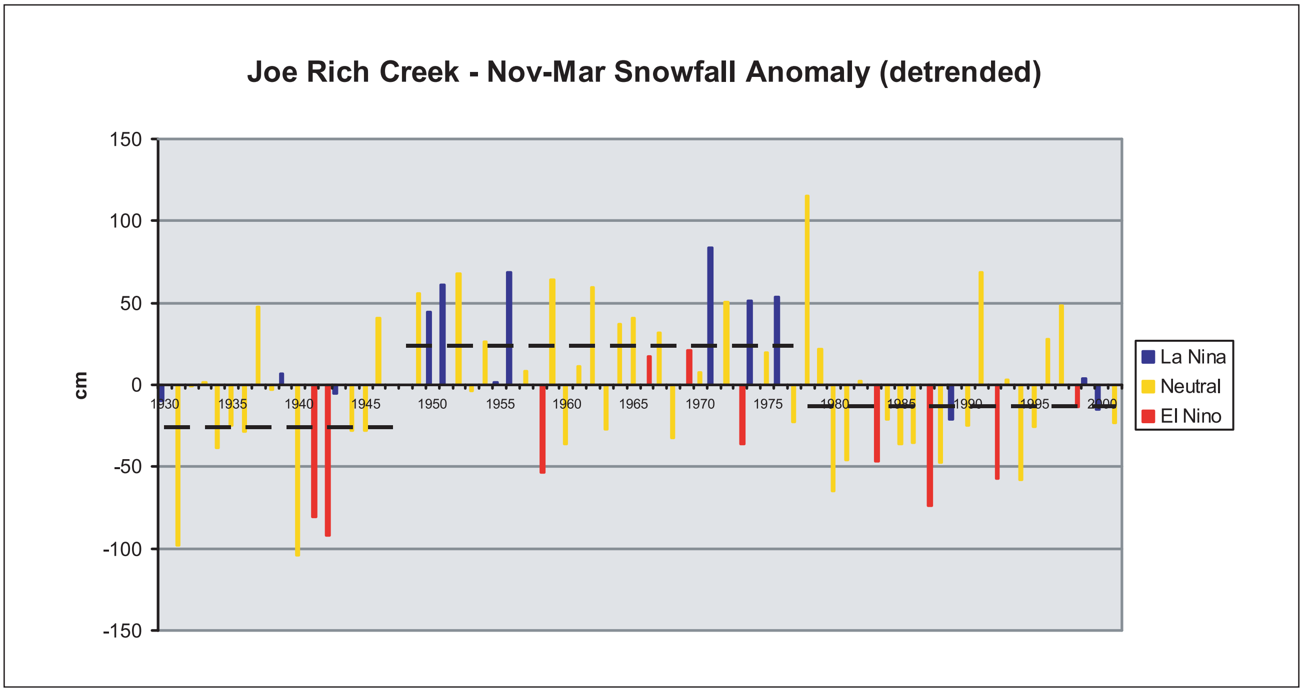

FIGURE 4.9

Time series of detrended snowfall anomalies at Joe Rich Creek from 1929 to 2000. Horizontal dashed lines show mean snowfall during the positive and negative phases of the PDO. Individual winters are colour-coded according to ENSO classification.

snow during La Nina winters. Significant differences in both total winter precipitation and snowfall were also found between PDO epochs for Joe Rich Creek during the latter half of the century. The time series for snowfall anomalies at Joe Rich Creek is plotted in Figure 4.9.

4.3.1.3 Radiation, clouds, humidity, barometric pressure

A statistically significant trend of increasing cloud cover was found at Penticton Airport as shown in Figure 4.10. A similar trend was found for Kelowna Airport. The Kelowna record has data gaps that limit its usefulness. Penticton observations began in 1953 and Kelowna observations date from 1959. Human observations of cloud cover continue to be made at hourly intervals at these airport weather stations.

Based on study results for 50 years of homogenized data, Penticton cloud cover, as shown in Figure 4.11, has increased by 0.6% in the daytime and 4.3% at nighttime between 1953 and 2003 (Wang *et al.*, 2004). The daytime increase is insignificant and the nighttime is marginally significant at an 83.2% confidence level (Wang pers. com.). Human cloud amount observations are limited to 1/10 increments of sky cover and are more difficult at night, however, regionally consistent trends were found at about 100 weather stations across Canada (Wang *et al.*, 2004). As shown in Figure 4.12, Penticton cloud cover is typically either 10 or 9 tenths of sky dome, or 0 tenths, with a low frequency of intermediate sky coverage amounts (Milewska, 2002).

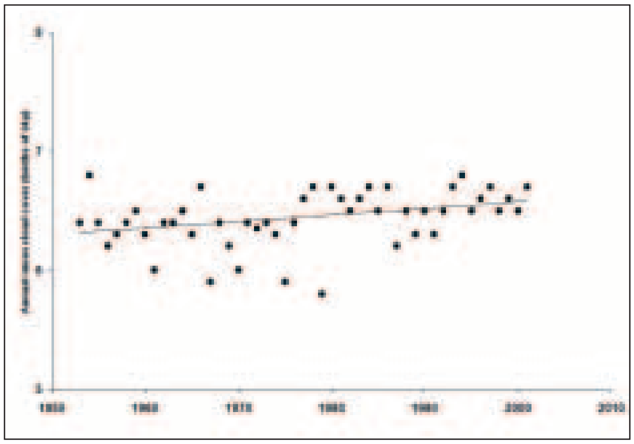

FIGURE 4.10

Penticton mean annual cloud cover 1953-2001. Trend is statistically significant.

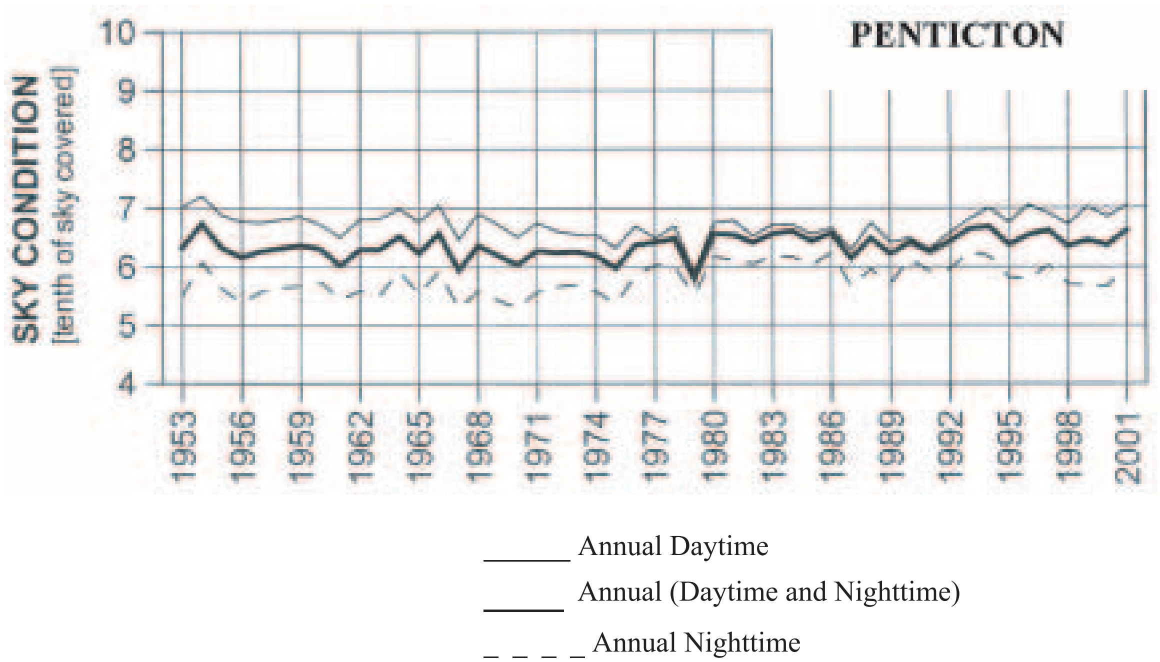

FIGURE 4.11

Time series of average annual cloud cover at Penticton Airport (Milewska, 2002).

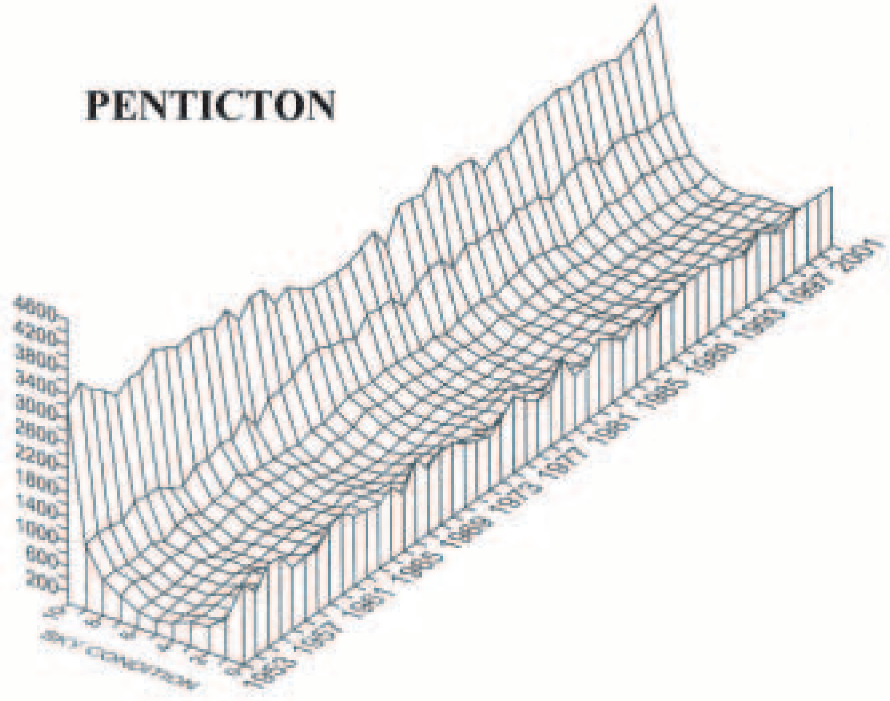

FIGURE 4.12

Time series of annual frequency histogram of hourly sky cover at Penticton Airport. (Milewska, 2002). Vertical axis is the number of hours per year for a given sky condition.

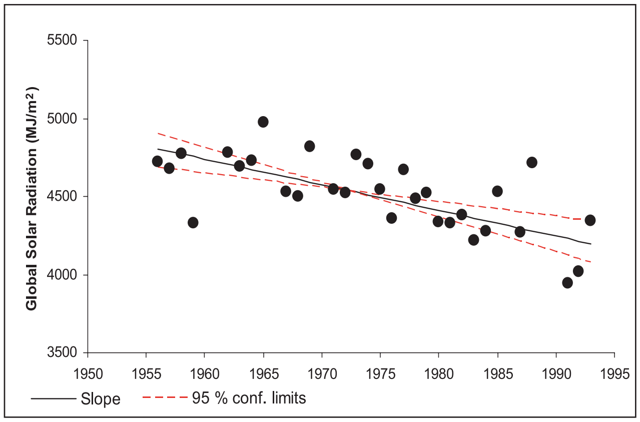

FIGURE 4.13

Summerland total annual solar radiation (MJm^{-2}) 1956-1993. Trend is statistically significant.

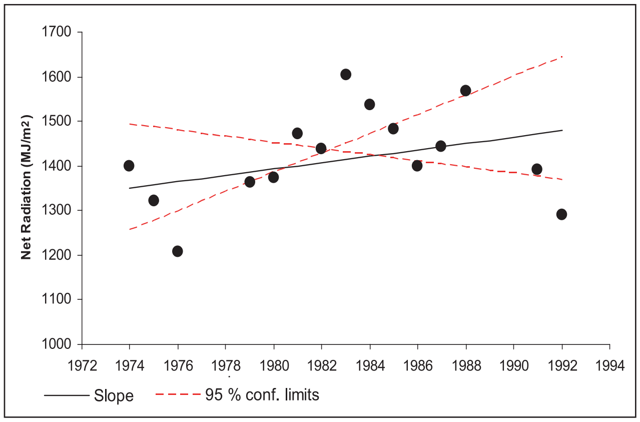

FIGURE 4.14

Summerland total mean annual net radiation (MJm^{-2}) 1974-1992.

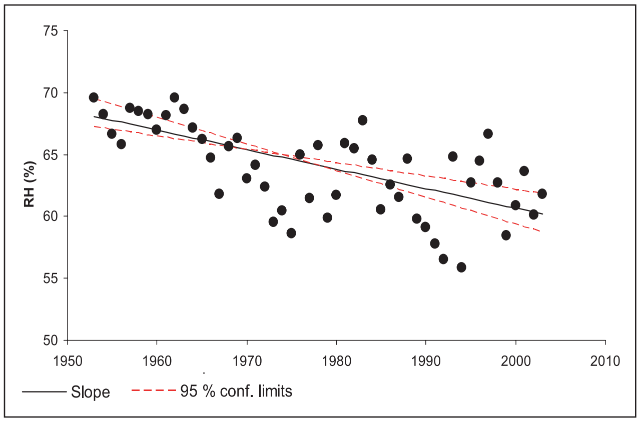

FIGURE 4.15

Penticton mean annual relative humidity (%) 1953-2003. Trend is statistically significant.

Annual mean solar radiation has decreased over the last 50 years as shown in Figure 4.13. This downward trend may be partly due to the increasing cloud cover. It is unfortunate that only one station currently measures solar radiation given the strong trend and its relevance to agriculture and forestry at a time of rapid climate change. Solar radiation is the total incoming direct and diffuse short wave solar radiation received from the whole dome of the sky on a horizontal surface. Solar radiation is (by definition) zero at night.

A short record of solar radiation data is available for Mt. Kobau, 1,862 m elev. located on the Okanagan basin boundary about 12 km NW of the north end of Osoyoos lake. Twelve years of data from 1967 to August 1979 show a significant downward trend. This provides limited support for the possibility that there is a general downward trend in solar radiation for the southern Okanagan basin area.

Net radiation is the resultant of downward and upward total solar (shortwave), terrestrial surface (longwave), and atmospheric (shortwave and longwave) radiation received on a horizontal surface. A weak upward trend in net radiation shown in Figure 4.14 is consistent with the observed rapid increase in Summerland minimum temperatures. A similarly large increase in minimum temperatures has been found in the US northwest (Groisman *et al.*, 2004). Increasing cloud cover enhances net radiation by increasing downward longwave radiation from the relatively warm cloud bottom surface. In the mean, net radiation is positive during the daytime and becomes negative from around sunset until sometime near sunrise. Positive values indicate a net gain at the instrument (ground) surface and negative values indicate a net loss from the surface.

Penticton annual mean relative humidity (68.0% in 1953) has gone down significantly as shown in Figure 4.15 (60.5% in 2003), a 7.5% reduction. This statistically significant trend is likely due mainly to the rapid rise in mean temperatures. It is most evident in winter where temperatures have increased the most. Winter relative humidity has declined by 8.9% over the 1953-2003 period.

No trend is noted in mean annual sea level pressure at Penticton. There were slight non-significant trends of increasing winter pressure and reducing fall pressure. Spring and summer pressures exhibited very slight upward trends. Kelowna mean annual sea level pressure has a similar lack of a trend.

4.3.1.4 Snowpack

Using the Mann-Kendall non-parametric test of significance, a statistically significant downward trend was found in the standardized SWE for the combined Okanagan and Thompson Basins from 1950 to 2003 as shown in Figure 4.16. Trends were also calculated for each of the 13 individual stations and about half display statistically significant downward trends as shown in Table 4.4. At individual snow courses, reductions in SWE in excess of 100 mm were found over a 54 year period. Most of the snow courses showing significant negative trends are at lower elevations (below 1,400 metres) as these sites are more prone to the effects of warming. Higher elevation sites remain below freezing throughout the winter, and are therefore less susceptible to melting due to temperature variations, and are also more likely to be guaranteed precipitation in the form of snow rather than rain.

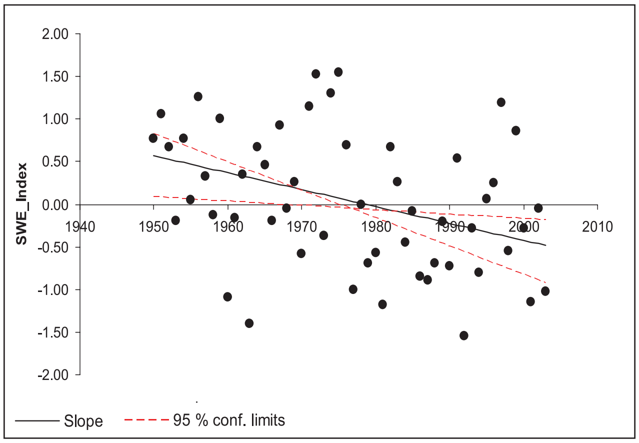

FIGURE 4.16

Trend in standardized SWE for 13 combined stations in Thompson-Okanagan. Trend is statistically significant.

A step change in climate in 1976 which appears to be related to a phase shift of the PDO, has been well documented (Trenberth, 1990; Moore, 1996; Brown and Braaten, 1997). A change point is readily apparent in the April 1 SWE in 1977 by observing the cumulative sum of departures from the mean. Following 1977, the standardized SWE was negative for 20 of the next 27 years. As indicated in Figure 4.17, April 1 SWE is also highly correlated with the NP Index, a result that is consistent with the correlation between the NP Index and temperatures and snowfall. Moore and McKendry (1996) also found an association between the NP Index and April 1 SWE, noting that lighter than average snowpack conditions are a predominant pattern for southern BC following 1977. They attributed this pattern to a rise in freezing levels and an increase in mid-winter snow melt due to higher temperatures associated with a deeper Aleutian Low.

No statistically significant differences in snowpack were found for El Niño years, however La Niña years are marginally significant (p<0.06) for positive SWE anomalies. The standardized April 1 SWE is significantly lower in the warm post-1977 PDO phase

TABLE 4.4

Trends in April 1 SWE at selected provincial snow course sites in the Okanagan and Thompson basins from 1950-2003. Stations are ranked in order of increasing elevation. Significant trends are bolded.

SNOW COURSE	ELEV	YEARS OF RECORD (AFTER 1950)	MEAN APRIL 1 SWE	SIG. LEVEL	SLOPE OF TREND LINE (MM/YR)	CHANGE IN SWE SINCE 1950 (MM)	% CHANGE IN SWE SINCE 1950
Brookmere	980	54	215	p<.01	**-1.85**	**-100**	**-46%**
Anglemont	1190	46	353		-2.00	-92	-26%
Knouff Lake	1200	48	149	p<.05	**-1.08**	**-52**	**-35%**
McCulloch	1280	54	159	p<.05	**-1.04**	**-56**	**-35%**
Summerland	1280	54	224		-1.07	-58	-26%
Aberdeen Lake	1310	54	148	p<.01	**-1.24**	**-67**	**-45%**
Lac Le Jeune	1370	48	109	p<.05	**-1.50**	**-72**	**-66%**
Monashee P.	1370	54	341		-0.47	-25	-7%
Postill Lake	1370	53	221		-0.76	-40	-18%
Trout Creek	1430	54	180		-0.63	-34	-19%
GreyBack	1550	50	231		-0.60	-30	-13%
McGillveray P.	1800	51	624		-2.45	-125	-20%
WhiteRocks	1830	49	564		-1.57	-77	-14%

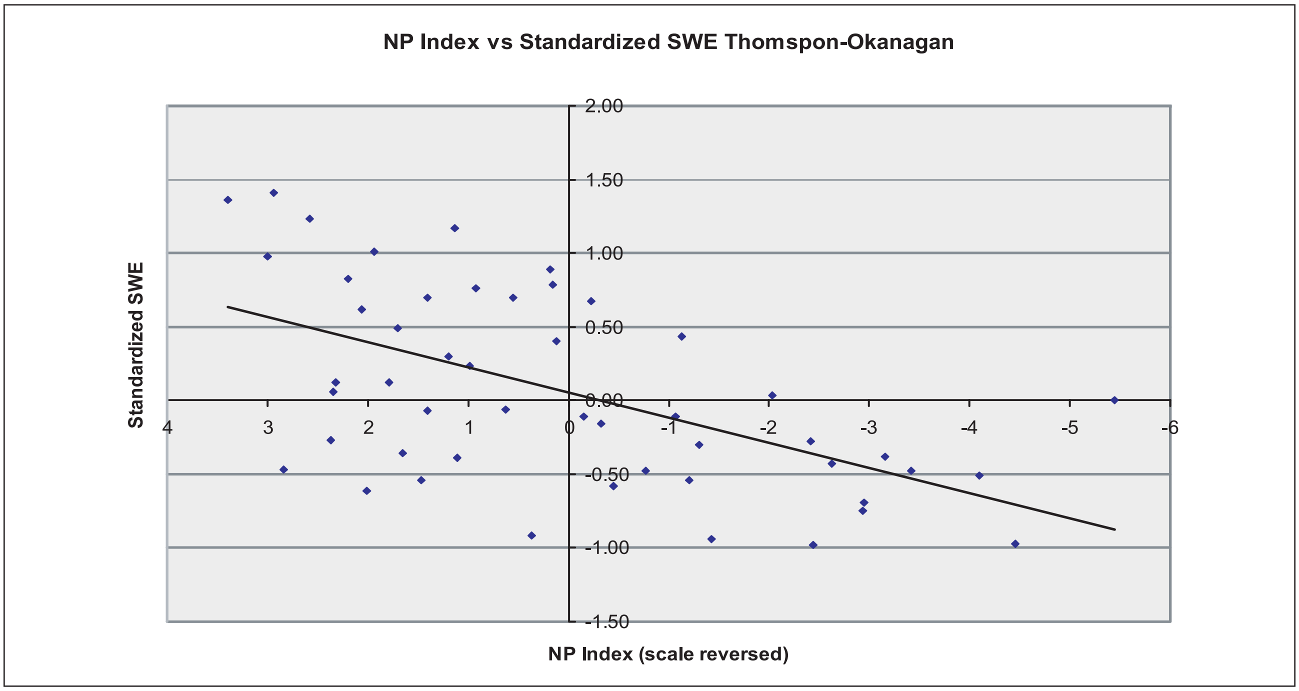

FIGURE 4.17

Relationship between standardized April 1 SWE for Thompson-Okanagan and NP Index (scale reversed).

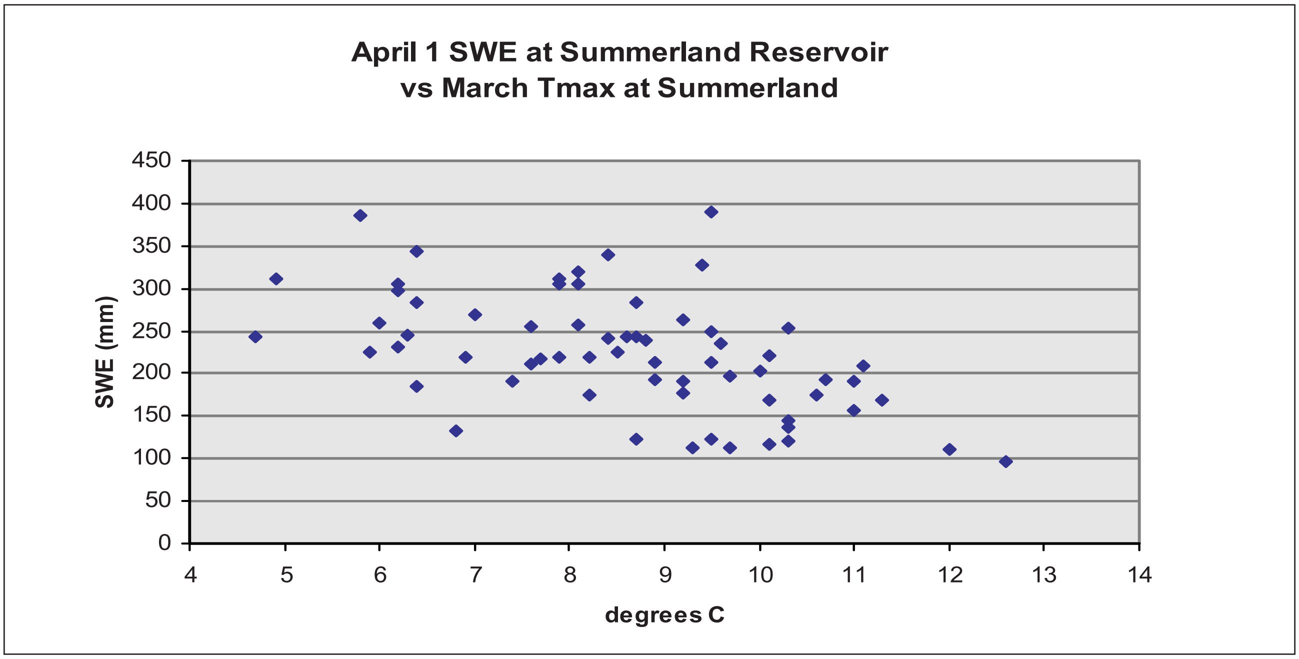

FIGURE 4.18

Relationship between April 1 SWE at Summerland Reservoir and March daily maximum temperatures at Summerland CDA.

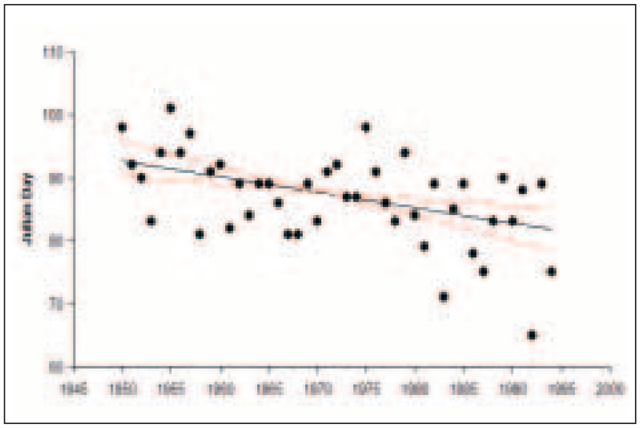

FIGURE 4.19

Change in date of onset of snowmelt at McCulloch.

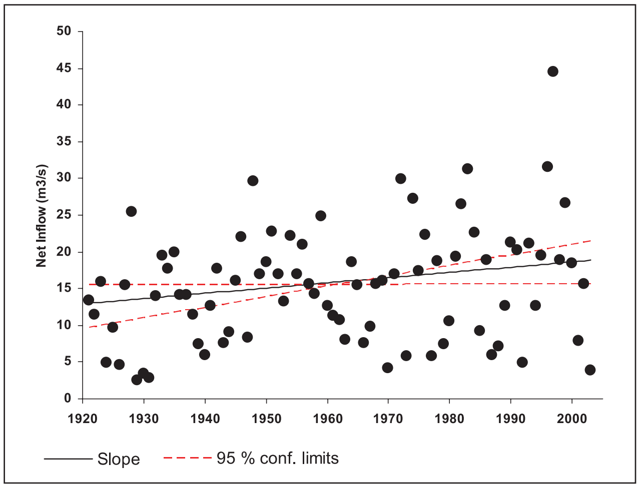

FIGURE 4.20

Okanagan Lake mean annual net inflow (m^3s^{-1}) 1921-2003. Trend is statistically significant. (Source: MWLAP-BC)

compared to the 1950 to 1976 period. Statistically significant differences in SWE were found for several individual snow courses for both La Niña and El Niño, however, an ENSO signal is not consistent across all sites. Significant differences are most apparent for low elevation snow courses including Summerland Reservoir (1280 m), Trout Creek (1430 m), and McCulloch (1280 m) which are more prone to the effects of temperature variations.

In comparing these trends in snow pack to the climate trends, there is a strong inverse relationship between springtime temperatures and the April 1 SWE. The relationship between SWE at Summerland Reservoir snow course and daily maximum temperatures for March at Summerland CDA climate station is shown in Figure 4.18.

As the climate has warmed, the onset of snow melt has also advanced. A simple interpolation scheme was used to determine the Julian day on which the daily average temperature made the transition each year from sub-zero to above freezing at McCulloch (1250 m). These transition dates were then plotted in a time series as shown in Figure 4.19. Based on the period of 1950 to 1994, and using Sen's slope estimator, the date of transition changed from April 2 on average at the beginning of the period to March 22, a statistically significant advance of 11 days over 45 years.

4.3.1.5 Lake inflows/outflows

Lake discharges are regulated and gauged at the south end of Okanagan Lake at Penticton. The water surface is generally kept to a range of 341.5-343.5 m elevation so that the competing demands of flood management, water supply, fish spawning and incubation, tourism and recreation (e.g. boat dock level) are met. Lake outflows have been recorded since 1922. Net inflow is calculated using the measured outflow, the change in lake level and a lake surface area of 341 km^2. This net value is the amount after evaporation losses and any other consumptive water use. As shown in Figure 4.20, there is a significant upward trend in calculated inflows despite declining snowpacks in recent decades. However, spring and summer precipitation have been increasing, and this may account for the increase in lake inflows. Furthermore, water efficiency has improved because of changes in irrigation practices and water conservation which partly offsets the increase in demand from rising population numbers, (Brian Symonds, pers. comm.). The trend is strongly influenced by the very dry period of the 1930s and an outlier in 1996. When these four years are removed from the record, there is no significant trend.

A large part of the difference in annual values in lake-outflow is due to variability in precipitation from year to year. Lake evaporation is also a factor, however, there are insufficient data other than that provided by evaporation pans. A 1980's Okanagan Lake evaporation study came up with an estimation of annual lake evaporation of about 360 mm (Trivett, 1983). This study did not provide estimates of evaporation for individual years. Evaporation is a function of wind speed, surface water temperature and humidity gradient above the lake surface. Increases in any of these variables due to climate change could lead to higher evaporation rates.

4.3.2 Drought

Drought is often defined for meteorological, hydrological, agricultural and socioeconomic purposes. However, the impact of a drought from each of these viewpoints is often dependent upon the combination of spatial, temporal and financial considerations at a given time. For example, the size of the affected region and the drought's duration along with the seasonal timing are the aspects that affect agricultural and economic impact the most in the Okanagan.

4.3.2.1 Drought indices

A practical definition of drought that permits the comparison of areas of dissimilar climate is most useful. Many drought indices are available and a fair number are in widespread use. The common drought indices were recently evaluated against clearly stated evaluation criteria (Keyantash and Dracup, 2002). In North America the Palmer drought Severity Index (PDSI) is widely used and mapped to show the severity and duration of drought. It is a very useful index for assessing drought where soil water holding capacity is known. However, it is not suited to the unknown soil conditions in the mountainous Okanagan valley. The Standardized Precipitation Index (SPI) gives a measure of the departure of precipitation from the norm in standard deviations (McKee *et al.*, 1993). It is easily calculated where homogenous precipitation data are available. SPI values can be calculated for time periods from 1-12 months and this allows droughts to be assessed on multiple timescales. It is far more readily calculated than PDSI and is currently being advocated over the PDSI as the more practical index for most common purposes (Redmond, 2002). The SPI index has been applied in the Okanagan at Penticton using homogenized precipitation data at a 3 month period basis as shown in Figure 4.21. The scatter in the SPI data is large and no significant trend is present. Three extremely dry years 1929, 1967 and 2003 are evident. The severe Okanagan basin drought of 2003 was preceded by severely dry conditions in the 2002 July-September period and this made the 2003 drought worse than the previous droughts.

The SPI has only been calculated for Penticton because it has a long homogenous, current and complete precipitation record. Calculation of the SPI at high elevation weather stations is highly desirable for analysis of conditions in the catchment areas of reservoirs. However, the short, incomplete, and inhomogeneous nature of precipitation data at these weather stations does not permit this. No weather stations currently measure precipitation in the critical 1,200 m plus elevation zone that is the source of almost all flow into about fifty non-valley bottom reservoirs.

SPI is supplemented with a simple percent of normal flow index for stream flow in the gauged and natural Camp Creek, a tributary of Trout Creek, the main source of water for Summerland Township. The percent of normal flow index is a useful index because it captures the long term hydrological aspects that are not reflected in the SPI. Snowmelt water is the key driver of high elevation Okanagan streams that feed into the high elevation reservoirs throughout the valley. The only high elevation Okanagan stream that is gauged and free from water withdrawals is Camp Creek. This creek flows into Trout Creek that in turn is the source of water for Thirsk reservoir, Summerland's primary water supply. Flow data presented here in Figure 4.22 as percent of normal is available for 1965-2003. Camp Creek flows were at their lowest in 2003. April-September flows were between 24 and 49% of the 1965-2003 mean. These extremely low natural flows indicate the severity and duration of the 2003 drought in the headwaters of the Summerland watershed.

4.3.2.2 Paleological perspective of drought

Tree-ring based reconstructions of precipitation and summer maximum temperature in the southern British Columbia mountains have been developed (Watson and Luckman, in-press, Wilson and Luckman 2003, Watson and Luckman, 2002). Precipitation reconstructions at Summerland and Oliver indicate that the drought of the 1920's and 1930's was probably the most severe in the last 300 years (Watson and Luckman, in-press). In the Okanagan valley, only the dry 1770-1810 period, in Summerland, was likely longer. Reconstructions show ten periods, of at least 5 years of below normal precipitation have occurred in the last three centuries. Site to site variation in the timing, severity and duration of the dry periods is evident in 13 southeast BC and southwest Alberta sites studied (Watson and Luckman, in-press). However, the drought of the 1920's and 1930's is very clearly evident at all sites studied. Precipitation reconstructions range in length from 167-668 years and the 1700-1990 period is common to most datasets.

Two independent reconstructions of the maximum May-August temperatures (1600-1997) indicate that since the 1930's maximum summer temperatures have been warmer than any period since 1600 (Wilson and Luckman 2003). This conclusion is based on dendroclimatic reconstructions developed from Engelmann spruce at high elevation tree line sites (1680-2050 m elev.) in southeast British Columbia

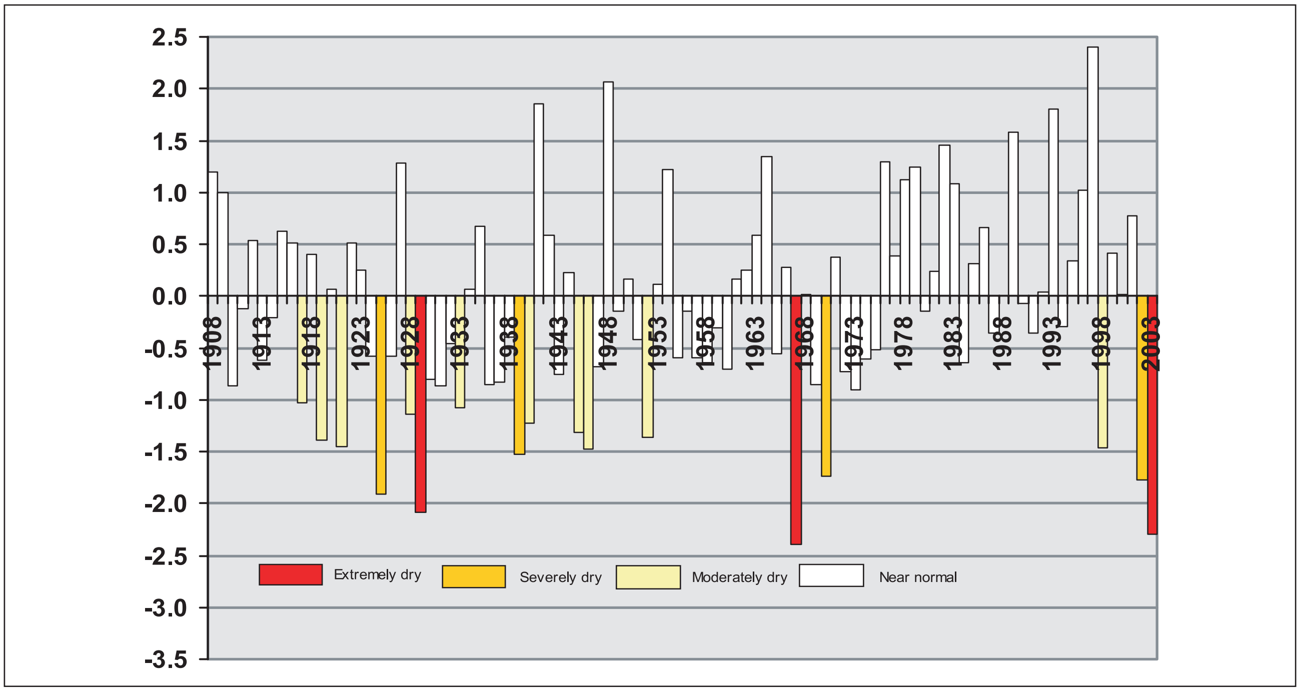

FIGURE 4.21

The 3-month (July-September) Standardized Precipitation Index (SPI) for Penticton 1908-2003. Only the dry years are colour-coded.

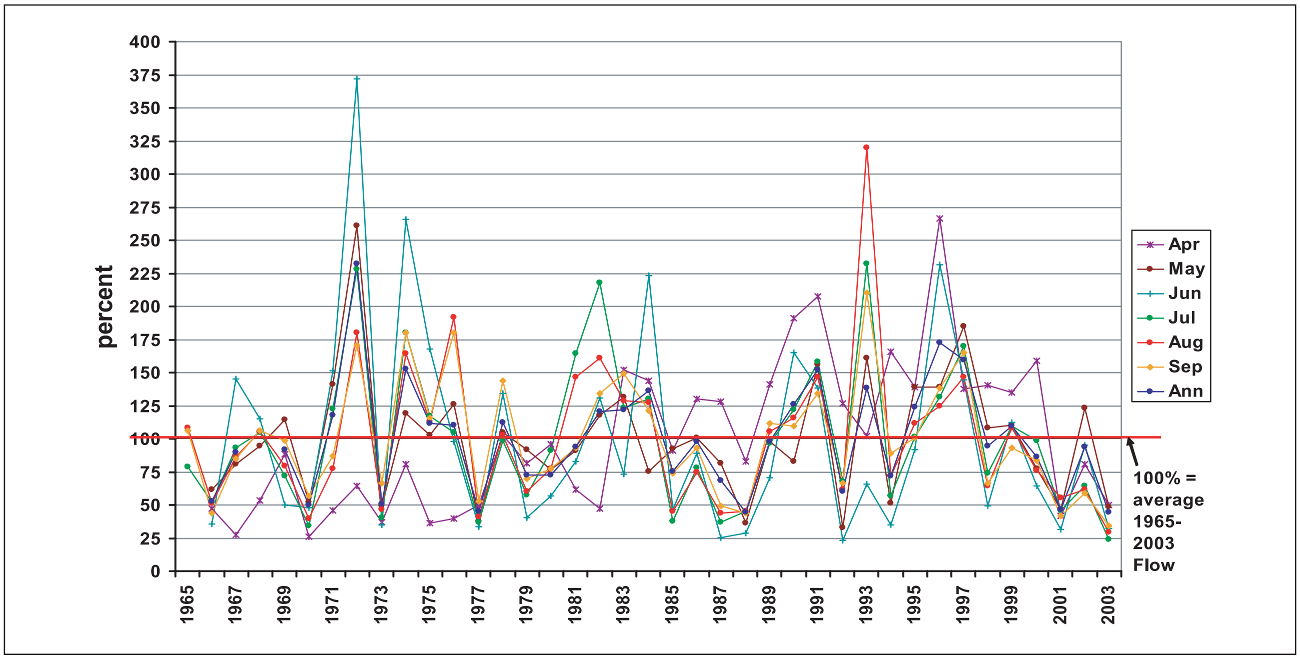

FIGURE 4.22

Camp Creek flows as a percentage of 1965-2003 mean flow.

(Wilson and Luckman 2003). Tree growth at treeline sites are usually temperature limited, whereas at lower elevation grassland sites, tree growth is often precipitation limited.

4.3.2.3 Summer 2003 drought

Drought and forest fire were severe in the summer of 2003. Fish flows were only maintained on Trout Creek by the water released from artificial reservoirs. Human intervention may well have kept several streams from going completely dry. This was only possible because of water conservation measures adopted by farmers with irrigated crops in areas such as Summerland and the availability of stored water for release.

Fires in the tinder dry forests destroyed Okanagan Mountain Park and hundreds of homes in the Kelowna area and burnt another large area near Vaseaux Lake. Low snowpack in the 2002-2003 winter followed by record breaking hot dry summer 2003 conditions created the worst drought the Okanagan has experienced in recent memory. Arguably, the impact was more devastating than the drought of the 1930's. Okanagan population is far higher than in the thirties and many housing developments around Kelowna are pushing back the forest fringes. This aspect combined with a heavy fuel load throughout the Okanagan Mountain Park and a lightning strike led to the devastating fire that destroyed 230 homes in August 2003.

4.4 Summary

The semi-arid climate of the Okanagan valley is ideally suited to grapes and tree fruit production which, along with tourism, are the mainstays of the agricultural economy. In most areas, agriculture is entirely dependent on irrigation supplied by annual runoff from the accumulation of winter snow in the surrounding mountains.

The climate of the Okanagan has warmed during the 20th Century. Winter temperatures have risen the most, and overnight minimums have increased faster than daytime maximums. The largest trends are in extreme minimum temperatures which have increased by at least 4 degrees Celsius. Okanagan precipitation has increased in spring and summer in the past century, but no trends in autumn or winter precipitation or snowfall were detected. Most significantly, a downward trend in snowpack was found at sites below 1,400 metres, and there has been a significant reduction in snowpack since 1976 when a step change in climate occurred. This decline is consistent with the warming trend, and is supported by a reduction in the snow fraction over time at lower elevations.

There is a strong correlation between the inter-annual variability of the Aleutian Low and winter weather in the Okanagan. When the NP Index is negative (anomalously low pressure over the North Pacific), winters are warmer, there is less snowfall, and winter snowpacks are reduced at lower elevations. El Nino winters are warmer and drier than other years, however the reverse is generally not true for La Nina winters. The PDO signal is strongly expressed in decadal variations in the snowpack: a significant decline in snow water equivalent occurred after 1976 coincident with the phase change from a cool PDO epoch to a warm one.

The region has become cloudier, mainly at night time, which would explain the rise in daily minimum temperatures. This has been accompanied by a marginal decrease in solar radiation and a weak increase in net radiation. Relative humidity has decreased likely due to the rise in temperatures. These trends, while based on very limited data, have important implications for agriculture, since solar radiation has a direct effect on soil and air temperatures, transpiration, soil moisture, humidity, photosynthesis and other biological processes. The intensity of solar radiation strongly influences grape quality (Ag. Canada, 1984).

Lake inflows appear to be increasing despite the general decline in snowpacks over the past two decades. The most likely explanation is an increase in spring and summer precipitation. A reduction in demand through more efficient water consumption resulting from recent changes in irrigation practices and water conservation measures may explain also the anomaly. When four outlier years are removed from the record, the trend is not significant.

The Okanagan is particularly vulnerable to drought because of its semi-arid climate and its dependence on irrigation. Precipitation reconstructions (Watson and Luckman, in press) show that the drought of the 1920s and 1930s was probably the most severe in the last 300 years. The Standardized Precipitation Index (SPI) provides a simple measure of drought that can be calculated for multiple timescales. The three-month SPI, based on Penticton precipitation data from 1908, shows three extremely dry years: 1929, 1967 and 2003. The summer of 2003 provided a close-up view of the devastating impacts of drought. Record high temperatures and very low stream flows threatened fish and municipal and agricultural water supplies. Losses due to forest fires totalled hundreds of millions. These events may foreshadow future threats to the region under a longer growing season.

4.5 Acknowledgements

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chapter 5

Climate Change Scenarios

Bill Taylor and Mark Barton

5.1 Global Climate Change

The Earth's climate is changing and while the reasons for this are complex, the Intergovernmental Panel on Climate Change in its Third Assessment Report concluded that, "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities" (IPCC, 2001). Foremost among these causes is the significant growth in concentrations of greenhouse gases during the last 100 years, and these are projected to continue to rise over the 21st Century. Even if society is successful in curbing emissions of greenhouse gases, the inertia in the climate system will cause the Earth to continue to warm well into the future. There remains considerable uncertainty in the projected rate and magnitude of future climate change especially at the regional scale. However, even the most conservative estimates suggest a warming over the next century that would be unprecedented in at least the past 1000 years. In this chapter, we consider the future climate projections of global climate models and methods for applying these results to a small region within BC.

5.2 Global Climate Models (GCMs)

Since it is not feasible to conduct a global climate experiment in any practical way (although it has been suggested that is exactly what mankind is doing inadvertently), climate scientists rely on physically-based computer models to determine how the global climate will respond to changes in concentrations of greenhouse gases, aerosols, and other climate forcings. GCMs are becoming more and more sophisticated in the processes they simulate as well as the interactions and feedbacks between the atmosphere, ocean, cryosphere and land surface. While considerable advances in modeling have been made over the past decade or so, global climate models (GCMs) are limited in the detail to which they are able to simulate the climate, and many simplifications are required. The primary limitation on GCM resolution remains computer processing speed. Even on today's fastest supercomputers it can take a month or more to produce a 100-year climate simulation.

GCM output is represented on a three dimensional grid whose horizontal dimensions are on the order of hundreds of kilometres. For example, the resolution of the Canadian coupled model (CGCM2) is 3.7 degrees latitude by 3.7 degrees longitude (Flato et al, 2000), or roughly 400 by 250 km at the middle latitudes as shown in Figure 5.1. Values of various climate variables are calculated at each grid box at twenty-minute time steps. In order to minimize the confounding effects of

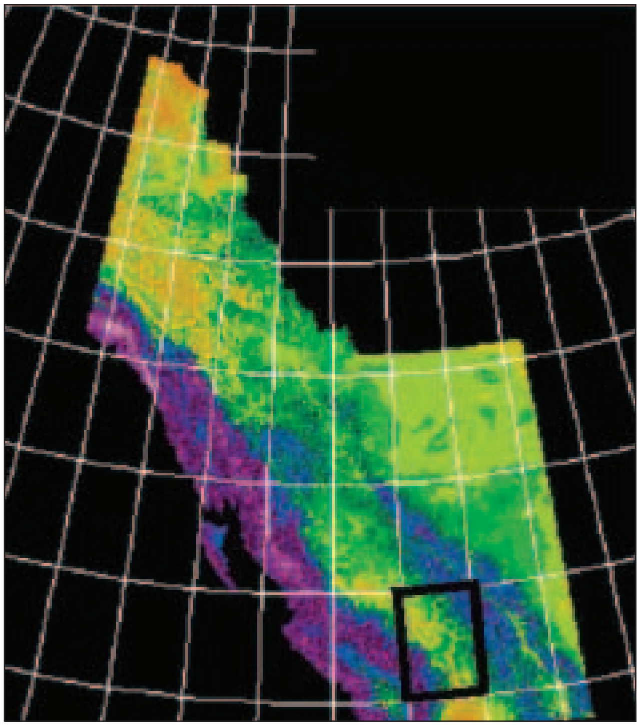


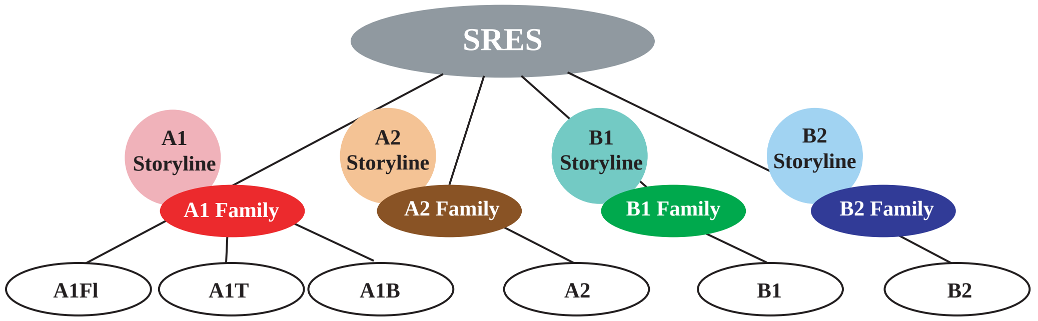
FIGURE 5.1

Grid scale resolution of the Canadian coupled climate model CGCM2. The grid cell covering the Okanagan Basin is highlighted.

natural variability, future climate changes are then typically expressed as 30 year averages of surface variables such as temperature, precipitation, humidity, atmospheric pressure, evaporation, as well as circulation variables of the upper atmosphere. The 30-year time slices are centred on the 2020s, 2050s, and 2080s, where the 2020s refer to the period 2010 to 2039, and so on.

5.3 Global Emissions Scenarios (SRES)

Estimates of future global greenhouse gas emissions represent one of the greatest sources of uncertainty in climate change projections. The IPCC, in its Third Assessment Report (IPCC, 2001), based its global temperature projections for the 21st Century on six emissions scenarios described in the IPCC Special Report on Emissions Scenarios (SRES; Nakicenovic et al, 2000). These six SRES emissions scenarios are based on a range of global population projections and assumptions about economic growth and technological change (see Box – Figure 5.2). The SRES marker scenarios are named A1, A2, B1, and B2 depending on which growth assumptions are used. In addition, there are three variants of A1 (A1B, A1FI, and A1T). Most of the results presented in the IPCC Third Assessment Report were based on two SRES scenarios: A2 and B2 (IPCC, 2001), and GCM model runs based on these scenarios are readily available. A2 is a high emission scenario based on continuously rising population and regionally oriented economic growth, while B2 is a low emission scenario that assumes lower growth rates in population and the global economy. The projected global temperature response to the six SRES marker scenarios over the 21st Century, computed using simplified models, is shown in Figure 5.3. Global temperature projections range from 1.6 °C to 5.8 °C by 2100 (IPCC, 2001). As expected, higher emissions scenarios result in a larger rate of growth of greenhouse gas concentrations and a higher temperature response.



A1 Storyline: very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Underlying themes are convergence among regions, capacity building and increased cultural and social interactions with a substantial reduction in regional differences in per capita income. Three A1 groups are distinguished by their technological emphasis: fossil intensive (A1FI); non-fossil energy sources (A1T); a balance across all sources (A1B).

A2 Storyline: a very heterogeneous world. Underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly resulting in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change more fragmented and slower than other storylines.

B1 Storyline: a convergent world with the same global population, that peaks in mid-century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

B2 Storyline: a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the A1 and B1 storylines. While the scenario is also oriented towards environmental protection and social equity, it focuses on local and regional levels.

FIGURE 5.2

The family of SRES scenarios and their storylines developed in the IPCC Special Report on Emissions Scenarios (Nakicenovic et al, 2000).

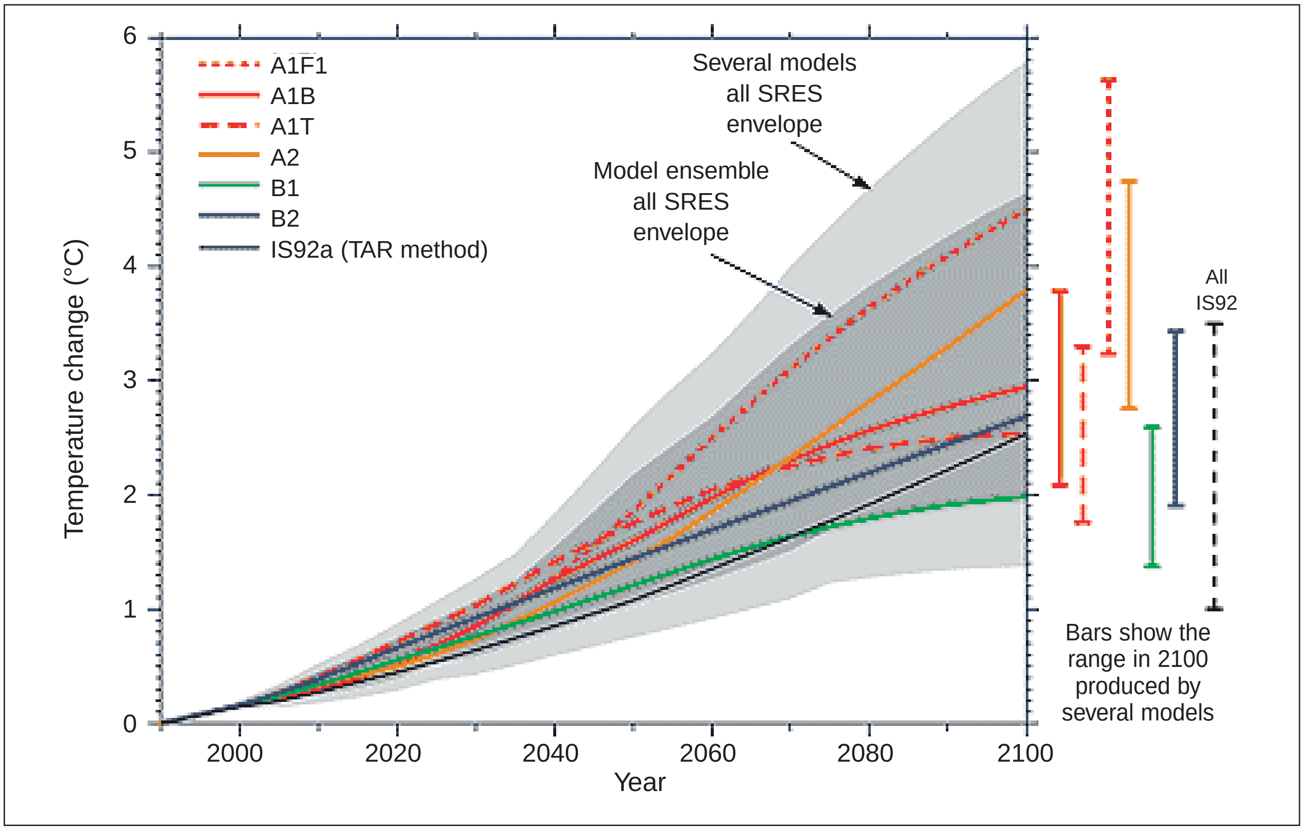


FIGURE 5.3

Global temperature response to six SRES marker emissions scenarios for the 21st Century (IPCC, 2001).

Additional uncertainties in the global temperature response are attributed to differences in sensitivity among models.

5.4 Constructing Regional Climate Change Scenarios

Our goal was to produce a suite of high resolution climate change scenarios which draw on a variety of different GCMs, use appropriate downscaling techniques, incorporate SRES emissions scenarios, and are suitable for use in hydrologic and agricultural modeling.

5.4.1 Choosing a Global Climate Model

Climate models are being actively developed at major scientific research centres throughout the world. Each model is unique in terms of its temperature response to increases in greenhouse gas concentrations. These differences are largest at the regional scale. To account for the uncertainty in these models, and to avoid having scenarios interpreted as predictions, climate change projections need to include a range of possible future climates. Accordingly, the IPCC (1994) recommends that the results from more than one global climate change model be considered in conducting climate change impacts work.

In deciding which GCMs to use, we were guided by the availability of published GCM data, and by criteria such as vintage, resolution, validation, and representativeness suggested by the Canadian Climate Impacts Scenarios project office and based on the work of Smith and Hulme (1998). Three different GCMs were selected: the Canadian global coupled model (CGCM2), the UK's Hadley Centre model (HadCM3), and the Australian model from the Commonwealth Scientific and Industrial Research Organization (CSIROMk2). It is common for a modeling centre to produce an ensemble of model runs using the same climate forcing but different initial conditions. The Hadley model (HadCM3) and the Canadian model (CGCM2) include ensembles of data from two or three such runs. GCM data were obtained from the Canadian Climate

Impacts Scenarios (CCIS) website. http://www.cics.uvic.ca/scenarios/index.cgi.

Scenarios were selected that represent all three GCMs and incorporate the results from both a high emissions scenario and a low emissions scenario. Based on these criteria, one ensemble member from A2 (high emissions) and one from B2 (low emissions) from each of the Canadian, Australian, and UK global climate models were selected for a total of six scenarios.

5.4.2 Downscaling methods

Global climate model projections describe climate changes for very large areas (grid cells of about 100,000 km^2). For this reason, GCMs do not have the ability to resolve small scale weather phenomena or the effects of local topography. Given the mismatch between the scale of the GCMs and the environmental impact being modeled, a method is required to downscale GCM output to the individual weather station scale.

Downscaling methods generally fall into two categories: dynamical and statistical. Dynamical downscaling involves the application of regional climate models which are high resolution, limited area models forced at their boundaries by output from a GCM. Developments continue on improving the Canadian Regional Climate Model (CRCM) at 45 km resolution, and preliminary results are encouraging. We did not pursue its use beyond an initial inquiry since no data are available as yet for the SRES scenarios, and CRCM is nested within only one GCM making it impossible to explore uncertainty through the use of multiple scenarios.

The second approach is statistically based. SDSM (Statistical Downscaling Model) allows the construction of climate change scenarios for individual sites at the daily timescale (Wilby et al, 2002). This approach to downscaling is based on the relationship between a surface weather variable and large area and/or large scale circulation variables which are reasonably well simulated by the GCM. SDSM generates a multiple linear regression statistical relationship between GCM output climate variables (predictors) and a local surface weather station variable (predictand) based on the historical record. Once generated, relationships are assumed to hold for the future time periods, thereby allowing future climates to be estimated from GCM output.

Our results using SDSM in the Okanagan indicate better performance in generating temperature scenarios than in generating precipitation scenarios. This is not surprising because temperature patterns have much larger spatial structure than do precipitation patterns. Correlation coefficients in the range of 0.3 to 0.7 were obtained for daily maximum temperature using modeled monthly mean temperature, warm season 500 hPa heights, and cold season near-surface humidity as predictors. However, only very weak correlations were found between surface precipitation and a number of predictor variables. Precipitation is inherently difficult to model using atmospheric predictor variables due to the influence of local topography, convective development and other small-scale processes on precipitation occurrence. The problem of downscaling precipitation is common to all regression-based downscaling methods. A number of suggestions have been made to try to improve the performance of SDSM for precipitation which remain to be tested. These include forward lagging the predictors to account for time differences between the surface observations and the model output, and using predictor variables in the grid cell to the west of the climate station (R. Wilby, pers comm.).

Another shortcoming of SDSM is that, at the present time, it is set up to operate only with model output from CGCM1 using the IS92a emissions scenario, and thus provides only a single climate change scenario. The Canadian Climate Impacts Scenarios project office advises that SDSM will soon be linked to two GCMs (CGCM2 and HadCM3) for two SRES emissions scenarios (A2 and B2)(T. Murdoch, pers comm.).

5.4.3 Climate Change Scenarios Results using the Delta Method

By far the simplest approach to constructing climate change scenarios, and the one most commonly used, is the delta method, whereby daily station data are perturbed by GCM-derived future changes in the 30-year means of monthly temperature and precipitation (IPCC, 1994). This method also allows the greatest flexibility in the selection of GCM scenarios, since it involves only a simple arithmetic operation.

The selection of GCM grid cells was influenced by the fact that the Okanagan basin is easily contained within the respective grid cell of each of the three GCMs. Since each GCM has unique grid spacing, the location of the centre and the dimensions of each grid cell are different. Some impacts researchers take an average of several grid squares encompassing their region of interest, while others use just one grid cell. The use of surrounding grid cells poses some difficulties when neighbouring cells border on different environments at, say, the ocean/land interface. In consultations with the CCIS principal investigator (Elaine Barrow, pers.

comm.) we decided it would be acceptable to use just a single grid cell from each of the three models.

At the grid cell scale, six climate change scenarios display a considerable range in temperature and precipitation projections. Scatterplots of temperature and precipitation projections for summer and winter for each of the six scenarios for the 2050s time slice are shown in Figure 5.4. These plots show that for the 2050s, changes in winter temperature relative to the 1961-90 baseline lie in the range 1.5 to 4 degrees Celsius with precipitation increases on the order of 5 to 25 percent. For summer, all models show a warming of roughly 2 to 4 degrees Celsius and precipitation changes ranging from almost no change to a 35 percent decrease in precipitation compared to the 1961-90 baseline. The greatest change in winter conditions are reflected by the Australian model (CSIROMk2) while the Hadley Centre model (HadCM3) shows the greatest change in summer climate.

Climate change scenario data include monthly changes in daily maximum and minimum temperatures in degrees Celsius and changes in daily precipitation expressed as percent. The changes in these climate variables for one such scenario, CGCM2 A21, are shown in Figure 5.5.

It is worth emphasizing that the plots shown in Figure 5.5 are the results of one ensemble member from one GCM based on the results of one SRES emission scenario. It is not a best guess of the future climate - all six scenarios are regarded as equally likely. The remaining five scenarios developed for this study are not included here due to space considerations.

While GCMs produce monthly outputs, the hydrological and agricultural models for this study require daily climate data to produce realistic results of stream discharge and crop water demand, respectively. It is generally accepted that climate data from the GCMs are at too coarse a scale to be used directly in regional climate change studies, and as noted previously, downscaling may be employed to obtain a time series of daily data. In this study, the delta method of applying GCM changes to local station data as used.

The delta method adds projected monthly changes in temperature from the GCM to the station daily time series, while daily precipitation observations are adjusted by a percentage. This method has an effect on the statistical properties of the original climate observations. In the case of temperature, the addition of a constant results in a scalar change in the mean, but it does not change the variance of the temperature distribution. However, because daily precipitation is not normally distributed, the percentage adjustment results in a change in both the mean and the variance that favours disproportionately greater changes in heavy precipitation. In the case of projected increases in precipitation, the percent adjustment results in only a small increase in the lower end of the distribution, and a larger increase in precipitation extremes. For projected decreases in precipitation, the effect is the same but in the opposite direction, i.e. disproportionately greater decreases in heavy precipitation events.

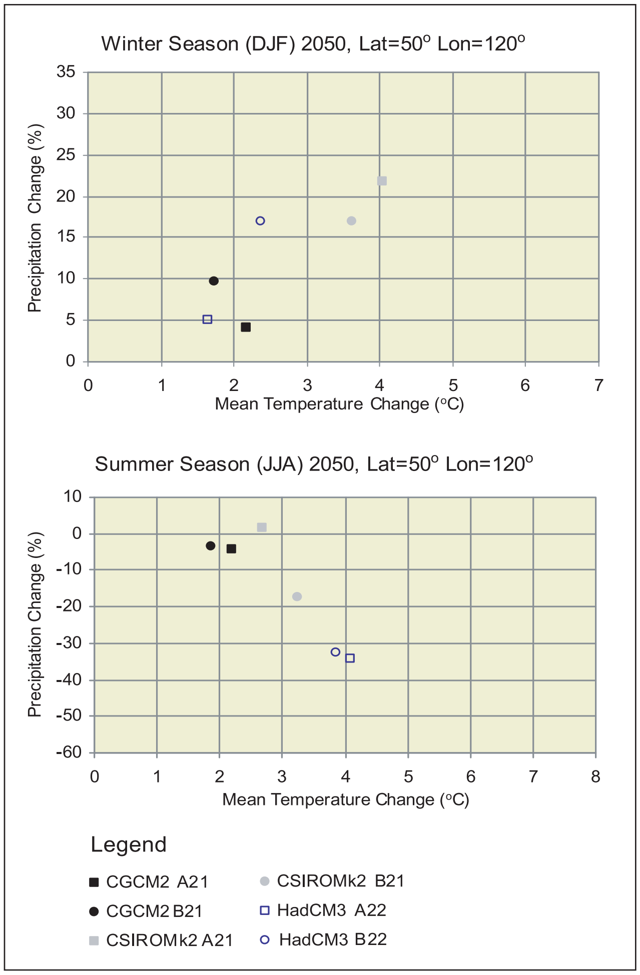


FIGURE 5.4

Scatterplots of projected changes in average daily temperature (degrees C) and precipitation (percent) for the 2050s relative to 1961-90 for winter (top) and summer (bottom) for three GCMs and two SRES scenarios for southern BC.

One of the computational issues associated with the delta method is that the perturbation of daily data using monthly means can result in large discontinuities at the monthly boundaries. This occurs when there are large differences in the deltas from one month to the next.

Note, for example, the large difference between the projected changes in daily maximum temperature for April (5.2 degrees C) compared to May (2.4 degrees C) in the 2050s in Figure 5.5. A smoothing algorithm is necessary to reduce abrupt changes at the monthly boundaries, which may result in an unrealistic climate simulation. We used a heuristic approach described by Morrison (2002) as shown in Figure 5.6, which redistributes the discontinuity throughout the entire month in such a way that produces smooth transitions from month to month and also preserves the GCM-predicted change in the monthly mean.

5.5 Summary

In this Chapter, we have provided a very brief overview of global climate change, global climate models (GCMs), and greenhouse gas emissions scenarios

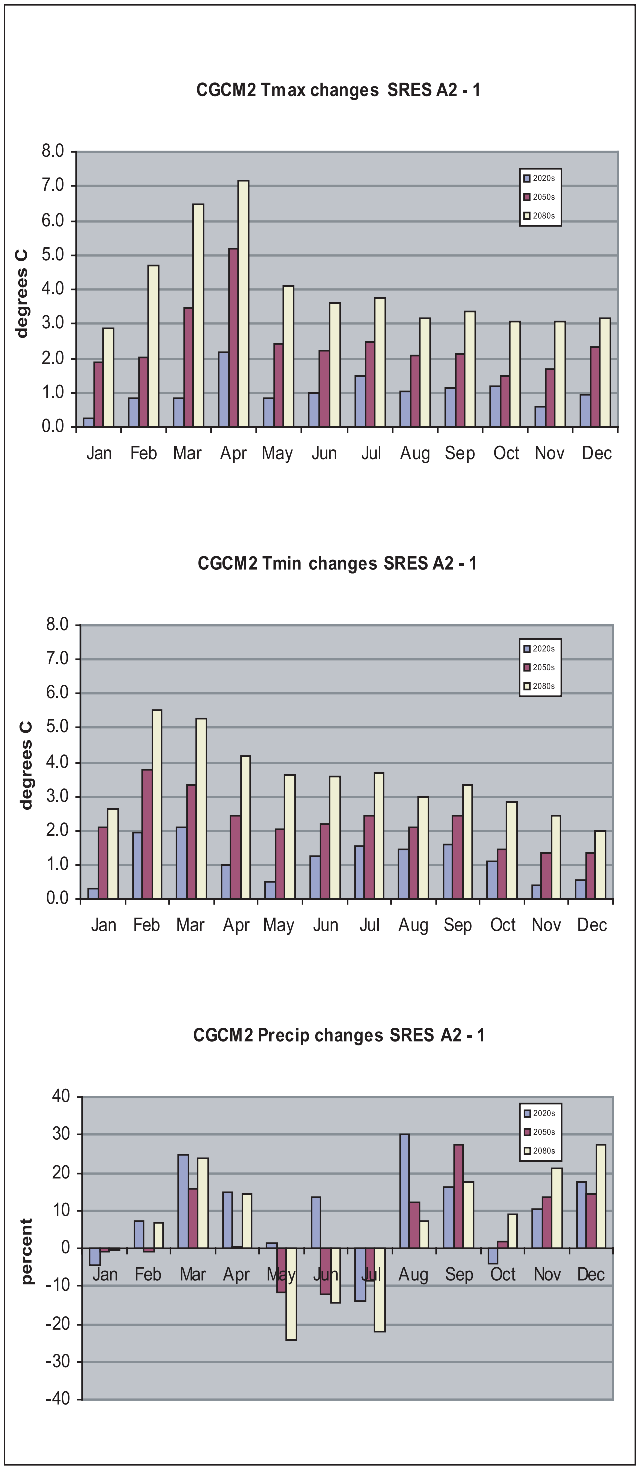


FIGURE 5.5

Projected monthly changes in daily maximum temperature (Tmax) and daily minimum temperature (Tmin) in degrees Celsius and Precipitation (Precip) in percent for three time slices 2020s, 2050s and 2080s, based on ensemble member 1, CGCM2, using SRES emissions scenario A2.

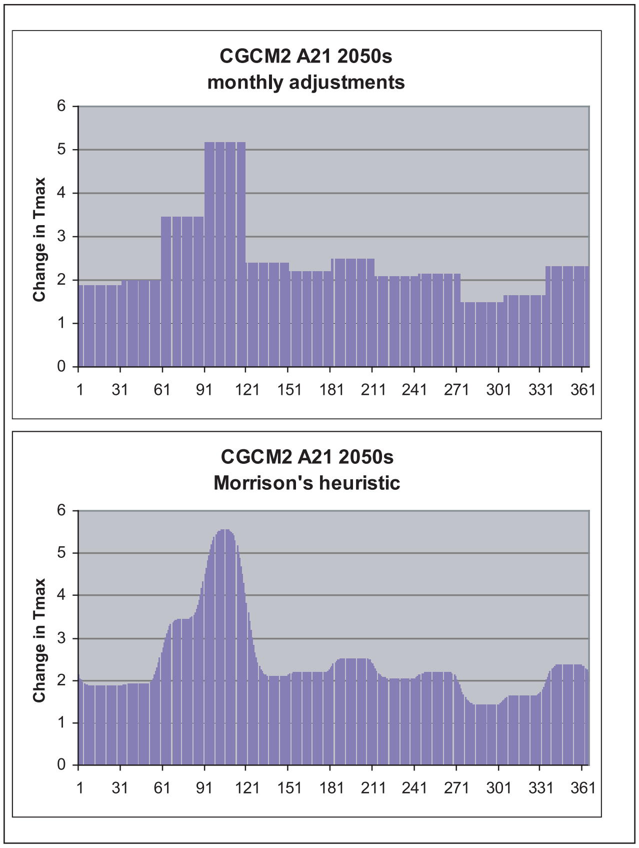


FIGURE 5.6

Effect of applying Morrison’s smoothing technique to monthly GCM adjustments. The top figure shows the Canadian model CGCM2 A2 monthly adjustments for the 2050s. The abrupt changes at the monthly boundaries are removed at the bottom after applying the smoother.

(SRES) as background to the construction of climate change scenarios. One of the biggest challenges of using GCMs in regional impacts studies is overcoming the mismatch in scales between coarse-scale GCM and the detailed landscape level of impacts work. Limitations exist in both dynamical downscaling, using Regional Climate Models, as well as statistical downscaling approaches. We opted for a much simpler and generally more common approach to downscaling using the "delta" method, where the 1961 to 1990 daily climate station record is adjusted by monthly changes from a single grid box of the coarse scale GCM. We selected three GCMs (Canadian, British, and Australian) and used two SRES emissions scenarios (A2 and B2) for a total of six climate change scenarios for southern BC. All models generally point to a similar future of warmer wetter winters and hotter drier summers for this region.

5.6 Acknowledgements

We are grateful to Elaine Barrow for the advice she provided during this project, and to Greg Flato for his useful comments on a draft of this chapter.

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chapter 6

Microclimate Network

Mark Barton, Denise Neilsen, and Grace Frank

A microclimate study is currently underway to help improve our understanding of the fine scale effects of topography on climate at the orchard and vineyard scale. The complex relationships between slope, aspect, elevation and temperature are being explored using a GIS. Farmers have intuitively selected areas of the valley with the most appropriate microclimates for their crops since the start of commercial agriculture in the early 1900's. This study attempts to quantify the range of thermal microclimate variation in Summerland and Naramata Orchards and vineyards so that climate change and crop water issues can be better managed and farmers will have scientific information to support their decisions.

6.1 Monitoring thermal microclimate

Many crops in the Okanagan Basin rely on various microclimates created by the complex topography (Figures 6.1 & 6.2). Current Environment Canada weather stations are too widely spaced to monitor microclimates. Therefore, a network of 47 temperature sensors was deployed in orchards and vineyards in Summerland and Naramata for the analysis of microclimate variations that affect the agricultural land, which is concentrated in valley bottom and low and middle elevation bench areas. Some of the 47 sensors were used for short periods when crop irrigation and its thermal signature were studied. Microscale topographic variations in slope, aspect and elevation, and the different crop types give rise to an assortment of microclimates that we are studying in detail.

Hobo computerized temperature loggers collect temperature data so that the microscale variations in climate can be mapped to aid the understanding of crop water demand and crop suitability with changing climate. Collection of data will continue for up to five years. This period allows a range of seasonal climate effects to be studied.

When setting up the climate monitoring network, a key consideration was that the data should be representative of the climate of the areas of interest. The instruments were carefully located so that they accurately measure the 'screen level' temperature. For air temperature measurement this requires installation at a particular height, screen height (~1.4m), so that measured temperatures are comparable with those measured in Summerland and at other weather stations in the study area. Another consideration was the degree to which measured temperatures are representative of a particular crop area such as an orchard or vineyard. This is achieved by locating the logger in the middle of large crop areas so that recorded temperatures are reflective of a particular crop with a particular slope, aspect and elevation for all wind speeds and directions.

Okanagan climate variables are currently measured by Environment Canada at about twenty locations within the Okanagan basin. Of these, only three weather stations, Summerland, Penticton and Naramata, are within the area we chose to study at the microscale. Only the Summerland and Penticton weather stations have hourly data that we use as base station data. Naramata weather station is no longer in service. Each station monitors a limited range of climate variables. Penticton airport weather station has an aviation bias in that it measures cloud, whereas Summerland is oriented towards agriculture and measures solar radiation. Both stations measure temperature, precipitation, atmospheric pressure, wind speed and wind direction at hourly intervals.

6.2 Data collection

Regular data collection commenced in late July 2002 at most of the 22 Summerland sites and 18 Naramata

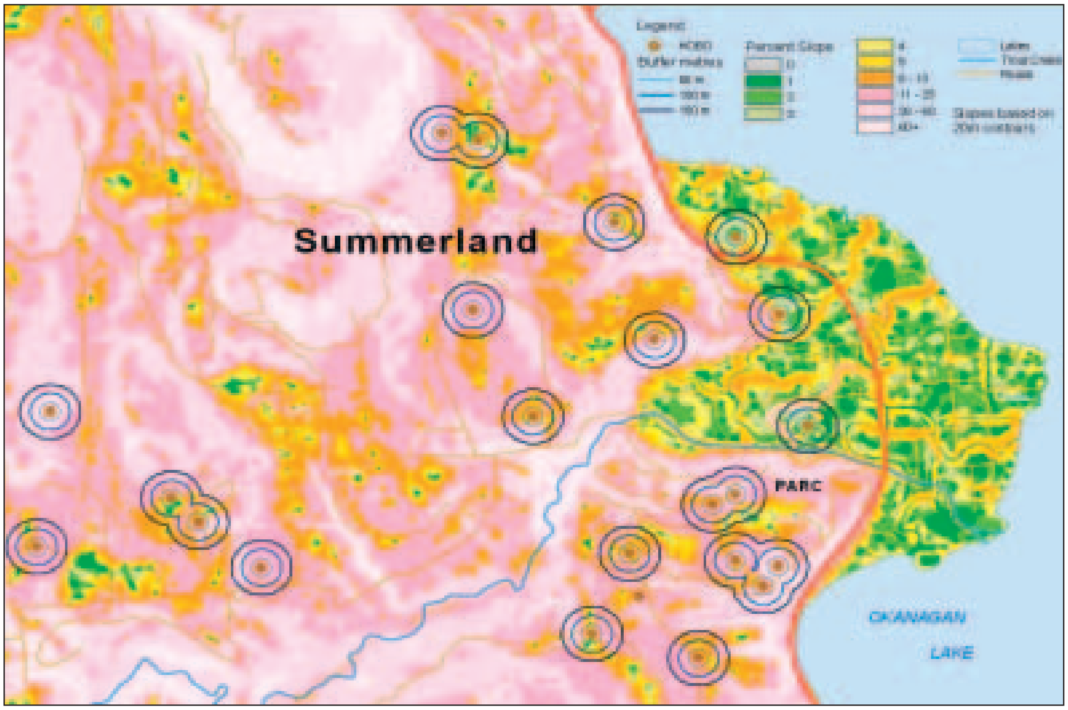

FIGURE 6.1

Slope classification and location of Hobo temperature sensors in the Summerland Water Purveyor District on the west side of Okanagan Lake. Concentric circles represent 50, 100 and 150m distances around Hobo sites.

sites, where temperatures were recorded at hourly intervals. Collection at two minute intervals was introduced later in the summer when an attempt to identify periods of crop irrigation from temperature changes was made. The cooling effect of irrigation was quite small. An initial cooling of about 3 °C declined to about 1 °C within ~5 minutes and remained at about 1 °C for about 25 minutes after irrigation ceased. Two Hobo loggers were attached to Environment Canada thermometer screens, one in Summerland and one at Penticton airport (Both loggers died within ~1 year). This permitted a limited (favorable) comparison of the low cost Hobo loggers that are used in this study with the more expensive Campbell Scientific equipment at the regular weather stations. Short-term field measurements in Summerland sites and Naramata sites will be compared with their respective long-term base weather station records (Summerland & Penticton) so that drought and frost risk can be assessed. The locations of the Hobo loggers, with reference to topography, are indicated in Figure 6.1 for Summerland and Figure 6.2 for Naramata.

The elevation range in the study area on the west side of the valley is 330-605 m and on the east side, 381-481 m. The complexity of the terrain is evident from the location map on the east side of the valley (Figure 6.2). Hobo site slopes range from 0-25% and a range of aspects was sampled, although, location on the east or west side of the valley determined the dominant aspect categories. Relationships will be derived between Hobo data, topography and climate, and data from the Environment Canada weather stations at Summerland and Penticton Airport to determine the modifying effect of landscape position on daily temperatures.

6.3 Topographic influences on climate – GIS & Solar Analyst

Topography influences climate on a range of scales from major continental scale features to within field undulations. The north to south long axis of the valley gives the west and east facing slopes their dominant aspect. However, analysis of micro-topography with 2 m contour interval mapping, within a GIS, reveals the highly complex slope and aspect variation on the 'within orchard' local scale (Figure 6.2). Slope, aspect and elevation have a significant control on a range of climate variables that are measured in the valley: solar

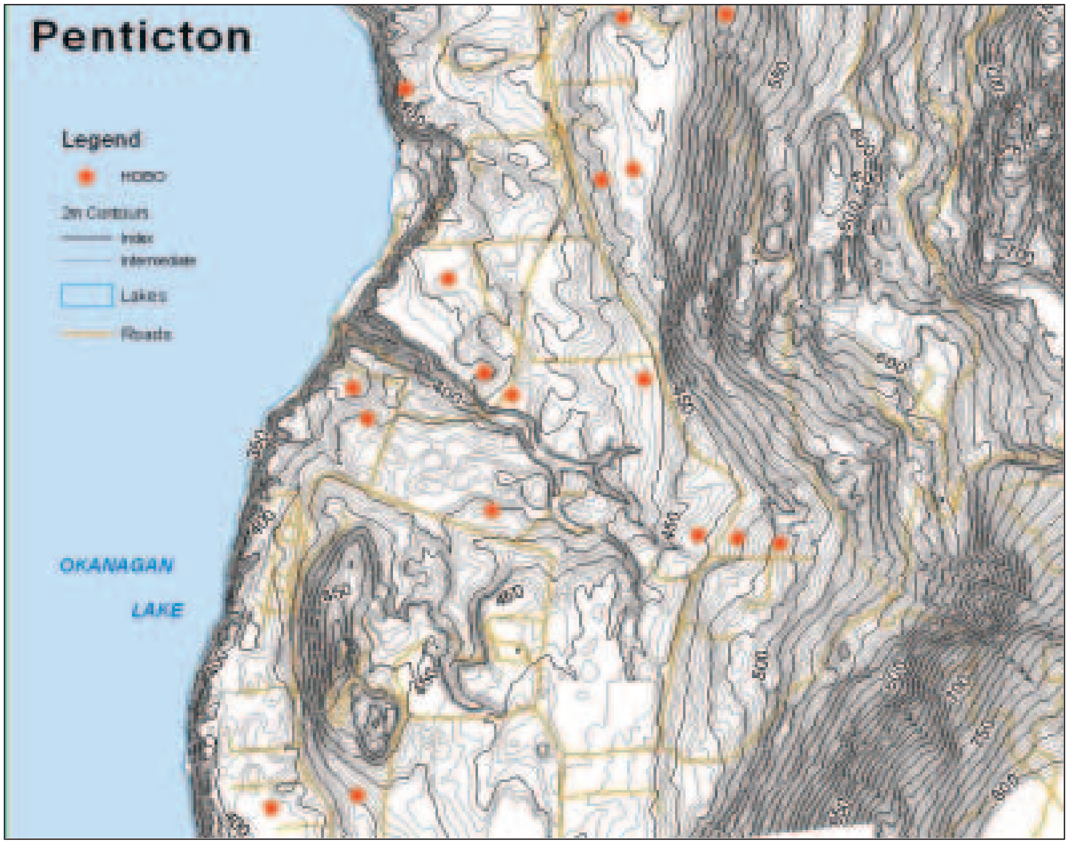

FIGURE 6.2

Topography and Naramata HOBO locations on the E. side of the Okanagan Valley within the Penticton water Purveyor District.

radiation, net radiation, wind speed, wind direction, air temperature and precipitation. An understanding of how topography and climate are linked is important because many of the climate variables are only measured at a selected point or points and must be mapped across the landscape for input into hydrological and crop water demand models. The effect of topography on the reception of solar radiation is important not only for measurement and estimation of solar radiation per se, but also to take into account the effects of solar radiation on temperature. The Solar Analyst program takes into account not only latitudinal and temporal effects on solar radiation but also shading by surrounding higher ground, the latter limited mainly by the available digital elevation model and is thus suited to regions of complex and high relief topography. Using GIS, output from Solar Analyst was incorporated with findings from the HOBO network and PRISM temperature coverage (Daly *et al.*, 1994) in a first attempt to produce a fine-scaled gridded data set for the area.

6.3.1 Gridded data sets derived from HOBO network data

The effects of micro-climate on growing degree day base 10 °C (GDD10) in the Okanagan basin have previously been summarized, based on relationships developed from a number of long and short term weather station records (Association of British Columbia Grape Growers. 1984). Favoured locations are the flat bench lands above the valley bottom, as the latter are affected by temperature inversions at some times of the year which affect not only GDD accumulation, but also the frequency of spring frosts and the number of frost free days. In order to determine the effects of future climates on land suitability for grapes, it is necessary to derive gridded data sets of current climate data which take into account these topographical effects on microclimate. The PRISM gridded data set (Daly *et al.*, 1994), which we have previously used to incorporate topographic effects into current and future crop/climate modeling has the disadvantage of: 1) coarse resolution and 2) a deliberate removal of inversions from the base data set (C. Daly, personal communication). An attempt has been made to modify the PRISM data set: 1) to a fine-scale spatial resolution of 50m x 50m, 2) to take into account the effect of landscape position on temperature using HOBO network data and Solar Analyst, 3) to locate bench lands using previous detailed soil mapping, and 4) to incorporate valley bottom to bench temperature inversions.

6.3.1.1 PRISM

The study area extends beyond the HOBO network region from Okanagan Falls at the southern end to the northern end of Summerland. Using GIS, the 4 x 4 km grid cells of PRISM containing mean monthly maximum and mean monthly minimum temperatures were combined to create an averaged grid of monthly mean temperatures; e.g. for the month of May AVG05 = (GMAX05 + GMIN05) / 2. PRISM data were used as the basis for the 50m x 50m gridded dataset as it was based on a longer set of observations i.e. 30 year normals for 1961-90.

6.3.1.2 Landscape factors

Using a subset of data from each of the HOBO networks, the effects of number of landscape position descriptors, solar radiation derived from Solar Analyst and weather station temperature, on temperature were examined using a neural network approach (Statstica, 2003). Results were compared with the subset of data not included in the neural network training to determine the relative effects of factors. From this exercise, it was determined that, in addition to station temperature, elevation, distance from large water features (e.g. Okanagan Lake) and estimated solar radiation, were the most important factors in describing location effects on temperature .

An elevation grid was created from the BC TRIM data with a cell size of 50m and superimposed on the PRISM grid. A coverage of the larger watershed lakes was created and was the base used to generate a 50 m grid of lake distance in which, for each cell, the Euclidean distance to the closest source was calculated. Solar radiation was calculated using ArcView 3.2, Spatial Analyst, and the extension Solar Analyst 1.0 from Helios Environmental Modeling Institute, LLC. Solar Analyst can calculate insolation integrated for any time period and accounts for site latitude and elevation, surface orientation, shadows cast by surrounding topography, daily and seasonal shifts in solar angle, and atmospheric attenuation (Fu and Rich, 2000). Elevation, slope, and aspect grids of the study area were created at a 50 m cell size and used as the input to Solar Analyst. Global (diffuse + direct) incoming solar radiation was calculated for each month. Sky Parameters were chosen that produced values similar to those shown in the Atlas of Suitable Grape Growing Areas (Association of British Columbia Grape Growers 1984).

6.3.1.3 GIS Programming

Units of measurement were adjusted so that the values for each input grid had similar levels of magnitude thus:

- The elevation grid was sliced by 10
  SFELEV = FLOAT(DEMB / 10)
- The lake distance grid was sliced by 100
  SLCLKB = FLOAT (SLICE (LKDISTB,EQINTERVAL,100, 0,0,20000))
- The global radiation grid was sliced by 1000
  SAFMAY = FLOAT(BGLB04 / 1000)

Input grids had the following ranges:

- elevation (SFELEV.STA)

MIN	MAX
31.000	172.000

- lake distance (SLCLKB.STA)

MIN	MAX
0.000	99.000

- solar radiation (SAFMAY.STA)

MIN	MAX
96.0	227.000

The temperatures assigned to individual 50 m x 50 m grid cells were generated within ArcInfo, from the series of grid overlays described above, using a sampling and regression procedure. In the sampling procedure, temperatures in the original 4 x 4 km PRISM grid cells are the dependent variable and are assigned to the centroid of the cell. Elevation, lake distance and solar radiation grids are sampled as independent variables at the same co-ordinates. A least squares linear regression procedure is used to determine the overall relationship between dependent and independent variables

$$Z = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + \ldots$$

and in the example given below for MAY, the following relationship was developed:

$$SF05 = 13.748 + (-0.045 * SFELEV) + (-0.018 * SLCLKB) + (0.001 * SAFMAY)$$

which was then applied to each 50 x 50m grid cell.

TABLE 6.1

Monthly differences in mean temperature between bench land stations and Penticton Airport, based on 1971-2000 normals (°C).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
Naramata	0.5	0.3	0.8	0.8	0.4	0.2	0.0	0.3	0.8	0.6	0.7	0.4
Summerland	-0.8	-0.5	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	-0.7	-0.8

6.3.1.4 Adjustment of bench land temperatures

The definition of bench lands proved problematic. Within GIS, it was difficult to define elevation and slope parameters that captured the many variants of this landscape classification. Yet, it is evident, from an agricultural perspective, that this factor is important. Consequently, previous mapping of the soil landscapes of the Okanagan (Witneben, 1986) was used to identify bench locations. Benches in the study area were thus selected based on primary soil types and on slopes less than 25% and superimposed on the 50 m x 50 m grid. Bench land temperatures were then adjusted by differences between mean monthly temperatures for valley bottom (Penticton Airport) and Naramata (E. bench) and Summerland (W. bench) for the 1971-2000 period (Table 6.1). An example of the 50 m x 50 m gridded data set for May mean temperatures is shown in Fig. 6.3.

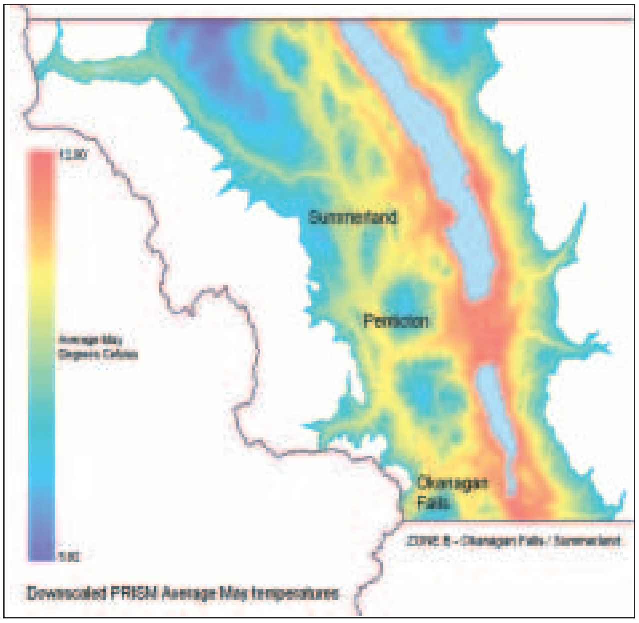

FIGURE 6.3

A 50m x 50m gridded dataset of monthly mean temperature for May for the region between Okanagan Falls and Peachland. The large water body is Okanagan Lake.

6.4 Preliminary findings

Analysis of hourly Hobo temperature data for July 2002-January 2004 shows that the variation of climate within Summerland and Naramata fields has about the same magnitude as that found in the full 180 km north to south latitudinal range of the Okanagan Valley. A three degree Celsius range in mean annual temperature (2003) between Hobo site 39 (11.0 °C) and Hobo site 27 (8.0 °C) is about the same as the 30 year climate normal difference of 2.9 °C between Armstrong North (7.2 °C, 1971-2000 annual mean) near the extreme north and Osoyoos West (10.1 °C, 1971-2000 annual mean) in the extreme south of the valley.

Very high temperatures were measured at most sites in the completely rain free (Penticton) month of July 2003. Seventeen of the forty Hobo sites recorded temperatures of at least 37 °C in July. The Hobo temperature sensor located at site P37 on the mid elevation Naramata bench recorded a peak temperature of 41.0 °C (106 °F) at 16:18 on July 22, 2003. Hobo site P27 with the coolest maximum at this time, located near a lake cliff top gorge, where it was 26.6 °C. Initial examination of the site conditions shows that the more open flatter and less vegetated site was 14.4 °C hotter than the coolest site that was on the same side of the valley. The next to coolest site (P26) was 30.9 °C at this time. There may be a difference in irrigation and the green groundcover that may play an evaporative cooling role. Greener moister sites are cooler due to evaporative cooling and the reduction in energy available for sensible heating of the ground and air.

Thermal microclimate variation and its accumulated thermal effect on plant growth is assessed from growing degree day (GDD) values calculated for all the sites that were in operation for the full 8,760 hours of the 2003

TABLE 6.2

Growing degree days calculated for Hobo sites in operation for the 2003 growing season (Five consecutive day rule).

HOBO SITE # 1-49 S=SUMMERLAND AREA P=PENTICTON (NARAMATA AREA)	2003 GDD_{10} BASE 10°C RANK	2003 GDD_{10} BASE 10°C TOTAL	2003 GDD_{10} BASE 10°C % OF COLDEST SITE TOTAL	2003 GDD_5 BASE 5°C RANK	2003 GDD_5 BASE 5°C TOTAL	2003 GDD_5 BASE 5°C % OF COLDEST SITE TOTAL
P39	1	1543	131	1	2572	120
S18	2	1504	128	2	2515	118
S48 Summerland CS	3	1472	125	8	2468	116
S4	4	1472	125	3	2488	116
P24	5	1468	125	4	2481	116
S7	6	1468	125	5	2479	116
S21	7	1463	124	10	2467	115
S1	8	1455	124	7	2471	116
P49 Penticton A	9	1453	123	6	2474	116
S3	10	1453	123	9	2467	116
S5	11	1446	123	11	2461	115
S2	12	1436	122	12	2451	115
S17	13	1428	121	14	2424	114
S15	14	1427	121	13	2429	114
P30	15	1420	121	15	2418	113
S6	16	1407	120	18	2401	112
S8	17	1407	120	16	2405	113
P42	18	1403	119	31	2311	108
P38	19	1400	119	20	2383	112
P37	20	1396	119	19	2387	112
P26	21	1392	118	17	2404	113
P29	22	1390	118	22	2377	111
P28	23	1379	117	21	2378	111
P33	24	1377	117	23	2375	111
S22	25	1376	117	24	2371	111
P31	26	1365	116	27	2353	110
P34	27	1364	116	25	2364	111
S10	28	1364	116	26	2357	110
S16	29	1359	115	29	2329	109
P23	30	1352	115	28	2347	110
P36	31	1329	113	30	2329	109
S13	32	1319	112	36	2286	107
S14	33	1312	112	37	2283	107
S19	34	1305	111	38	2258	106
S45	35	1305	111	39	2258	106
P25	36	1304	111	34	2297	108
S9	37	1303	111	33	2299	108
P40	38	1298	110	32	2301	108
S12	39	1286	109	40	2252	105
P35	40	1283	109	35	2290	107
S11	41	1190	101	42	2136	100
P27	42	1177	100	41	2158	101

calendar year. As shown in Table 6.2, there are wide ranges in the 2003 growing degree day annual totals, 1,543-1,177 Base 10 °C (GDD_{10}) and 2,572-2,136 Base 5 °C (GDD_5). Thirty-one percent more GDD_{10} degree days were accumulated at the warm site P39 than the cool site P27. Similarly, twenty percent more GDD5 degree days were accumulated at site P39 than site P11. Growing degree day accumulation (growing season) started when the mean daily temperature, on 5 days in a row, are above the base temperature and ends when 5 days in a row are below the base temperature. The 5 °C (GDD_5) or 10 °C (GDD_{10}) base temperature is the mean daily air temperature above which a daily amount accumulates during the growing season.

Climate warming will likely lead to changes in crop suitability at some sites due to a longer growing season, reduced risk of severe cold weather, and increased risk of sun scald to apples as summer temperatures exceed the 37 °C threshold more and more frequently (Parchomchuk *et al.*, 1991; Williams, 1993). Some orchard sites may well become thermally suited to production of grapes for heat loving varieties of vines, e.g., red varieties such as Merlot, Cabernet Sauvignon, Cabernet Franc and Syrrah, and less suited to the current apple crop as GDD_5 totals exceed the green tip to harvest period GDD_5 accumulation, 2,225 GDD_5 total threshold (Okanagan Valley Tree Fruit Authority, 1995).

An examination of the trends in GDD_{10} accumulation for grapes at Summerland CDA/CS since 1961 indicated that the grape and wine industry in the Okanagan Basin is currently benefiting from improved growing conditions. Growing degree accumulation using three methods (total accumulation, accumulation from April-October and accumulation based on five consecutive days of mean daily temperature above or below 10 °C) indicated that since 1990, GDD_{10} accumulation has been consistently higher than the minimum for Class 2 grape growing in the area, and has exceeded thresholds for production of high quality red wines (Fig. 6.4).

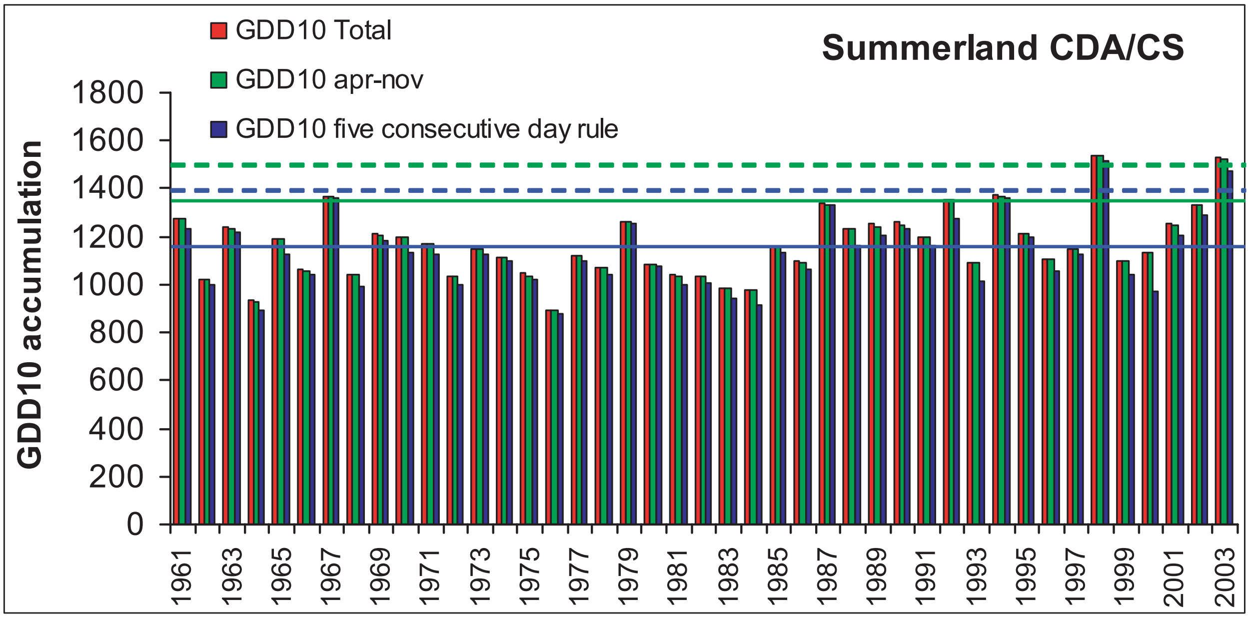

FIGURE 6.4

Growing degree days base 10°C (GDD10) calculated in three ways for Summerland CDA/CS from 1961-2003. The horizontal solid and dashed blue lines represent the thresholds for class 2 and class 1 land respectively, using GDD10 five consecutive day rule (Grape Atlas, 1984). The horizontal solid and dashed green lines represents the thresholds for medal winning Bordeaux varieties, particularly Merlot in the Summerland/Peachland and Oliver/Osoyoos areas respectively (P. Bowen, personal communication)

6.5 References

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chapter 7

Hydrology

Wendy Merritt and Younes Alila

7.1 Introduction

7.1.1 *Modelling the impact of climate change on hydrology*

In a special report of the Intergovernmental Panel on Climate Change (IPCC) Working Group II, regional vulnerabilities to climate change were categorised as ecosystem, hydrology and water resources, food and fibre production, coastal systems or human health vulnerabilities (IPCC, 1998). These categories are highly interrelated, with changes to hydrology and water resources under climate change likely to have substantial impact on the other categories, in addition to the direct impacts of climate change on these sectors. IPCC (1998) noted that water quantity and quality in Northern America are particularly sensitive to climate change. Climate change will affect the hydrology of a region through changes in the timing, amount, and form of precipitation, evaporation and transpiration rates, and soil moisture, as well as through changes in the frequency and duration of storms, floods and droughts. With the wetter and warmer climates predicted over much of British Columbia, most impact studies suggest a tendency towards a more rainfall driven streamflow regime (e.g. Whitfield *et al.*, 2002). Watersheds that are currently rainfall dominated are predicted to show an increase in overall flood magnitude and frequency of occurrence (e.g. Loukas *et al.*, 2002; Whitfield *et al.*, 2002). In contrast, a decrease in the number and magnitude and flood events is predicted for many snowfall dominated watersheds, particularly in the semi-arid interior regions (Cohen and Kulkarni, 2001; Loukas *et al.*, 2002). Table 7.1 summarises some simulation studies that have explored the potential hydrologic impacts of climate change in watersheds in British Columbia.

Regardless of the approach chosen for impact studies, relating global climate change predictions to regional scales is problematic. Over recent years GCMs have been developed that explicitly model river flow at the continental scale (e.g. Arora *et al.* 2002). The algorithms describing hydrologic processes in early models were relatively simplistic and consequently there has been a large volume of work over the last decade exploring the coupling of more detailed hydrologic models with global climate models. These models are often incorporated within soil-vegetation-atmosphere-transfer-schemes (SVATS). The Variable Infiltration Capacity (VIC) model is a notable example of such a model that has been applied widely to continental and large-scale regional studies (e.g. Liang *et al.*, 1994; Nijssen *et al.*, 1997). While GCMs and SVATS are able to incorporate a considerable amount of the complexity of the global system, and are highly valuable for modelling the hydrology of continental scale basins, they are not applicable for finer resolution regional studies (IPCC, 1994; Xu, 1999). At finer resolutions, the accuracy of outputs from GCMs and SVATS become increasingly more uncertain. While climate change is a global issue, the effects of the physical change, as well as the impacts of policies introduced to curb that change, will be felt at the regional and local scales. At the regional scale, hydrologic regimes are determined by large-scale atmospheric circulation patterns and latitude as well as regional physiographic features, geology, vegetation and land-use (Loaiciga *et al.*, 1996). Although conceptual streamflow simulation models, and equally finer resolution process-oriented hydrologic models, are inherently incompatible with GCMs (Nijssen *et al.*, 1997), downscaling techniques provide a means by which climate change scenarios generated using GCMs can be applied to regional scale.

Relating global climate change predictions to regional scales in an effort to model hydrologic processes is problematic. The simplest downscaling method is achieved by perturbing historical time series data by the change in the long-term monthly or seasonal descriptor (e.g. precipitation) under the climate change scenario. This approach has been referred to as the simple alteration, delta and perturbation methods, and has been widely recognized as being severely limited,

TABLE 7.1

Selected modelling studies investigating the potential impact of climate change on water resources in British Columbia.

SOURCE	STUDY SITE	GCM SCENARIOS	HYDROLOGY SCENARIOS	CHANGES TO FLOW QUANTITY
UBC Watershed Model				
Loukas et al., (2002)	Upper Campbell Ck ($1194\ km^2$) Illicillewaet Basin ($1150\ km^2$)	*CGCMa1* (Boer et al., 2001) – Transient simulation with observed increases CO_2 concentrations from 1900 to 1995 and assumed 1% increase annually until 2100	Present climate 1970-1990 Future climate 2080-2100	*Upper Campbell Ck* Wetter and warmer climate with an increase in overall flood magnitude and frequency of occurrence *Illicillewaet Basin* Wetter and warmer climate with a decrease in the number and magnitude of peak flows and flood events
Morrison et al., (2002)	Fraser River Basin ($217000\ km^2$)	CGCM1 (Flato et al., 2001) HadCM2 (Johns et al., 1997)	Present climate 1961-1990 Future climate 2020's: 2010-2039 2050's: 2040-2069 2080's: 2070-2099	Modest average flow increase in the 2080's with a decrease in the average peak flow. General shift to earlier peak in the hydrograph (approx. 24 days)
Whitfield et al., (2002)	Six watersheds within the approximately 50000 km^2 Canadian portion of the Georgia Basin	CGCM1 – IPCC IS92a[1] greenhouse gas plus aerosols	Present climate 1973-1993 Future climate 2020's: 2013-2033 2050's: 2043-2063 2080's: 2073-2093	Increased winter flows in rainfall driven streams, increasingly early onset of the spring freshet in snowmelt dominated streams, and a tendency for hybrid (rain/snow) streams to become dominantly rainfall driven.
Other Models				
Cohen and Kulkarni (2001) – HBV	Six subwatersheds of the Okanagan Basins	CGCM1 – 3 ensemble runs with different initial conditions, IS92a scenario ECHAM (Lohmann et al., 1999) - IS92a scenario HadCM2 - IS92a scenario	Present climate 1961-1990 Future climate 2020's: 2010-2039 2050's: 2040-2069 2080's: 2070-2099	Earlier onset of spring peak flows (up to 6 weeks) with reduced magnitude of peak flows.
Clair et al., (1998) – applied an un-named artificial neural network (ANN) model to a number of basins in Canada's main ecozones	*Rivers in Montane Cordillera ecozone:* Salmon, Thompson, Fraser at Hope, Columbia at Birchbank, Columbia at international boundary, Kootenay, Elk, Similkameen, Okanagan, Howell Creek *Rivers in Pacific Maritime ecozone:* Skeena, Quinsam	CGCM2 (Flato and Boer, 2001 - x 2 CO_2	N/A	Predicted increases in total runoff for the Pacific and Montane Cordillera ecozones. An earlier onset of the spring melt was predicted along with increased winter and early spring flows in these two ecozones.

1 employs observed CO_2 levels until 1990 followed by a 1% increase in CO_2 and aerosols thereafter (IPCC, 1996)

namely as no consideration is made for changes in the variability of descriptors with climate change (e.g. Evans and Schreider, 2002). This method has an effect on the statistical properties of the original climate observations. In the case of temperature, there is a scalar change in the mean although no change to the variance of the temperature distribution. As daily precipitation is not normally distributed, the percentage adjustment disproportionately favours greater changes in heavy precipitation and results in a change in both the mean and the variance. In the case of projected increases in precipitation, the percent adjustment results in only a small increase in the lower end of the distribution, and a larger increase in precipitation extremes. For projected decreases in precipitation, the effect is the same but in the opposite direction, that is, disproportionately greater decreases in heavy precipitation events. However, given uncertainties in the variability of climate parameters under future climates, combined with the range of equally plausible estimates of climate variables from different GCMs, the delta method is commonly applied in hydrologic studies of climate change (e.g. Lettenmeier *et al.*, 1999; Loukas *et al.*, 2002, Morrison *et al.*, 2002). Wood *et al.* (1997) stated that, although continued improvements in the performance of nested models will likely see them become preferred downscaling techniques, at present there does not appear to be a practical alternative to the delta method. The delta method described in Section 5.4.3 is commonly applied in hydrologic climate change impact studies (e.g. Lettenmeier *et al.*, 1999, Loukas *et al.*, 2002, Morrison *et al.*, 2002).

Uncertainties in regional water resource impact analyses stem from a number of sources, namely from uncertainties in GCM outputs, downscaling of GCM outputs, specification of the climate change scenarios, and impact models (Wood *et al.*, 1997). In GCMs, runoff and evapotranspiration processes tend not to be well represented (e.g. Loaiciga *et al.*, 1996) and precipitation estimates are notoriously uncertain in both magnitude and timing. Much emphasis has been placed on the mis-match in scales between modeled atmospheric processes that are formulated at large scales and water resources management processes that are described at much smaller scales (e.g. Lins *et al.*, 1997; Nijssen *et al.*, 1997; Xu, 1999). Lins *et al.* (1997) are of the opinion that the 'scale' limitations in using climate models for water resources planning and management have been overstated in the literature. They argue that scale is only one aspect that limits the accuracy of climate model simulations and that the key impediment for any user of climate model outputs is the accuracy of the climate simulation in time and space. Additional uncertainty stems from the development of scenarios, particularly those transient scenarios that incorporate projections of population and demand growth forecasts, which can be highly speculative into the future. The last source of uncertainty is from the impact model. For all hydrologic models, it is not certain whether the processes and assumptions incorporated in the model structure, or the parameterisation of the model under present climates, will hold true for future climates. This uncertainty increases with the degree of empiricism in the model. However, Wood *et al.* (1997) stated that as long as the differences between the current and future climates are modest compared with the inter-annual and inter-seasonal variability in the historic records of atmospheric forcing, then this should not be a serious issue. From this, a greater level of certainty can be placed on scenario outputs for the early 21st century than further in the future. Relative to the errors from GCM simulations and downscaling methodologies, errors from hydrologic modelling can be expected to be modest given good reproduction of the streamflow hydrograph in model testing and simulation. For studies utilizing the delta downscaling method for applying climate scenarios, the differencing errors between the base (calibrated) flows and the scenario flows are less than those errors obtained in model verification. For this reason, Wood *et al.* (1997) considered that the application of a hydrologic model constitutes a relatively minor source of prediction errors and uncertainties in the overarching methodology for assessing the water resource implications of climate change.

The hydrologic component of the Okanagan project extends work detailed in Cohen and Kulkarni (2001) to provide basin wide estimates of the impacts of the climate change scenarios on the discharge of tributaries entering the Okanagan River and the main-stem lakes. The application involved the calibration and testing of the UBC Watershed Model (Quick, 1995) on unregulated and gauged tributaries in the Okanagan Basin. The model is then applied to ungauged tributaries that enter the Okanagan lakes and main-stem river to predicting natural (or unregulated) flows. While most of the tributaries of the Okanagan River are regulated to some degree, the extent and timing of these abstractions are not well documented. As the Okanagan River and main-stem lakes are heavily regulated, in this phase of the project we did not attempt to route these flows through to the outlet of the Okanagan Basin. The following sections describe the hydrologic scenarios developed in the Okanagan project and application of these scenarios to the gauged subwatersheds used to test the hydrologic model. The hydrologic scenarios are used to provide initial inferences on likely management issues with respect to fisheries, the regulated lakes and reservoirs, forestry, bushfire risk and water supply issues. While recognised as important (e.g. Loukas *et al.*, 2002), land cover effects such as the elevation of the timber-line under future climates or changes in agricultural covers, are not considered

7.2 The Okanagan River Basin

7.2.1 Management issues

Water resources in the Okanagan Basin are under increasing stress with rapid population growth and land use change. Areas of the basin are heavily regulated for urban water supply as well as to support one of British Columbia's largest horticultural and viticultural industries. Agriculture is confined to the low elevation areas near the main-stem lakes with the higher elevation zones supporting forestry and recreation related activities. Along the main-stem river, the outlets of five of the six lakes are regulated via dams. In addition, many of the upstream tributaries have reservoirs that store much of the water used for agricultural and domestic purposes. Managers of these lakes and reservoirs are also required to provide necessary environmental flows for maintaining the water quality of the waterways and provide indigenous fish species with sufficient flows for successful spawning.

7.2.2 Climate Change in the Okanagan Basin

Changes in the hydrologic regime are likely to occur in response to changes in the timing and magnitude of the annual snow pack that are due to the warmer climates predicted by most GCMs. Recent trends suggest that the basin is getting warmer and wetter, with minimum temperatures increasing at a rate greater than maximum temperatures, and frost-free days having increased by approximately 3.1 days per decade during the 20th century (Cohen and Kulkarni, 2001). If this continues there will be a move towards a more rainfall-dominated hydrologic regime. Previous modelling in subwatersheds of the Okanagan Basin suggests that an earlier onset of spring peak flows will occur under climate change, with these peaks having less volume than current peak flows (Cohen and Kulkarni, 2001). Over the last 50-100 years, net inflow in the Okanagan Basin usage, net inflow or streamflow has increased by 0.3% to 0.5% per year, due largely to the increase in precipitation (cited in Obedkoff, 1994). However, it is not certain whether the trend of increased precipitation will continue and whether or not this will continue to be reflected in changes to the streamflow. With increasingly warmer temperatures, changes in the rates of evaporation from water bodies and land surface and transpiration from vegetation may increasingly influence surface hydrology.

In a review undertaken by the IPCC Working Group II (IPCC, 1996), arid and semi-arid climates were identified as particularly sensitive to climate variation, a feature noted by other researchers (e.g. Frederick and Major, 1997). In drier climates, evaporation from land and water surfaces and transpiration from vegetation are large components of the regional water balance, and temperature effects on evapotranspiration may greatly impact runoff. Additionally, any changes in precipitation may have a disproportionately larger effect than in wetter climates. Nash and Gleick (1993) summarized a number of studies that investigated possible impacts of changes in temperature and precipitation on annual runoff in several semi-arid rivers. These studies suggested that relatively small changes in precipitation and temperature might have large effects on runoff. Schaake (1990) investigated the influence of climate on streamflow in the United States and provided estimates of the elasticities of runoff with respect to climate and evapotranspiration – defining elasticity as the percentage change in runoff resulting from a 1% change in precipitation or temperature. The work of Schaake (1990) suggests that runoff elasticities are higher for drier climates and also that warming alone will decrease runoff much less than a warming accompanied by a decrease in precipitation (reflected in the higher runoff elasticities for changes in precipitation than evapotranspiration). This work suggests that climate change in the Okanagan Basin may have a large impact on water resources due to the aridity of the regional climate.

In mountainous regions like the Okanagan Basin, any changes in the snowpack season under future climates may lead to an increased risk of disruptions in water supplies (IPCC, 1996; Frederick and Major, 1997). The accumulation and recession of the snowpack is the most important factor controlling the timing and amount of water that is available in the basin. Currently, the winter snowpack is used as a guide to the managers of the lakes and reservoirs who release or store water based on whether or not a water surplus or deficit is foreseen. If an earlier onset of the spring peak flows occurs, as suggested in previous studies, this has major implications for water managers, particularly during low flow periods in the late summer. At this time, domestic and irrigation water requirements in the basin are greatest and a lengthening of the low flow period will exacerbate conflicts between consumptive and environmental uses of the water. Changes to the snow pack also affect the soil moisture status and consequently will influence the risk of fire danger in the forested areas.

7.2.3 Available Data

A number of datasets pertaining to the land use, geology, climatology and water resources of the Okanagan Basin were used in this study. Table 7.2 summarises the major datasets for the region, detailing the temporal and spatial scales over which they were developed, the variables they describe and the agency responsible for collection and maintenance of the data sets. Daily time series of maximum air temperature, minimum air temperature, and precipitation are required to drive the hydrologic model. Stations used in calibration and testing of the hydrologic model are listed in Table 7.3. For calibration purposes, daily discharge data is also required. Nine stations in the basin have a sufficient length of record of unregulated streamflow, and are of sufficient quality, to test the hydrologic model (Figure 7.1 and Table 7.4). These gauged watersheds are largely confined to the mid-to-high elevation regions of the basin. The watersheds are located throughout the basin, from the high elevation tributaries of Mission Ck (e.g. Pearson Creek [08NM172]) to the more arid southern watersheds discharging to Okanagan River and main-stem lakes near Osoyoos (e.g. Vaseaux Creek above Dutton Creek [08NM015] and Vaseaux Creek above Solco Creek [08NM171]). All watersheds are largely forested although varying degrees of logging have taken place inside their watershed boundaries.

The key inputs for the hydrologic model detailed in Section 7.3 are the temperature and precipitation time series data. The GIS data detailed in Table 7.2 is used to determine the characteristics of each of the elevation zones defined for the model watershed. However, model outputs are most sensitive to the meteorological inputs. As with most mountainous watersheds, the existing network of climate stations has a number of deficiencies. Although Environment Canada – the main agency responsible for collection of meteorological and discharge data in Canada – has established approximately 30 stations across the Okanagan, there is a low density of climate records at high elevations. Only one higher elevation station (1123750, Joe Rich Creek) has records over the entire 1961-1990 baseline period used in this study. The elevation of this station is 875 masl although elevation in the Okanagan Basin exceeds 2000 masl in upper reaches of Mission Ck and Trout Creek tributaries. The hydrology of the Okanagan Basin is largely controlled by the development and recession of the snowpack. For this reason, it is essential that a modelling application is capable of accurately capturing snow accumulation and melt processes. Without high elevation stations, modellers are forced to rely on lower elevation stations and make assumptions with respect to how precipitation and temperature change with elevation. Precipitation, in particular, is extremely variable and is more difficult to predict and extrapolate between sites than temperature. A low density of stations can potentially introduce large errors into the modelling exercise. In this case, supporting data that is not used to drive the hydrologic model, such as snow course data or short-term records at high elevations, should be used to verify as best as possible the assumptions that are made.

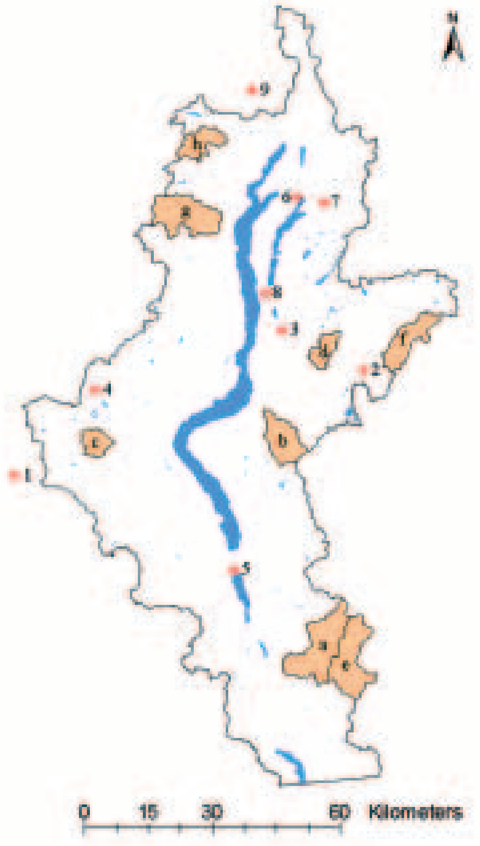


FIGURE 7.1

Unregulated watersheds used in climate change study and Environment Canada maintained climate stations with long-term records. See Tables 7.3 and 7.4.

TABLE 7.2

Sources of meteorological, discharge and GIS data sets for the Okanagan Basin.

DESCRIPTION	TIME SCALE / DATE OF CAPTURE	SPATIAL RESOLUTION	OUTPUTS OF INTEREST FOR THE OKANAGAN PROJECT[1]	SOURCE
Meteorological Data				
Time series data (~30 stations of varying length record)	daily	N/A	Tmin, Tmean, Tmax, rainfall, snowfall, total precipitation (mm)	Environment Canada
Snow survey data (26 stations)	monthly to fortnightly	N/A	Snow water equivalence (SWE), snow depth	River Forecast Centre, Ministry of Sustainable Resource Management http://srmwww.gov.bc.ca/aib/wat/rfc/archive/historic.html.
Time series data (5 stations, 3 above 1000 masl)	daily over the snow-free periods	N/A	Temperature, precipitation	Ministry of Forestry
Time series data (8 stations, 3 at high elevations)	daily to sub-daily during the winter months	N/A	Tmax, Tmin, snowpack depth, precipitation	Ministry of Transportation
Hydrometric Data				
Time series data	daily	N/A	Discharge, stage height, lake level	Environment Canada HYDAT CD-ROM
GIS Data Layers				
Canada Land Inventory	~1966	1:125000	Land use	Geogratis (http://www.geogratis.ca)
Baseline Thematic Mapping	mid-1990's	1:250000	Land use	Decision Support Services, Ministry of Sustainable Resources Management
Forest cover		1:50000	Air crown cover	British Columbia Ministry of Forests
Biogeoclimatic ecosystem mapping	--	1:100000 to 1:500000	Vegetation zones, climate sub-zones	British Columbia Ministry of Forests
TRIM	N/A	1:20000	Digital elevation model	Ministry of Sustainable Resources Management
Aggregate resource potential		1:50000	Primary and secondary geology	Brobowsky et al., (1998) [obtained from http://www.geogratis.ca]

[1] Additional outputs are provided with some datasets

7.3 Hydrologic Modelling

7.3.1 Methodology

7.3.1.1 Model Selection

Hydrologic modelling applications of the Okanagan Basin have generally been undertaken in selected subwatersheds (e.g. Cohen and Kulkarni, 2001) or as part of broad scale modelling of the Columbia River Basin (e.g. Hamlet and Lettenmeier, 1999). An exception to this is the work of Obedkoff (1973), who estimated mean monthly runoff for the extent of the Okanagan Basin with a 5 km^2 grid cell resolution. Developing a hydrologic model of the Okanagan Basin is a complex task, due largely to the recognized challenges in modelling the hydrology of semi-arid regions, deficiencies in the meteorological and hydrometric networks, and the high degree of regulation in the basin. In semi-arid regions, changes in the timing and rate of snowmelt are potentially more

TABLE 7.3

Meteorological time series data used in the hydrologic modelling. The locations of these stations are shown in Figure 1.

	ID	STATION	ELEVATION (M)	RECORD USED
1	1120633	Bankier Chain Lake	1020	1974-1988
2	1123750	Joe Rich Creek	875	1970-1993
3	1123970	Kelowna A	430	1968-2001
4	1126077	Peachland Brenda Mines	1520	1970-1990
5	1126150	Penticton A	354	1960-2001
6	1128551	Vernon	556	1971-1994
7	1128580	Vernon Coldstream Ranch	482	1970-1997
8	1128958	Winfield	503	1974-2001
9	1126785	Falkland Salmon Valley	635	1975-1984

significant in the region than in areas of water abundance (Pipes, 1971). If minimum temperatures are increasing at a rate greater than maximum temperatures, as recent trends have suggested, capturing this is of crucial importance given the temperature thresholds that determine the development and depletion of snowpacks. Existing climate data is predominantly located at low elevations. In the Okanagan Basin, where a strong elevation gradient exists, in addition to the precipitation gradients running east to west and north to south, this further complicates the process of accurately representing the rainfall and snow processes in the model.

Depending on the level of complexity of the hydrologic investigation, Xu (1999) categorised the suitability of different classes of hydrologic models for impact studies as: empirical models that yield annual outputs, monthly water balance models, daily to sub-daily lumped conceptual models, and sub-daily distributed process-based models. The author stated that for detailed assessments of surface flow, conceptual lumped parameter models that operate at a daily time-step should be used. Such a model provides a compromise between model complexity and model utility. In snow-dominated watersheds, a daily time-step is required, at a minimum, to properly capture snow accumulation and melt. Process-based distributed models have the added utility of being able to provide estimates of the spatial patterns of hydrologic outputs (e.g. soil moisture, snow cover). However, such models tend to have large input data requirements and, for this reason, are often limited to small scale applications. Process-based distributed models tend to discretise the study area into a grid, with computations made for all cells in the grid. Outputs from the cells are routed through a flow network to produce estimates of hydrologic indicators at points in the basin. Lumped conceptual models, on the other hand, often break the basin into watersheds and are a conceptually simpler way of representing the basin. Semi-distributed conceptual models tend to model the watershed as a set of pre-defined regions, usually elevation bands, and aggregate model outputs for these regions up to the watershed outlet. These models largely fit into the categories of either large-scale models that are routinely linked with Global Climate Models (GCM) and tend to be applied at resolutions greater than ⅛th degree (e.g. Variable Infiltration Capacity [VIC] – Liang *et al.*, 1994), or models developed for application at much finer

TABLE 7.4

Unregulated gauged watersheds in the Okanagan Basin used in the calibration and testing of the UBC Watershed Model. The location of these watersheds are shown in Figure 1.

	WATERSHED	AREA (KM^2)	ELEVATION (M)			FOREST AREA (%)	MEAN FLOW (M^3/S)
			MIN.	AVE.	MAX		
a	08NM015 – Vaseaux Creek above Dutton Ck	255	570	1580	2300	75	1.44
b	08NM035 – Bellevue Ck	73.3	590	1500	2140	85	0.51
c	08NM134 – Camp Ck	33.9	1040	1460	1920	64	0.15
d	08NM137 – Dave's Creek	31.1	850	1310	1670	46	0.11
e	08NM171 – Vaseaux Creek above Solco Ck	112	1180	1700	2300	77	0.88
f	08NM172 – Pearson Ck	73.6	920	1550	2030	82	0.95
g	08NM174 – Whiteman Ck	112	610	1400	2030	89	0.63
h	08NM176 – Ewer Ck	52.8	640	1380	1760	76	0.40

resolutions (< 150 m^2). Neither of these are suitable for application to the Okanagan Basin. Semi-distributed conceptual models are a more suitable alternative. Two examples are the UBC Watershed Model (Quick, 1995) and the HBV model (Bergstrom, 1995). The two models are similar in terms of their input requirements and the outputs that are simulated. HBV was used in an earlier climate change study in several unregulated creeks in the Okanagan Basin (Cohen and Kulkarni, 2001). In this project, the UBC Watershed Model was applied to all tributaries entering the main-stem lakes and Okanagan River. This work required the transferral of parameters of the UBC Watershed Model from gauged watersheds to the ungauged tributaries. The longer history of application of the UBC Watershed Model in British Columbia compared with HBV, combined with the work done by Micovic and Quick (1999) to develop standard parameter sets for application to ungauged watersheds, made it the more appropriate model.

7.3.1.2 UBC Watershed Model

The UBC Watershed Model has been used extensively in British Columbia and shown to adequately reproduce the hydrologic response of watersheds. The model has previously been used in climate change studies in Canada (e.g. Loukas *et al.*, 2002; Morrison *et al.*, 2002; Whitfield *et al.*, 2002). The model conceptualises a watershed as a series of elevation bands. Meteorological data is distributed by elevation to each band, with the precipitation form at each elevation band estimated based on temperature. Snowpack accumulation is estimated based on temperature and elevation, whilst snowmelt is modeled using a simplified energy balance approach. Snowmelt and rain distribution between the runoff response components (very slow, slow, medium, and fast) is controlled by the soil moisture model. The water allocated to each runoff component is subject to a routing procedure based on the linear storage reservoir concept. The quick and medium components use a set of reservoirs, while the slower components are represented by a single reservoir. Each component runoff is summed to produce runoff for each band, and for the watershed at each time step. Quick (1995) provides a detailed model description of the UBC Watershed Model.

7.3.1.3 Data processing

Each elevation band in a watershed is described by the mid-elevation point (in metres) of the band, the area of the band (km^2), the forested fraction of the band, the density of the forest canopy (%), the orientation index (0 = North, 1 = South), the fraction of impermeable area, a precipitation adjustment factor, and climate station indices for temperature, precipitation, and evapotranspiration. The band area, mid-point elevation and orientation index for each band was determined from Terrain Resource Information Management (TRIM) elevation data provided the Ministry of Sustainable Resource Management. The forested area of each band was estimated from Baseline Thematic Mapping [BTM] data (Source: Decision Support Services, Ministry of Sustainable Resource Management). The Ministry of Forestry forest cover GIS dataset includes maps of the percentage canopy cover at a resolution of 1:20000 for crown land in the Okanagan Basin. This dataset was used to provide estimates of the density of the forest cover. The impermeable area of each band, the parameter that largely defines the surface (very quick) runoff component of the streamflow in a band and at the watershed outlet, was determined using the BTM data and Aggregate Resource Potential dataset developed by the British Columbia Ministry of Energy and Mines (Bobrowsky *et al.*, 1998). The dataset covers much of the Okanagan Basin, although the upper reaches of the Trout Creek and Mission Creek tributaries are not covered by the dataset. Here the impervious area is set to the area of each band not covered by vegetation. Alternatively, the impervious area can be calibrated, although if acceptable calibrations can be obtained without having to calibrate this parameter, the transfer of model parameters to ungauged watersheds is more valid. From the BTM dataset, the land use classifications of urban, fresh water, wetlands and the barren surfaces (unless morainal deposits are the primary geology) add to the impermeable area. When bedrock, glaciolacustrine, and organic deposits are the primary geology these areas add to the impermeable area of the band. Classifications were based on those used in applications of the UBC Watershed Model in British Columbia (Micovic and Quick, 1999; Loukas *et al.*, 2002; Morrison *et al.*, 2002). The impervious area included those areas where the primary geology was colluvial and the secondary geology was bedrock. The assumption here is that these are the shallow colluvial deposits over bedrock referred to by Wittneben (1986). This last category was included to further increase the fraction of the impermeable area as well as increase the proportion of water that is partitioned as quick flow. Improved calibrations were obtained using this classification.

TABLE 7.5

Initial parameterizations used in calibration of the UBC Watershed Model

NAME	DESCRIPTION	RANGE
Precipitation Parameters		
P0RREP	Rainfall adjustment factor	-1 to 1
P0SREP	Snowfall adjustment factor	-1 to 1
P0GRADL	Precipitation gradient applied to elevations lower than E0LMID	1 to 10
P0GRADM	Precipitation gradient applied when E0LMID < elevation > E0LHI	1 to 10
P0GRADU	Precipitation gradient applied to elevations greater than E0LHI	1 to 10
E0LMID	Lower elevation threshold (m)	
E0LHI	Upper elevation threshold (m)	
Soil Moisture Parameters		
P0AGEN	Impermeable area modification factor	25 to 200
P0PERC	Groundwater percolation (mm/day)	0 to 50
P0DZSH	Fraction of groundwater in deep zone	0 to 1
Time Distribution Parameters		
V0FLAS	Flash flood threshold	50 to 100
P0FRTK	Fast runoff time constant for rain (days)	0 to 2
P0FSTK	Fast runoff time constant for snow (days)	0 to 2
P0IRTK	Interflow time constant for rain (days)	1 to 10
P0ISTK	Interflow time constant for snow (days)	1 to 10
P0UGTK	Time constant for upper groundwater runoff (days)	10 to 50
P0DZTK	Time constant for deep groundwater runoff (days)	100 to 250

While the UBC Watershed Model has a large number of parameters, previous work has illustrated that most parameters can take a standard value. The semi-automatic calibration scheme allows the optimization of the key variables. Initial parameter ranges were defined according to Micovic and Quick (1999) and discussions with the model developer (Table 7.5).

7.3.2 *Model application to unregulated and gauged watersheds*

As the UBC Watershed Model is used in the Okanagan project to explore climate scenarios in both gauged and ungauged watersheds, model tests were undertaken to ascertain that the model performs adequately under different climate regimes and between different subwatersheds. To establish model validity, model calibration was split into two components as suggested by Klemes (1986) and Xu (1999); a *split-sample* test of climate transferability and a *proxy-basin* test of the geographic transferability. Tests of the geographic transferability of the models were detailed in the Interim Report (Cohen and Neale [Ed.], 2003). The Nash and Sutcliffe (1970) coefficient of model efficiency (*E*) and the coefficient of determination (*D*) are used to measure the quality of the model calibration. The model efficiency describes how well the volume and timing of the calibrated hydrograph compares to the observed hydrograph and is calculated as

$$E = 1 - \frac{\sum_{i=1}^{n}\left(Q_{obs}^{i} - Q_{cal}^{i}\right)^2}{\sum_{i=1}^{n}\left(Q_{obs}^{i} - \overline{Q}_{obs}\right)^2} \qquad (1)$$

where,

$$\overline{Q}_{obs} = \frac{\sum_{i=1}^{n} Q_{obs}^{i}}{n}, \qquad (2)$$

n is the number of time-steps, Q^i_{obs} is the observed flow at time step *i*, and Q^i_{cal} is the modeled flow at time step *i*. The coefficient of determination, *D*, measures how well the shape of the model hydrograph reflects the observed hydrograph and depends solely on the timing of changes in the hydrograph. The closer the values of *E* and ***D*** are to 1, the more successful the model calibration. The performance statistics for the *split-sample* calibration are shown in Table 7.6. Model performance over the verification period is generally acceptable although the Dave's Creek (08NM137) watershed showed considerable reduction in the model performance statistics.

TABLE 7.6

Performance statistics for the split-sample test of climate transferability (mean annual flow volumes are provided for the calibration and verification periods).

WATERSHED	DATE	Q (10^6 X M^3)	E	D
Calibration Period				
08NM015	01/01/1971 to 31/12/1975	5.16	0.77	0.77
08NM035	01/01/1971 to 31/12/1976	1.30	0.74	0.75
08NM134	01/10/1975 to 31/12/1981	0.41	0.84	0.85
08NM137	01/01/1971 to 31/12/1976	0.37	0.74	0.74
08NM171	01/10/1980 to 30/09/1987	3.27	0.75	0.76
08NM172	01/10/1970 to 30/09/1975	2.96	0.89	0.89
08NM174	01/01/1972 to 31/12/1982	2.22	0.80	0.80
08NM176	01/01/1975 to 31/12/1979	0.98	0.72	0.72
Verification Period				
08NM015	01/01/1976 to 31/12/1982	2.55	0.72	0.74
08NM035	01/01/1977 to 31/12/1983	1.08	0.75	0.78
08NM134	01/01/1982 to 31/12/1988	0.43	0.74	0.74
08NM137	01/01/1977 to 31/01/1983	0.42	0.44	0.48
08NM171	01/10/1987 to 30/11/1994	3.87	0.63	0.65
08NM172	01/10/1976 to 31/01/1983	2.99	0.59	0.68
08NM174	01/01/1983 to 31/12/1993	1.71	0.71	0.71
08NM176	01/01/1980 to 31/03/1984	1.32	0.85	0.86

7.4 Effect of Climate Change Scenarios on Hydrologic Response in Gauged Watersheds

The scenarios produce a wide range of changes in the hydrologic regime of the model watersheds. All combinations of GCMs and emissions indicate an earlier onset of the spring freshet and peak flows compared to the base scenario. However, there is a large degree of variation between predicted annual and seasonal flow volumes and the scale of the timing shift. In analysing the results from the scenarios, three key aspects are focussed on; the range in modelled hydrologic response between the three GCMs, differences in the potential impacts of the two emission scenarios, and key management issues that may arise under climate change. When comparing emission scenarios we focus on the more distant time slices (2050's and 2080's) where the differences between the emission scenarios become more apparent. For exploring the potential management issues that may arise under climate change we focus on the 2020's time slice. It is widely acknowledged that less certainty can be placed on the more distant predicted climates. This uncertainty is demonstrated with the increased spread in precipitation and temperature estimates into the future from the different global climate models (IPCC, 2001: Section 9.3). In addition, the assumptions built into hydrologic models are more valid when the differences between the baseline climate (on which the hydrologic model was calibrated) and the future climate are not large (Wood *et al.*, 1997). Given the added uncertainties in model predictions and the tendency to manage resources over the short to mid term, any changes over the next few decades are of most immediate concern to managers. Hence, planning for future climate change is more likely to focus on the 2020's than later time periods.

7.4.1 Precipitation Form

Much of the change reflected in the streamflow hydrograph under scenarios of climate change is due to an overall increase in temperature under the various climate scenarios and the impact that this has on the partitioning of precipitation form in the UBC Watershed Model. In the model, total precipitation is partitioned as snowfall when the daily minimum temperature is less than or equal to 0°C and as rainfall when the minimum temperature exceeds a threshold of 2 °C. For daily minimum temperatures between these thresholds, the proportion of the precipitation that occurs as rainfall is set equal to the ratio of the minimum temperature and the temperature threshold for rainfall (2 °C). Over the 30 years of record, the proportion of precipitation days with minimum temperatures less than 2 °C is substantially lower across all scenarios compared to the base scenario. For the Summerland Research Station (1127800, 475 masl), the number of precipitation days where the minimum temperature is below 0°C was reduced by approximately 35%, 75% and 55% under the CGCM2, CSIROMk2, and HadCM3 A2 2080's scenarios, respectively. At the higher elevation station, Joe Rich Creek (875 masl) the reductions are close to 40%, 60% and 55% respectively.

The most sensitive period controlling changes in hydrologic regime under climate change, at least at higher elevations, are the transition months before and after winter where daily minimum temperatures are close to the thresholds defined in the UBC Watershed Model. Temperature increases in this period impact the modelled development and recession of snowpacks.

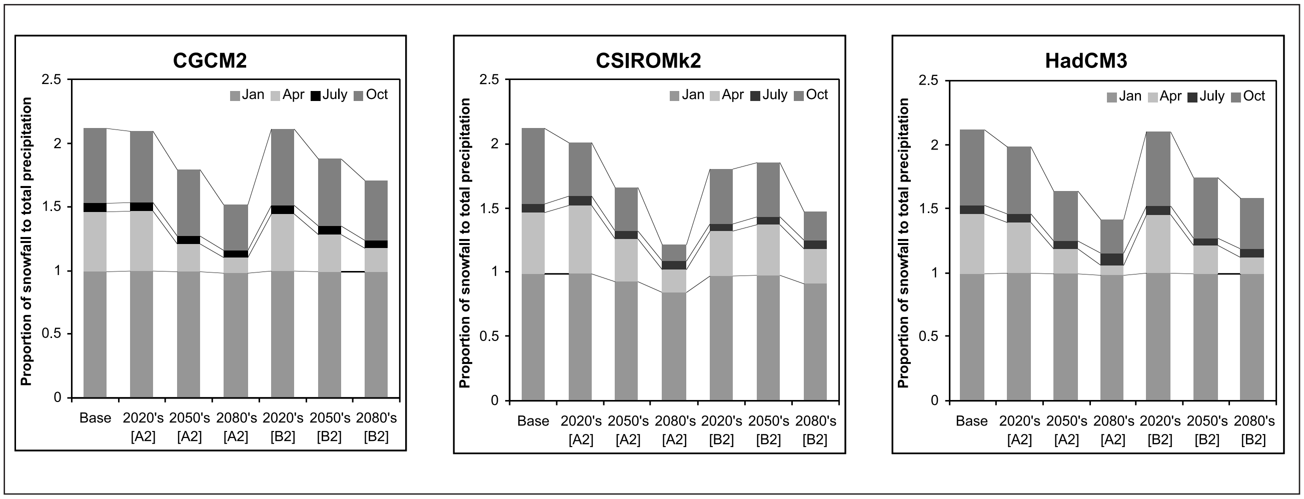


FIGURE 7.2

Impacts of warmer temperatures on the partitioning of total precipitation between rainfall and snowfall in the UBC Watershed Model (Watershed: Pearson Creek [08NM172]; Reference climate station: Joe Rich Ck [1123750]).

Figure 7.2 shows plots of the average monthly snowfall, as a proportion of total precipitation, for January, April, July and October for Pearson Ck [08NM172]. Across all scenarios the precipitation is partitioned almost entirely as snowfall in winter months (e.g. January) and as rainfall in summer months (e.g. July). Considerably more precipitation is allocated to rainfall under the scenarios of climate change in both April and October. This is consistent across all GCMs and emission scenarios. Generally, this trend of increased rainfall and decreased snowfall is stronger in the latter time slices. The exception to this is the B2 emission scenario generated using the CSIROMk2 climate model. A slight increase in the proportion of snowfall occurs between the 2020's and 2050's followed by a decrease in the 2080's. From Figure 5.4 it can be seen that there is not a large difference between precipitation change in the B2 scenario for the 2020's and 2050's winter, and approximately 0.5 °C difference in the mean temperature. Consequently, there is not a large change in the precipitation form as determined by the UBC Watershed Model (Figure 7.2).

7.4.2 Development and recession of the snowpack

The increased proportion of precipitation occurring as rain under the perturbed climate reduces the modelled annual snowpack. In addition, many authors have noted the importance of rain-on-snow events in controlling the rate of recession of the snowpack (e.g. Singh and Kumar, 1997). An increase in such events under climate change will hasten the rate of snowmelt thus exacerbating low season flow shortages that occur due to the earlier onset of peak flows. Over the 30-year simulation period, most scenarios result in an increase in rain-on-snow events. The HadCM3 model exhibits the greatest increase, explaining in part the rapid recession of the hydrograph compared with the CGCM2 and CSIROMk2 scenarios. The impact of these rain-on-snow events is illustrated for two years in the 2050's – corresponding to 1976 and 1982 in the historical time series – for the Ewer Ck watershed [08NM176] Figure 3. The increase in precipitation in the 2050's augments the snowpack in the year corresponding to the 1982 baseline year. The warmer temperatures predicted by the HadCM3 model in February and March results in a greater proportion of total precipitation being partitioned into rainfall compared with the other GCM scenarios. At the end of the winter period where temperatures exceed 0 °C the added rainfall ripens the snowpack, providing the extra energy for snowmelt.

Overall, the snowpack under altered climate scenarios is present over smaller time periods than in the base scenario. Simulated snow accumulation begins later in the season in all gauged watersheds although the peak snow pack and snowmelt processes occur earlier in the year. The peak snowpack is predicted to shift from mid March in watersheds such as Vaseaux Creek above Dutton Creek [08NM015] and Whiteman Creek [08NM174] to late January or early February

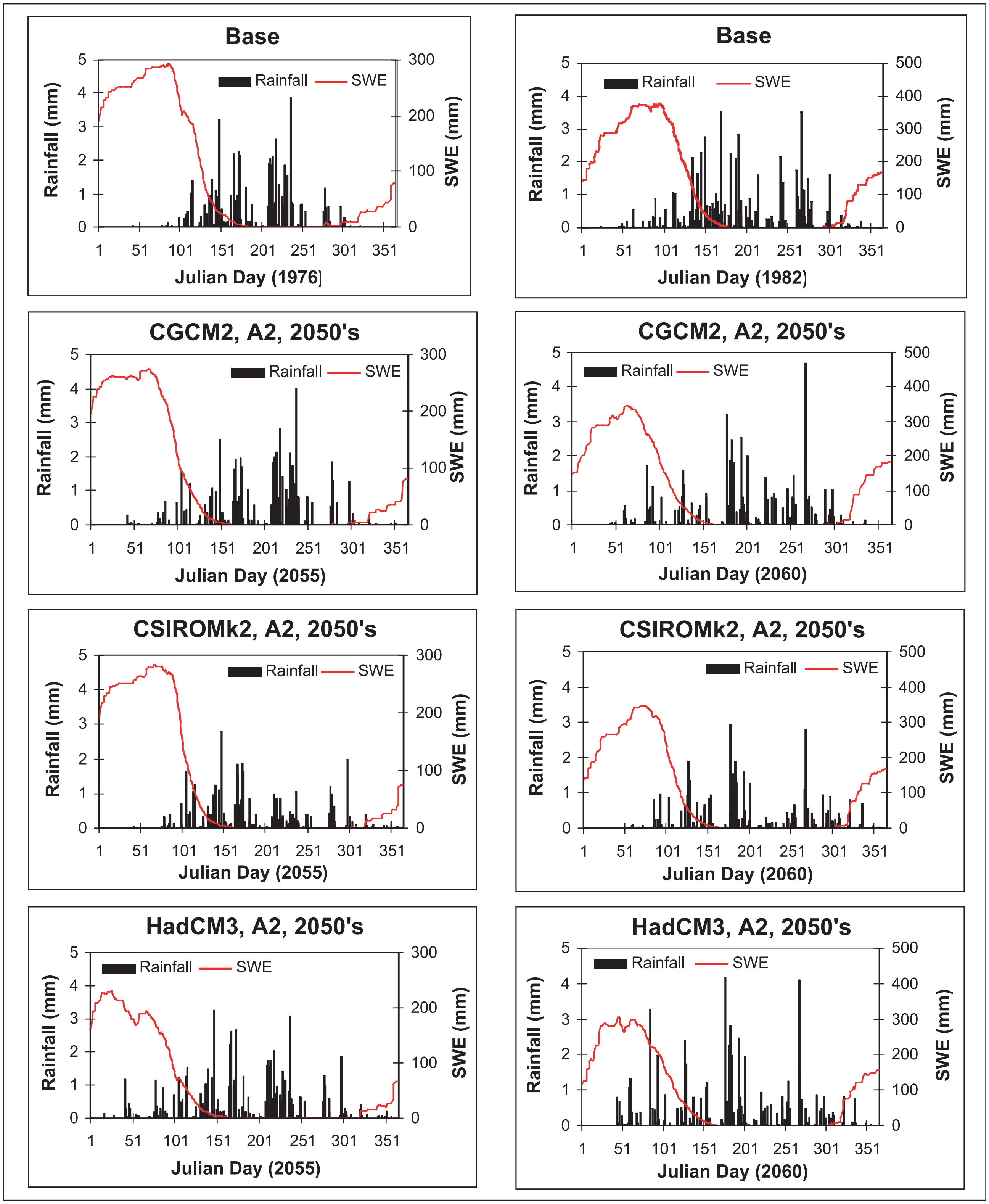


FIGURE 7.3

Increased recession rates of the snow pack associated with an increase in simulated rain-on-snow events under perturbed climates: Ewer Creek [08NM176]. See text for explanation regarding years.

TABLE 7.7

Average date of maximum snowpack under altered climates

	08NM015	08NM035	08NM134	08NM137	08NM171	08NM172	08NM174	08NM176
base90	14-Mar	24-Mar	3-Mar	18-Feb	23-Mar	25-Mar	15-Mar	15-Mar
CGCM2 [A2]								
s20ca2	14-Mar	22-Mar	1-Mar	18-Feb	15-Mar	22-Mar	14-Mar	6-Mar
s50ca2	1-Mar	18-Feb	15-Feb	3-Feb	5-Mar	18-Feb	5-Mar	1-Mar
s80ca2	8-Feb	15-Feb	1-Feb	26-Jan	16-Feb	16-Feb	15-Feb	15-Feb
CGCM2 [B2]								
s20cb2	14-Mar	22-Mar	15-Feb	18-Feb	15-Mar	22-Mar	14-Mar	6-Mar
s50cb2	4-Mar	1-Mar	15-Feb	16-Feb	15-Mar	5-Mar	5-Mar	6-Mar
s80cb2	1-Mar	18-Feb	3-Feb	3-Feb	2-Mar	18-Feb	5-Mar	1-Mar
CSIROMk2 [A2]								
s20sa2	22-Mar	25-Mar	15-Feb	15-Feb	29-Mar	25-Mar	18-Mar	16-Mar
s50sa2	8-Feb	15-Feb	31-Jan	15-Jan	5-Mar	18-Feb	15-Feb	15-Feb
s80sa2	26-Jan	3-Feb	23-Jan	14-Jan	4-Feb	3-Feb	6-Feb	26-Jan
CSIROMk2 [B2]								
s20sb2	1-Mar	18-Feb	3-Feb	3-Feb	5-Mar	18-Feb	5-Mar	18-Feb
s50sb2	1-Mar	18-Feb	15-Feb	16-Feb	15-Mar	27-Feb	5-Mar	1-Mar
s80sb2	26-Jan	28-Jan	26-Jan	15-Jan	31-Jan	3-Feb	2-Feb	26-Jan
HadCM3 [A2]								
s20ha2	14-Mar	22-Mar	3-Mar	18-Feb	23-Mar	24-Mar	15-Mar	15-Mar
s50ha2	14-Mar	22-Mar	3-Mar	18-Feb	15-Mar	22-Mar	14-Mar	8-Mar
s80ha2	1-Mar	27-Feb	15-Feb	16-Feb	5-Mar	1-Mar	5-Mar	1-Mar
HadCM3 [B2]								
s20hb2	14-Mar	15-Mar	3-Mar	18-Feb	23-Mar	24-Mar	15-Mar	15-Mar
s50hb2	5-Mar	9-Mar	15-Feb	18-Feb	5-Mar	13-Mar	7-Mar	1-Mar
s80hb2	4-Mar	5-Mar	3-Mar	18-Feb	23-Mar	5-Mar	5-Mar	15-Mar

TABLE 7.8

Average early onset (in days) of maximum peak flows under altered climates. The onset is related to the average date of peak flows simulate for the baseline period.

	08NM015	08NM035	08NM134	08NM137	08NM171	08NM172	08NM174	08NM176
CGCM2 [A2]								
s20ca2	13	13	13	12	9	8	9	7
s50ca2	27	37	30	30	31	31	23	23
s80ca2	46	54	43	43	51	50	37	36
CGCM2 [B2]								
s20cb2	14	13	12	12	13	10	9	7
s50cb2	22	27	24	21	24	19	16	16
s80cb2	30	39	30	31	33	33	25	25
CSIROMk2 [A2]								
s20sa2	1	6	12	8	7	1	10	4
s50sa2	30	41			33	18	16	28
s80sa2	63	74			67	50	27	58
CSIROMk2 [B2]								
s20sb2	1	34	12	34	32	21	8	24
s50sb2	25	30	28	28	39	24	14	22
s80sb2	50	62		52	55	41	21	20
HadCM3 [A2]								
s20ha2	16	18	10	7	18	15	4	7
s50ha2	21	27	15	14	26	25	25	14
s80ha2	32	40			36	34	58	24
HadCM3 [B2]								
s20hb2	11	13	7	7	15	14	23	6
s50hb2	21	27	13	13	25	26	17	13
s80hb2	28	34			30	30	48	20

depending on the GCM and emission scenario, and from mid February to mid January or early February in Dave's Creek [08NM137] (Table 7.7).

7.4.3 Timing and Magnitude of Peak Flows

With the earlier recession of the snowpack, there is a shift across all modelled watersheds in the peak of the streamflow hydrograph to earlier in the year, although there is considerable variation in the extent of these shifts between the GCMs. The average early onset (in days) for each scenario, compared with the base scenario, is shown in Table 7.8 for each of the gauged watersheds. Generally the trend of earlier peaks continues through all time slices for both emission scenarios and there is reasonable agreement between watersheds in the mean shift. The low number of gauged watersheds makes it difficult to ascertain whether differences between watersheds reflect the basin characteristics (e.g. aspect, elevation) or simply the climate station(s) that were used to drive the hydrologic model. There is considerable inter-annual variability in the extent of the timing shifts simulated under altered climate change. This is illustrated in Figure 7.4 for Vaseaux Creek above Dutton Creek [08NM015] and Bellevue Creek [08NM035] and Ewer Creek [08NM176] subwatersheds. The plot shows, in days, the maximum, median and minimum shifts in the peak flow and the 1st and 3rd quartiles for the CGCM2, CSIROMk2 and HadCM3 climate models. The low emission (B2) scenarios from the CSIROMk2 climate model do not show that same pattern of increasingly earlier maximum peak flows from the 2020's through to the 2080's that was observed for all other scenarios. Not only does the mean shift decrease over the time periods but the inter-annual variability also decreases. These results reflect the differences in GCM output for the CSIROMk2 model as discussed earlier. Overall, the timing shift in peak flows simulated using the HadCM3 scenarios exhibit much lower variability between years than the CGCM2 and the CSIROMk2 scenarios. The CSIROMk2 model is particularly variable moving further into the future as there is the tendency toward a bi-modal annual hydrograph.

The magnitude of peak flows under climate change varies considerably between GCM's and emission scenarios. Using the HadCM3 climate model, peak flows, while occurring earlier, generally exceed the base scenario in the 2020's. By the 2080's, the snowpack development is insufficient to provide the volume required to maintain peak flows. Under the CSIROMk2 climate model, a decrease in the magnitude of peak flow is evident in the 2020's, which then progressively decreases in the 2050's and 2080's. For the Ewer Ck watershed as example, there is little difference in the peak of the 2020's hydrographs for both emission scenarios obtained from the CGCM2 climate model (Figure 7.5). Similarly, the A2 scenario from the CSIROMk2 climate model produced similar magnitudes to the base scenario, although the B2 scenario shows significantly reduced peak flows, contrary to what would be expected under a low emission scenario. In the 2020's, the HadCM3 climate model scenarios predominantly exceed the magnitude of the base scenario peak flows, raising the possibility of a heightened risk of flooding which managers of the lakes and reservoirs in the basin may have to plan for. For the 2050's, the increase in temperature predicted by both the CGCM2 and CSIROMk2 climate model results in lower peak flow magnitudes than predicted for the base scenario. The reduction is more moderate with the B2 scenario. The HadCM3 model, in contrast to the other climate models, still predicts increased peak flows for both emission scenarios although by the 2080's the warming is sufficient to reduce peaks, for most years, to below that of the base scenario. Figure 7.6 shows similar plots for the Dave's Ck watershed. Similar patterns are seen to the Ewer Ck watershed with the B2 scenarios generally exhibiting a more modest response to perturbed climates than the A2 scenarios. However, the response seen in the Ewer Ck watershed to the CSIROMk2 scenarios is not as extreme in the lower elevation Dave's Creek watershed. Despite the increase in precipitation over the winter months predicted by the CSIROMk2 GCM, the increased predicted minimum temperatures significantly reduces the modelled snowpack development and, therefore, the magnitude of peak flows during the freshet. In the 2080's, the adjustments applied to the historical minimum temperature data series are considerably smaller for the B2 scenario than for the A2 scenario, with the exception to the month of February. In the UBC Watershed Model, more precipitation is partitioned into snowfall in the B2 scenario than in the A2, and this, combined with lower maximum temperatures and therefore lower potential evapotranspiration, increases the volume of water that contribute to runoff as well as the magnitude of maximum peak flows.

7.4.4 Flow Duration Curves

Over the entire period of record, differences in the flow regime under altered climates become more apparent at lower flows. Flow duration curves are shown in Figure 7.7 for the A2 scenarios in the 2050's in four of the test

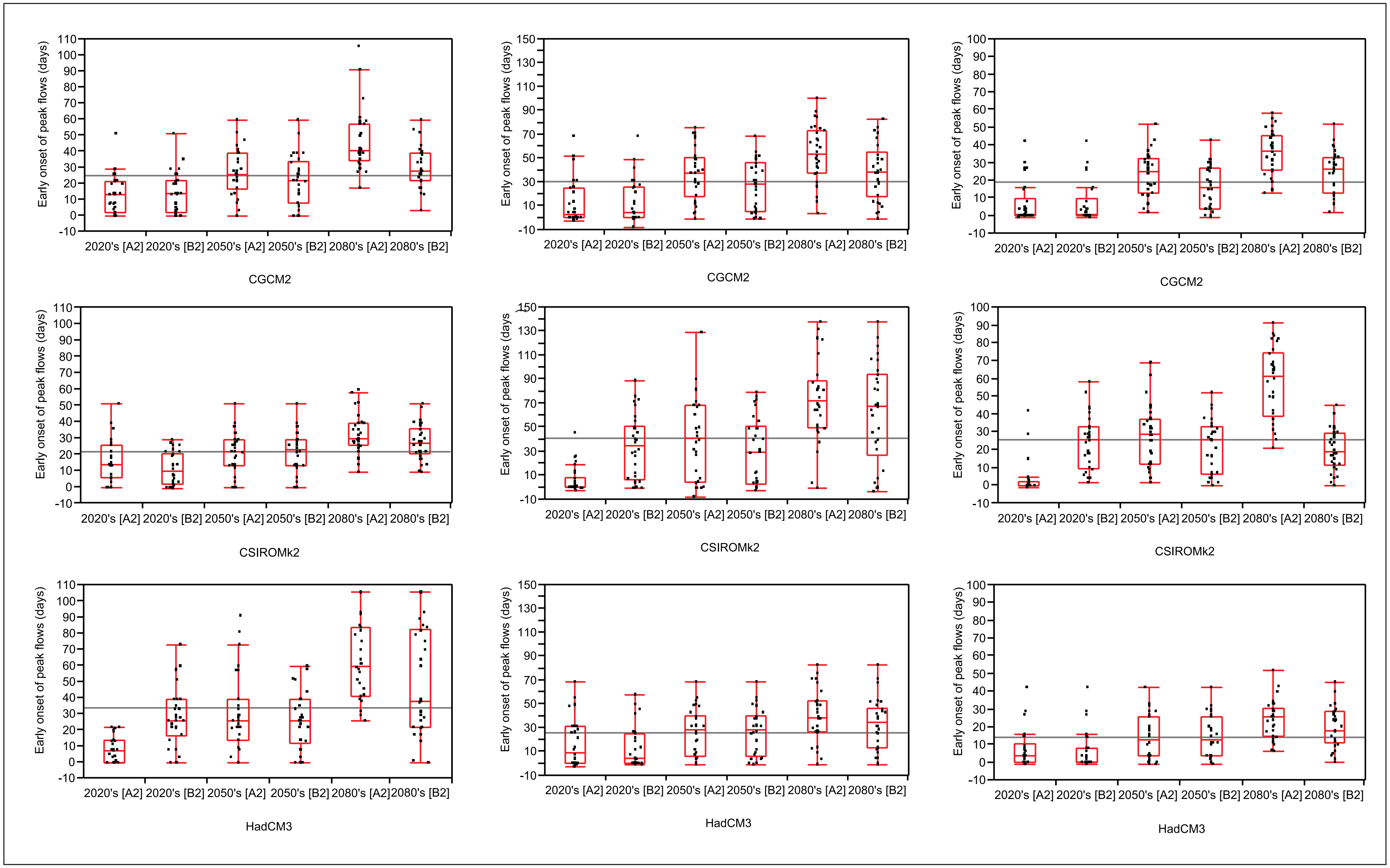


FIGURE 7.4

Early onset of maximum peak flows under perturbed climate scenarios for (a) Vaseaux Creek above Dutton Creek [08NM015], (b) Bellevue Creek [08NM035] and Ewer Creek [08MN176]. From left to right, the scenarios are the A2 scenarios for the 2020's, 2050's and 2080's followed by the B2 scenarios for the 2020's, 2050's and 2080's.

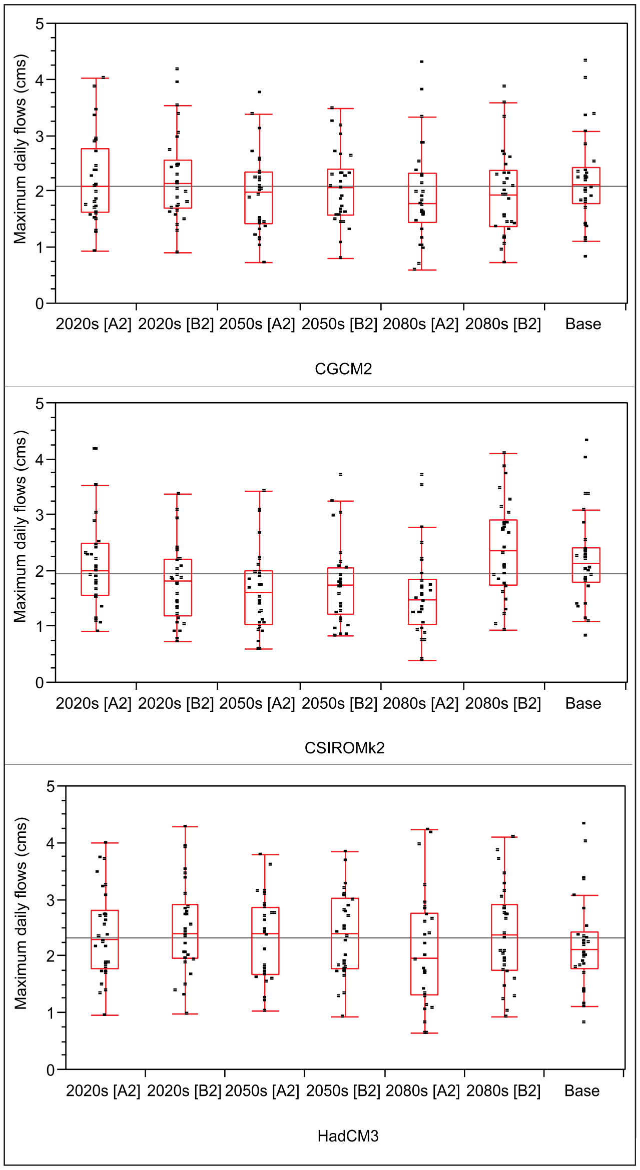


FIGURE 7.5

Magnitude and variability of maximum peak flows under climate change scenarios: Ewer Creek [08NM176]

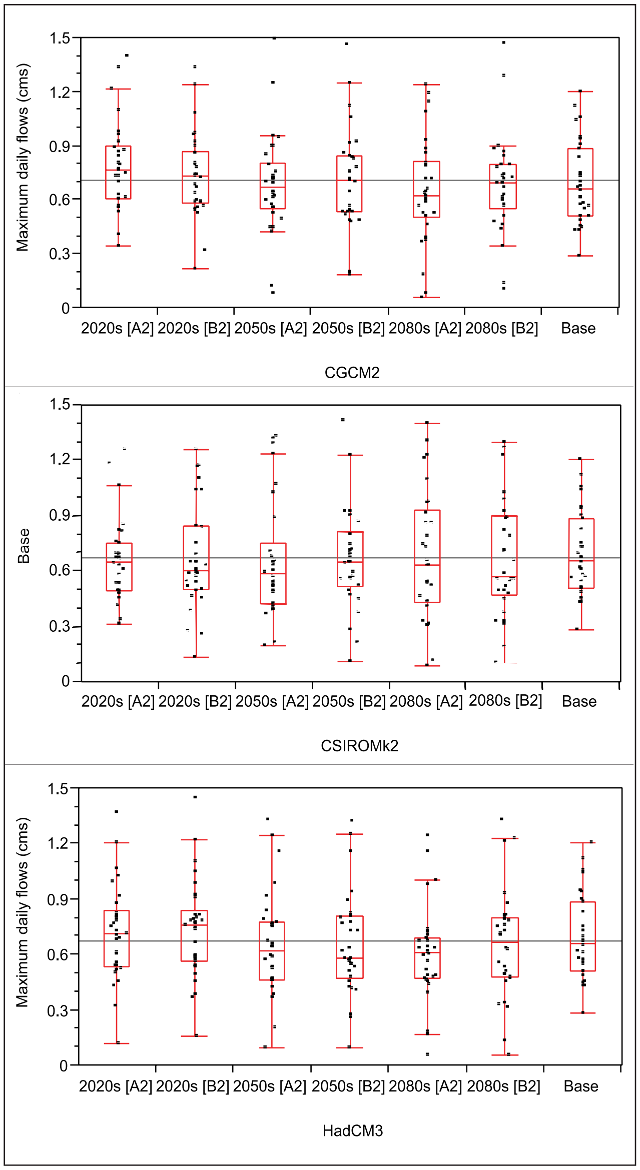


FIGURE 7.6

Magnitude and variability of maximum daily flows under climate change scenarios: Daves Creek [08NM137]

watersheds. In all of the watersheds, non-peak flows are generally reduced, although occur more frequently under the climate change scenarios. For the CSIROMk2 model, non-peak flows were greater for the peak flows for Pearson Creek, perhaps reflecting that the higher elevation of the watershed may moderate the losses of water due to evapotranspiration and soil moisture deficits, under warming conditions. As with the other watersheds, the increase in temperature reduces the modelled snowpack for Pearson creek, and shifts the onset of the freshet to earlier. At higher elevations, the snowpack is likely to be maintained for longer relative to the lower elevation or more southern watersheds. While peak flows are reduced, the mid-to-low range flows are predicted to occur more frequently.

7.4.5 Seasonal and Annual Flow Volumes

A key issue for managers of the reservoirs and lakes in the Okanagan Basin is not only the possible changes to annual flow volumes under climate change but also how seasonal flow volumes may change. For the 2020's

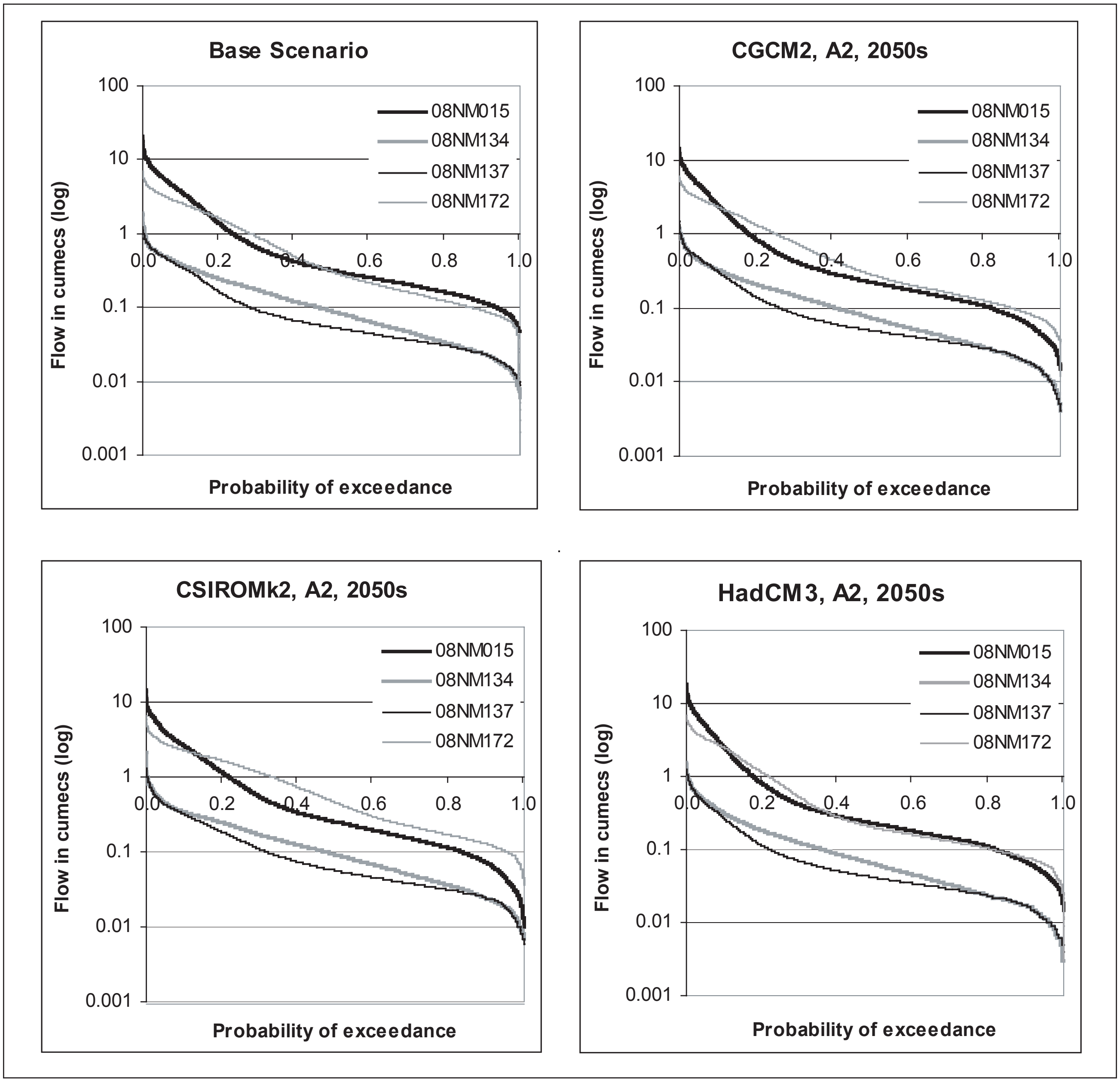


FIGURE 7.7

Flow duration curves for 2050's A2 scenarios over the 30-year simulation periods.

scenarios, annual flow volumes were predicted to change between -12% for the Bellevue Creek watershed [CSIROMk2, B2] and +13% in the Dave's Creek watershed [CGCM2, A2]. While keeping in mind the additional uncertainties associated with longer term predictions, all models suggest a significant decrease in annual volumes in both the 2050's and 2080's (Table 7.9). At these later time slices, the differences between the high and low emission scenarios become more apparent. The greatest changes in flow volumes are predicted for the more arid Vaseaux Creek above Dutton Creek [08NM015]. The changes for this watershed are more extreme than for upstream tributary, Vaseaux Creek above Solco Creek [08NM171]. The same reference climate station was used for each watershed and both watersheds are largely forested. The difference in hydrologic response to perturbed climates is due largely to elevation

TABLE 7.9

Mean annual flow volume in the gauged watersheds of the Okanagan Basin (10^6 x m^3).

	08NM015	08NM035	08NM134	08NM137	08NM171	08NM172	08NM174	08NM176
base90	3.94	0.95	0.49	0.39	28.1	2.75	1.80	0.99
CGCM2 [A2]								
s20ca2	3.60	1.03	0.53	0.44	28.8	2.96	18.5	1.02
s50ca2	2.67	0.78	0.42	0.36	21.3	2.46	1.52	0.87
s80ca2	2.18	0.73	0.40	0.32	19.4	2.43	1.43	0.80
CGCM2 [B2]								
s20cb2	3.57	0.98	0.51	0.42	26.3	2.80	1.87	1.02
s50cb2	3.05	0.88	0.46	0.39	23.7	2.64	1.69	0.94
s80cb2	2.64	0.78	0.38	0.35	21.3	2.45	1.55	0.87
CSIROMk2 [A2]								
s20sa2	3.53	0.94	0.48	0.38	26.6	2.75	1.77	0.97
s50sa2	2.70	0.92	0.47	0.38	25.5	2.81	1.66	0.90
s80sa2	1.49	0.75	0.40	0.31	20.5	2.43	1.37	0.72
CSIROMk2 [B2]								
s20sb2	2.90	0.86	0.51	0.36	24.8	2.60	1.61	0.88
s50sb2	2.91	0.79	0.42	0.33	24.3	2.50	1.57	0.89
s80sb2	1.78	0.76	0.39	0.31	20.3	2.48	1.30	0.87
HadCM3 [A2]								
s20ha2	3.63	0.89	0.47	0.37	25.0	2.54	1.80	0.98
s50ha2	2.83	0.76	0.39	0.31	21.2	2.30	1.52	0.84
s80ha2	2.14	0.71	0.37	0.30	18.8	2.19	1.30	0.76
HadCM3 [B2]								
s20hb2	3.78	0.92	0.48	0.38	26.0	2.59	1.90	1.03
s50hb2	3.15	0.82	0.43	0.34	24.0	2.41	1.70	0.99
s80hb2	2.81	0.78	0.40	0.38	21.1	2.31	1.60	0.87

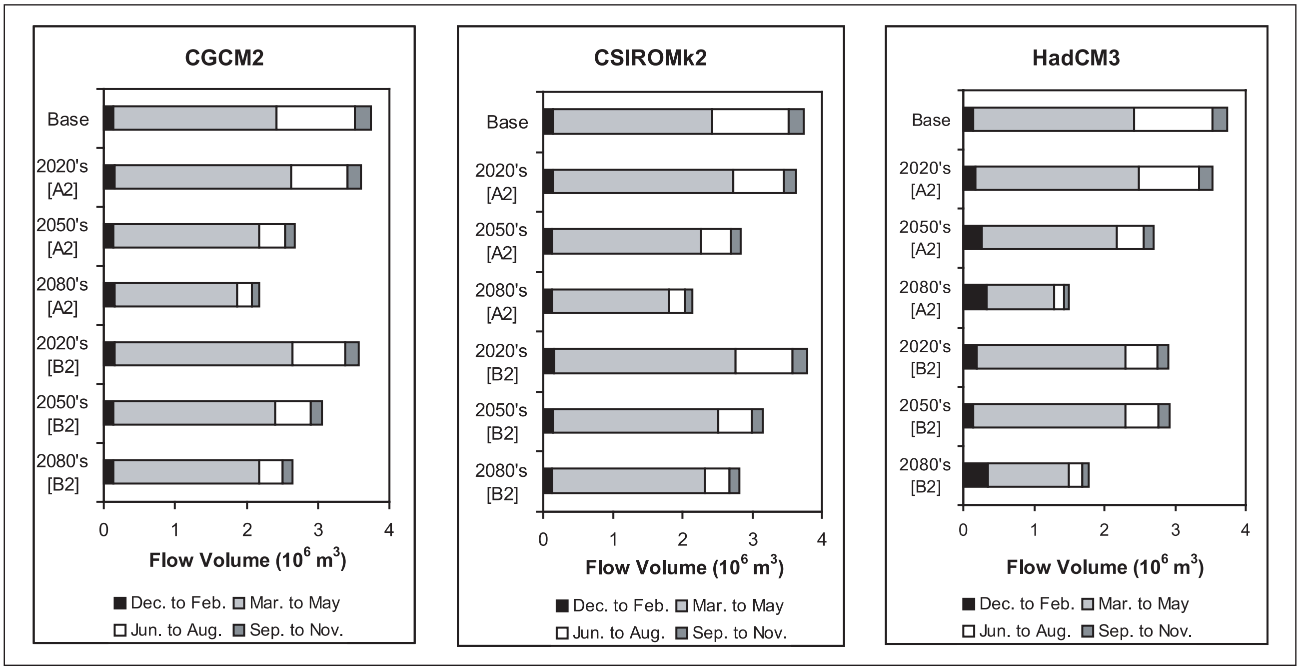


FIGURE 7.8

Mean seasonal flow volumes under perturbed climates for Vaseaux Creek above Dutton Creek [08NM015]

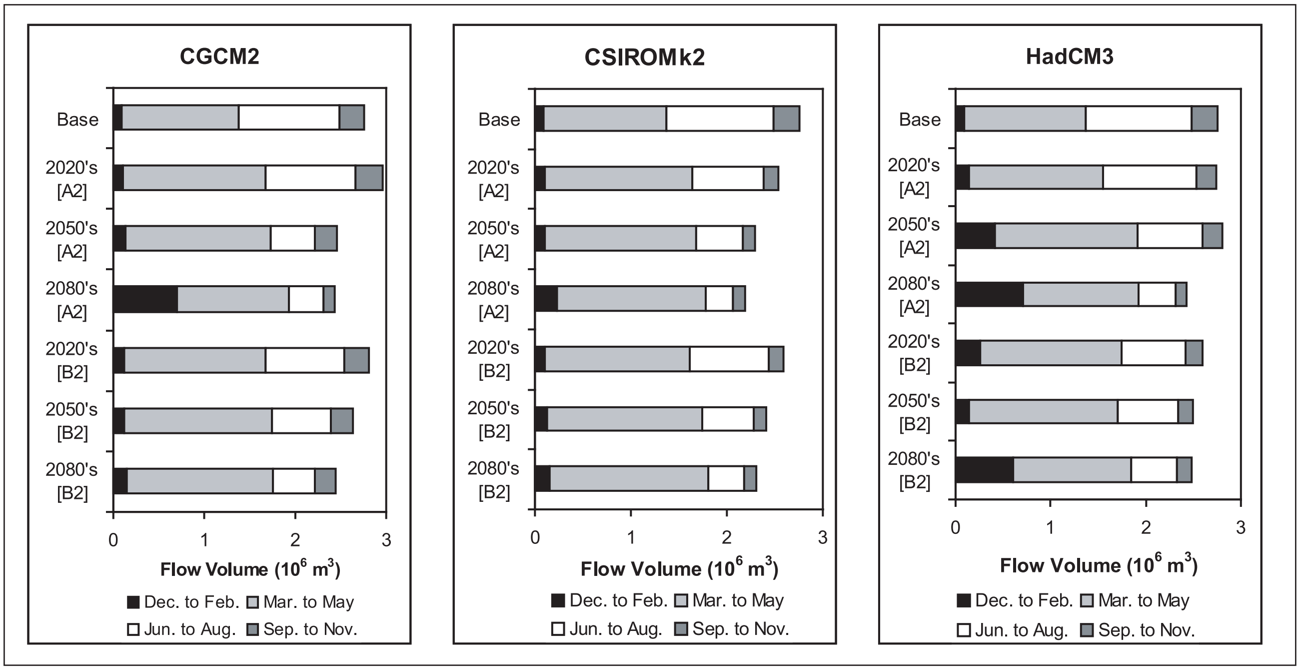


FIGURE 7.9

Mean seasonal flow volumes under perturbed climates for Pearson Creek [08NM172]

differences. The downstream gauge is located at an elevation of 560 masl compared with the upstream outlet at 1150 masl. The highland regions are less impacted by climate change than the lower elevations. Snowpack development at mid-to-low elevations is greatly reduced under the warmer temperatures predicted for the future. During winter and early spring, potential evapotranspiration increases with temperature, further reducing the volume of water that reaches the watershed outlet. The other two gauged stations that have a considerable portion of the watershed area at lower elevations, 08NM035 and 08NM174, also exhibit a strong hydrologic response to climate change scenarios. However, these impacts are not as large as the watersheds located in wetter and cooler parts of the basin.

For all scenarios, the greatest change in flow volumes is for the months of April through to June. However, significant proportional changes occur in other seasons. For example, the decrease in flow volumes in the July to August period under the HadCM3 high emission climate scenario is of the order of 80% and 50% of the base scenario volumes in the 2080's for Vaseaux Creek above Dutton Creek (Figure 7.8) and Pearson Creek (Figure 7.9) respectively. Although an extreme scenario, in terms of emissions and the high uncertainty associated with simulating future climates, if such a scenario eventuates then the managers of reservoirs have an increasingly difficult task in managing water resources throughout the year. The smaller freshet volumes may potentially make it difficult for managers to store sufficient volumes of water to maintain downstream flow requirements. Although the largest changes in absolute flow volumes occur in the spring freshet period (April to June), the changes are relatively linear across the years for each of the climate models. However, over the January to March period, inter-annual differences between the scenarios are more apparent. The plots in Figure 7.10 show the minimum, 25% quartile, median, 75% quartile and maximum seasonal volumes for Vaseaux Creek above Dutton Creek [08NM015].

7.5 Impacts of Climate Change on Lake Inflow into Okanagan Lake

The objective of the hydrologic modeling component of this project was to develop a basin scale model of the Okanagan Basin as well as models for specified outlets (e.g. the Penticton Creek and Ellis Creek models utilized in Chapter 9). This requires the UBC Watershed Model to be run on the ungauged tributaries of the basin. The methodology for transferring parameters calibrated for the gauged catchment to ungauged tributaries was described in the Interim

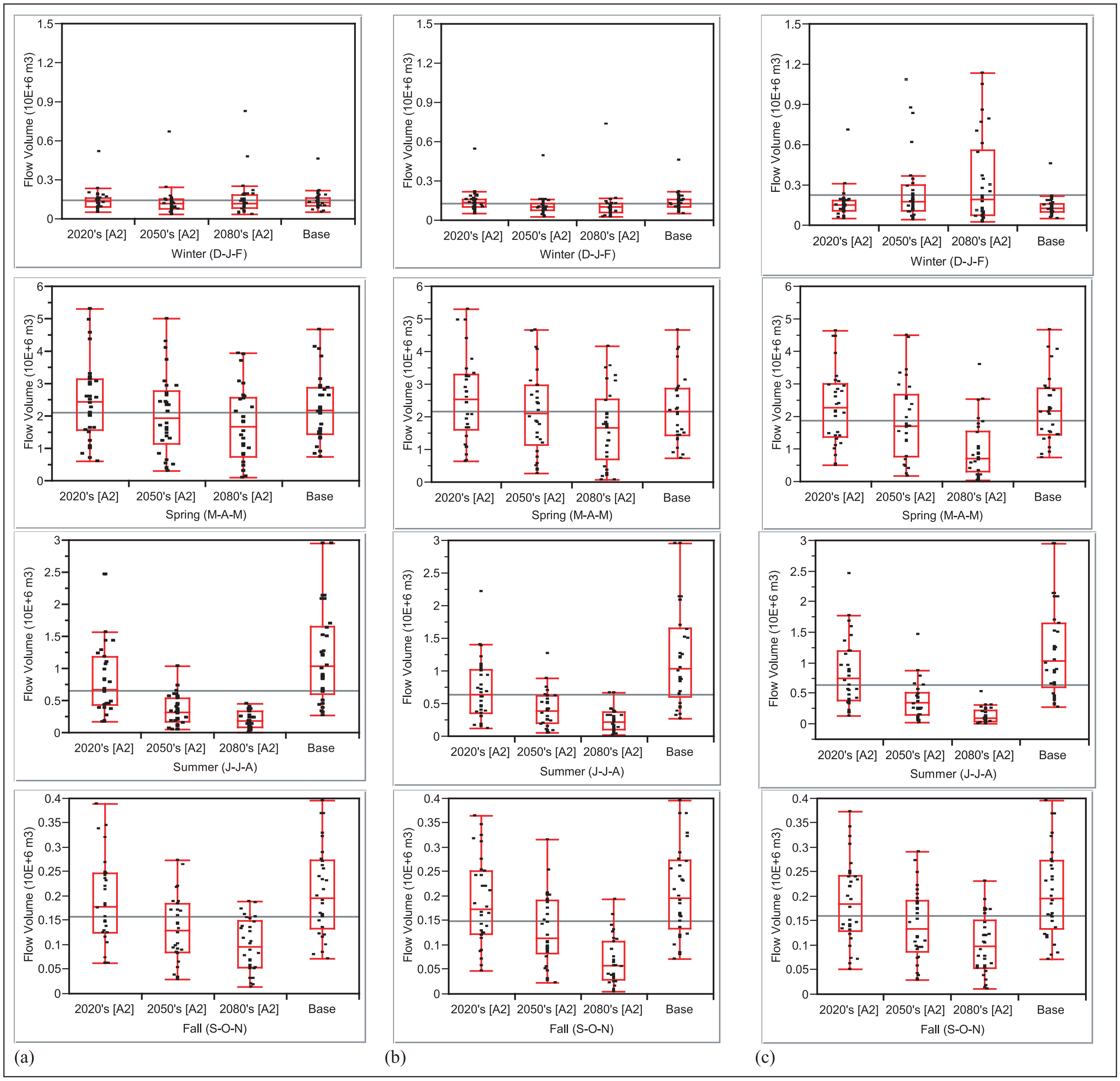


FIGURE 7.10

Inter-annual variability in flow volumes for Vaseaux Creek above Dutton Creek for the A2 climate change scenarios developed from the (a) CGCM2, (b) CSIROMk2, and (c) HadCM3 global climate models.

Report (Cohen and Neale [Eds] 2003). Tests of the regionalisation procedure suggested that estimating the UBC Watershed Model precipitation parameters using supporting meteorological data and using a standard set of the other parameters provides a simple procedure for predicting discharge in the ungauged watersheds that performs relatively well. Despite this, predictions in ungauged watersheds are inherently more uncertain than predictions for the calibrated watersheds. Extra care should be taken in interpreting hydrologic response to the climate scenarios in the ungauged watersheds.

The Okanagan Basin was split into a number of watersheds to which the UBC Watershed Model was applied (Figure 7.11). Large tributaries such as Trout Creek (See Chapter 9) and Mission Creek tributaries

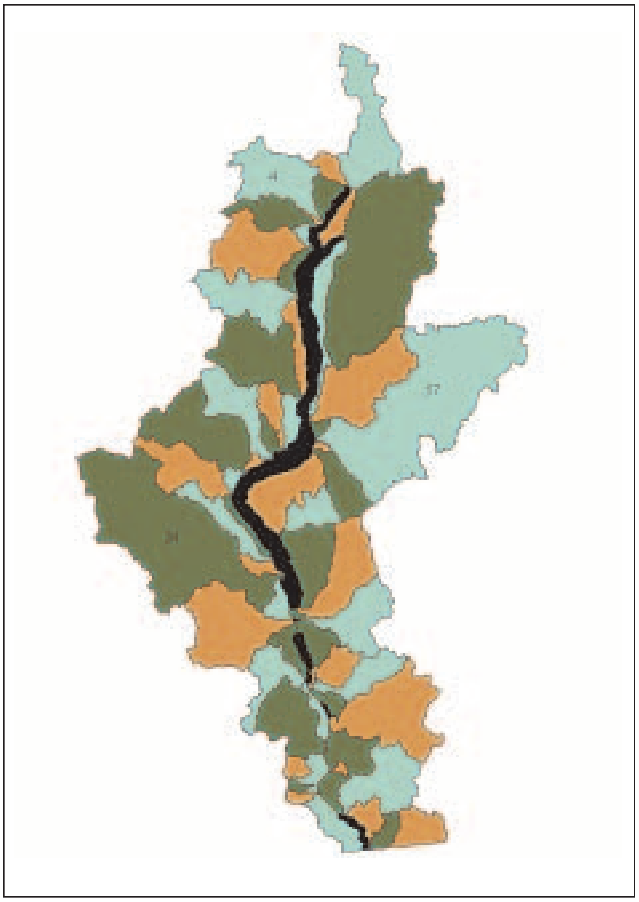


FIGURE 7.11

Delineation of model watersheds in the Okanagan Basin. See text for details.

(indicated by 24 and 57 in Figure 7.11), or tributaries with significant water storage reservoirs, were modelled both as a whole and as a number of subwatersheds, so as to provide estimates of discharge at specific locations. Natural flows for smaller tributaries are modeled as a whole system (e.g. Equesis Creek indicated by 4 in Figure 7.11). Aggregating model outputs from tributaries entering the main-stem lakes above the outlet to Okanagan Lake provide estimates of the annual natural inflow to Okanagan Lake. The natural inflow to Okanagan Lake is predicted to decrease significantly under climate change, particularly in the 2050s and 2080s. In the 2020's, the CGCM2 scenarios predict slight increases in mean annual inflow (< 5%), while both the CSIROMk2 and HadCM3 simulation result in decreased annual inflow. In the 2050s and 2080s, all simulations suggest significant decreases in annual inflow to Okanagan Lake (Figure 7.12).

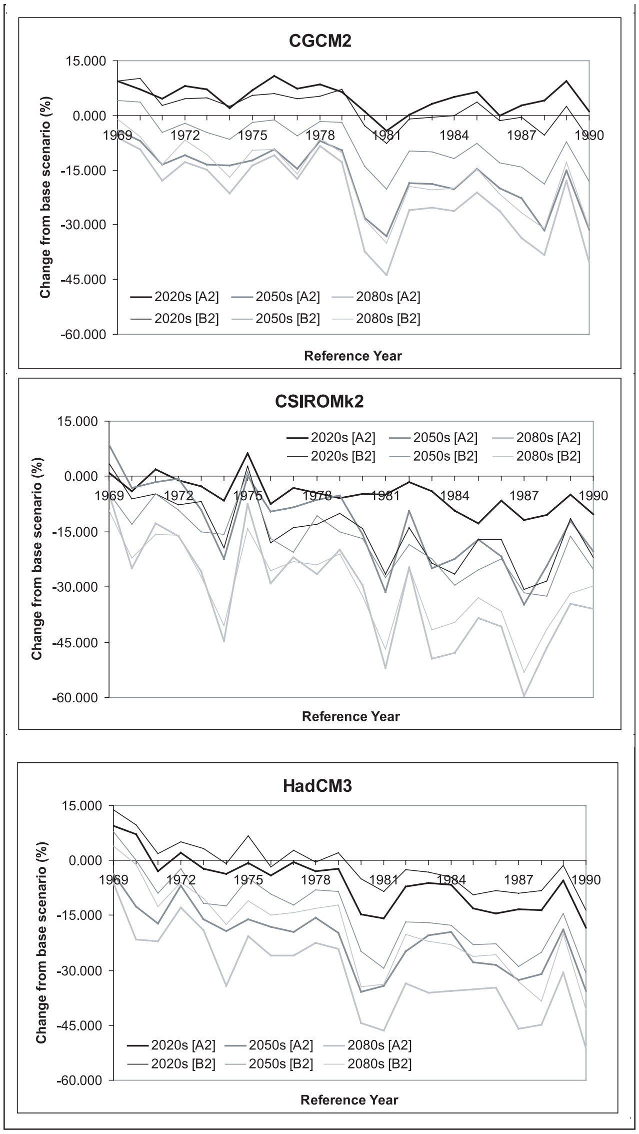


FIGURE 7.12

Percentage change in unregulated inflow to Okanagan Lake for all scenarios.

7.6 Discussion and conclusions

7.6.1 Global climate models and predicted hydrologic response

The CGCM2, HadCM3 and CSIROMk2 climate scenarios provide three quite different, although equally plausible, outlooks for the future hydrology of watersheds in the Okanagan Basin. All scenarios consistently predicted an early onset of the freshet, a tendency towards a more rainfall dominated hydrograph and considerable reductions in the annual and freshet flow volumes, particularly for the 2050's and 2080's scenario runs. Of the three climate models used in this study, the Canadian Global Coupled Model (CGCM2) provided the most conservative estimate of the impacts of climate change in the Okanagan Basin. The shape of the model hydrograph was similar to the base scenario when using the CGCM2 scenarios, and estimated flow volume reductions in the 2050's and 2080's were not as extreme as for the scenarios developed from simulations using the CSIROMk2 and HadCM3 GCMs. The CSIROMk2 climate model predicts the greatest increase in winter temperature and as a result has much reduced snowpack and flow volumes despite a sizeable increase in the winter precipitation. The greatest increase in summer mean temperatures was predicted with the HadCM3 models. Mean annual flows are not predicted to decrease to the levels reached by the CSIROMk2 model as the simulated lower winter temperatures allow the snow pack to develop to a greater level than the CSIROMk2 despite smaller increases in precipitation. This combined with a lower rate of evapotranspiration combined with those associated with the large increases in temperature predicted by CSIROMk2 maintains a greater annual volume of streamflow.

Results from the climate change simulations are largely consistent with other studies undertaken in the snow-driven watersheds in British Columbia. Most studies have predicted early onset on the spring freshet in these regions. The scenarios in this paper that were based on the CSIROMk2 model are more extreme than in other papers although this GCM has not previously been applied to hydrologic impact studies in British Columbia. Also consistent with most studies are the predictions of a reduced magnitude peak flows, particularly in the more distant time periods. There is less consistency in whether there is likely to be an increase or decrease in annual flows under climate change. In this paper, the scenarios resulted in decreased annual flows under future climates, consistent between the gauged watersheds. Other studies have reported an increase in total runoff under climate change (e.g. Clair *et al.*, 1998). This disparity may be due in part to differences in the scenarios used in the studies as well as physiographic differences between the regions. The Okanagan Basin is a semi-arid basin, and while there may be an overall increase in precipitation, reductions in the annual flow could be attributed to a potentially large increase in evapotranspiration with the much warmer temperatures that are predicted.

The scenarios presented in this paper, and the simulated impacts on the hydrologic regime, raise questions over the availability of future water resources in the Okanagan Basin, particularly in terms of the magnitude of seasonal flow volumes. Table 7.10 summarises results from the climate change and hydrologic scenarios as well as the implications for management of the basins' water resources.

7.6.2 Potential impacts of emissions scenarios

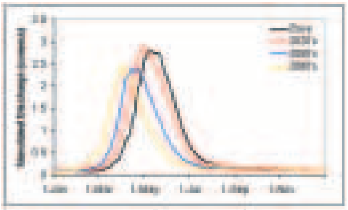
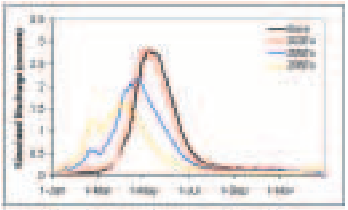
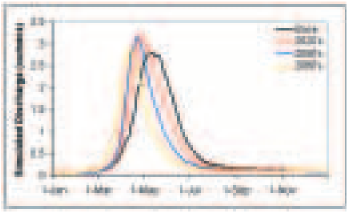
By the 2050's and 2080's, the climate scenarios illustrate the moderating effect of low emissions on the hydrologic response under future climates. Using scenarios derived from the CGCM2 and HadCM3 climate models annual flow volumes predicted in the 2080's for the B2 scenario are of the order of those predicted for the A2 scenario in the 2050's, averaging 80% and 75% of the base scenario annual flow volume across the test watersheds. This pattern is replicated in two of the test watersheds [08NM015 and 08NM176] using the CSIROMk2 model although there is little difference in the predicted annual volumes between the low emission and high emission scenarios in the 2080's for the remaining watersheds. In the 2080's, all the GCMs show the mean daily winter temperatures under the B2 scenario to be approximately 1 °C cooler than under high emissions. However, only the CSIROMk2 model predicts a significantly larger increase in precipitation from the base scenario under the A2 scenario (31%) than the B2 scenario (16%). This difference in precipitation between the two emission scenarios is sufficient in most watersheds to counteract the benefits of the cooler temperature under the B2 scenario.

7.6.3 Near-management issues – the 2020's

Most tributaries entering the main-stem lakes and the Okanagan River are already regulated to varying degrees. The larger tributaries mostly have reservoirs constructed upstream that supply much of the water used for agricultural and domestic purposes. Managers of these reservoirs are required to manage for a number of competing uses. The major consumptive water use in the basin is the irrigation of agricultural and horticultural crops during the growing period (late March to late October). Managers are also required to maintain flow requirements for fish stocks during migration, spawning, incubation and emergence periods. Flood management is also a critical consideration in the daily operation of the basins' reservoirs. The simulations presented in this paper point to potentially large changes in non-peak flows under warmer climates that will impact the annual and seasonal water yields for the tributaries of the Okanagan Basin. Declining peak flows and flows in the freshet period have strong implications for management of water resources in the basin. Although the purpose of this paper was not to simulate the impacts of the

TABLE 7.10

Impacts of climate change scenario on hydrologic regimes and implications for the management of the Okanagan Basins' water resources.

	CGCM2	CSIROMK2	HADCM3
Example of mean annual hydrograph Whiteman Creek [08NM174], A2 [high] emissions scenario			
Global climate	• Equilibrium (2xCO_2) climate sensitivity 3.5°C [Source: IPCC, 2001: Table 9.1]	• Equilibrium (2xCO_2) climate sensitivity 4.3°C [Source: IPCC, 2001: Table 9.1]	• Equilibrium (2xCO_2) climate sensitivity 3.3°C [Source: IPCC, 2001: Table 9.1]
Regional climate	• ***Winter:*** increased mean temperatures and precipitation of the order of 2°C and 5-10% • ***Summer:*** increased mean temperatures of approximately 2°C and decreases in precipitation of 5-10%	• ***Winter:*** increased mean temperatures and precipitation of the order of 4°C and 15-25% • ***Summer:*** increased mean temperatures of approximately 3°C and 0 to 20% decrease in precipitation	• ***Winter:*** increased mean temperatures and precipitation of the order of 2°C and 5-15% • ***Summer:*** increased mean temperatures of approximately 4°C and greater than 20% decrease in precipitation
Modelled changes to the hydrologic regime	• Early onset of freshet (up to 6 weeks) • Increased peak flows in the 2020's • Reduced flows in later time slices due to significantly reduced snowpack and increased winter and early spring evapotranspiration	• Move towards a more rainfall dominated hydrologic regime • Early onset of freshet (up to 8 weeks) • Trend towards a bi-modal annual hydrograph • Decreased flow volumes in all perturbed climates	• Early onset of freshet (up to 4 weeks) • Increased peak flows in the 2020's • Bulk of the total annual flow occurs over a more confined time period
Implications for management of the Okanagan Basin water resources	• Reservoir management for - irrigation at the end of the agricultural growing season - flow releases for fish stocks - increased peak flows in 2020's	• Management of reservoirs for greatly reduced flow volumes • Timing of peak flows relatively easy to manage (i.e. flows are distributed more evenly through the year)	• Reservoir management for - confined period of inflows to reservoirs - flow releases for fish stocks - extended periods of low flow coinciding with increased demand for water
Recommendations for the future	• Assessment of implications of increased peak flows in the 2020's on existing infrastructure (NB. this may not be an issue further into the future)	• Consideration of wide-ranging water saving practices in agricultural and domestic water use • Reservoir development in as yet undeveloped (and suitable) tributaries entering the Okanagan main-stem lakes and Okanagan River	• Investigate capacity of reservoirs to cope with the bulk of inflows occurring over shorter time periods • Develop or amend existing plans for allocating and storing water resources to cope with the demand during low flow periods

changes in the hydrology on fisheries, ecosystems and water storage systems, inferences can be drawn with respect to issues such as the management of reservoir storages or the provision of adequate environment flows for maintaining both fish stocks and acceptable water quality.

Under future warming, evidence suggests that crop water demand in the Okanagan region will increase considerably, due largely to increased rates of evapotranspiration combined with a lengthening of the growing season (Neilsen *et al.*, 2001). In Chapter 9, water demand scenarios for the Summerland region, suggest that demand will increase under future warmer climates, and that these increases will coincide with the extended periods of low flow predicted under climate change. This indicates the potential for more severe water shortages over periods of greater demand, a threat that may require considerable adaptation from water users in the Okanagan Basin. More extreme increases in crop water demand are predicted under the CSIROMk2 and HadCM3 climate models, both of which suggest hotter and drier summers in the future than the CGCM2 model. Full details of the crop water demand modelling component of this project are provided in Chapter 8".

Under climate change, the task of managing the system of reservoirs in the basin may be further complicated. With the HadCM3 climate model, the hydrograph is peaky and quite confined in the period of elevated flows. Such a scenario would pose difficulties for water managers who would have to cope with the majority of water entering their reservoirs in a very short time frame. They would have to manage water levels in the reservoir(s) keeping in mind the prolonged shortage of flows downstream of the reservoir during the dry season. In contrast, the CSIROMk2 scenarios produce flatter hydrographs that distribute water more evenly through the season, in this sense making the job of managers easier. However, this would be offset by the extreme reduction in flows predicted by the climate model. Under both situations, managing for environmental flows may be given a low priority. While provisions exist for maintaining sufficient flows for indigenous species during spawning and other key periods, if water resources are over-stressed, or peak flows increase, these considerations may be given a lower priority. Additionally, a move towards a more rainfall dominated precipitation regime under warming may make forecasting more difficult. Managers of the lakes and reservoirs use the winter snowpack as a guide to for releasing or storing water based on whether a water surplus or deficit is foreseen. With less snowfall events, anticipating extreme high or low flow periods and instigating pre-emptive management practices to cope with extreme flow conditions may prove problematic.

7.6.4 Future Work

This chapter detailed model development and hydrologic scenarios developed as part of the *'Expanding the dialogue on Climate Change and Water Management in the Okanagan Basin, British Columbia'* project. The UBC Watershed Model was used to model the hydrologic response of both gauged and ungauged watersheds of the basin under perturbed climates. Linking the hydrologic scenarios with the scenarios of agricultural and domestic water use could extend this work. This would allow the volume of regulated inflows to the main-stem lakes and Okanagan River to be estimated and, if coupled with appropriate lake water balance models, could be used to simulate the fluctuation in lake water levels under perturbed climates.

Key to the development of acceptable models of the hydrology of the Okanagan Basin under climate change is the lack of long-term climate records covering the 1961 to 1990 base line period particularly at high elevations. Establishing a number of high elevation long-term climate gauges could make improvements to the hydrologic models of the basin. While expensive, this would provide invaluable data for future studies in the Okanagan Basin. Alternatively, improvements could be achieved by instigating detailed studies to investigate the relationship between elevation and precipitation (both amount and form) in the basin. The study site(s) could be selected to complement existing networks, such as the active snow survey sites in Trout Creek or Trepanier Creek. Information from these studies may allow improved extrapolation of precipitation from the existing network to higher elevation zones as well as guide the estimation of precipitation parameters for the UBC Watershed Model in ungauged watersheds.

7.7 Acknowledgements

The UBC Watershed Model was developed, and provided for use in this project, by Dr. M.C. Quick and the Civil Engineering Department at the University of British Columbia. The authors wish to thank Edmond Yu for technical assistance provided over the projects' duration. The BC Ministry of Sustainable Resource Management and BC Ministry of Forestry provided the GIS data used in this work. Hydrometric and meteorological time series were provided by Environment Canada.

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chapter 8

Crop Water Demand Scenarios For The Okanagan Basin

Denise Neilsen, Walter Koch, Scott Smith and Grace Frank

8.1 Introduction

Most studies of the impacts of climate change on agriculture have focused on potential yield responses to changes in climate and this work has been undertaken primarily for annual crops in rain fed production systems. Less information is available on perennial crops and crops under irrigation although Belanger *et al.*, (2002) defined a series of new agro-climatic indices to assess potential climate change impacts on winter damage to perennial forages and tree-fruits in Quebec. For high-value horticultural crops, successful production is an issue of quality rather than quantity (yield) and management practices are focused on improving quality attributes. In much of N. America and throughout the world, horticultural crops are grown under irrigation, as high returns warrant expenditures on expensive infra-structure. Timely availability of water is imperative to economic production of such crops both to assure quality and to protect investment in perennial plant material. In some crops, planned water deficits are used to enhance quality attributes (Behboudian, 1998; Dry, 2001) while conserving water. Consequently, potential limitations and adaptation to the availability of irrigation water under current and future climates are important considerations for agriculture, particularly in regions were there is strong competition for the resource.

As a tributary, the Okanagan sub-basin is subject to some of the potential pressures identified for the Columbia River system in response to climate change (Mote *et al.*,2003; Barnett *et al.*, 2004), in particular, the conflict over allocation of water resources for in-stream use by fish and wildlife and consumptive use by agriculture. Within the Columbia system, the Okanagan has similar characteristics to the Yakima River, being a snowmelt watershed which is highly subscribed to supply water for high-value crops (Mote *et al.*, 2003). Irrigated agriculture in the Okanagan Basin consists primarily of perennial crops (high value tree fruits and wine-grapes, with the balance in pasture and forage) planted in suitable micro-climates. There is also a small acreage of vegetables.

In studies of regions where land use varies from year to year, spatial distribution is often approximated by a dominant land use assigned to a predetermined land area (e.g. river basin - Rosenberg *et al.*, 2003) or grid cell (e.g. 50 km x 50 km RCM – Mearns *et al.*, 2003; Tsvetinskaya *et al.*, 2003). In contrast, the relatively stable land use patterns in our study were based on recent mapping, in the expectation that these would best reflect current conditions. Regional crop water demand scenarios were developed in a GIS by integrating spatial land use data with gridded climate datasets and estimates of water use for specific crops. The following outlines the data sources, assumptions and methodology used in calculating regional crop water demand.

8.2 Land Use

8.2.1 Data sources

Agricultural land within British Columbia is protected by legislation and is held within the Agricultural Land Reserve (ALR). Within the Okanagan basin, irrigated croplands comprise only a portion of the ALR which also includes large areas of unirrigated land, mainly used as range (Fig. 8.1). For this study, an agricultural land use database was compiled and incorporated into a GIS using ArcInfo™ (Figs. 8.2-8.5). Several data sources were used – Okanagan Vineyards (Pacific Agri-Food Research Centre, 2001), at a scale of 1:10,000; Tree fruit database (OVTFA, 1994) updated by data from the Okanagan Valley Sterile Insect release program at a scale of 1:20,000; Terrestrial Ecosystem Mapping (BCMSRM, 2001) at a scale of 1:20,000. Where gaps existed, they were filled by reference to the Canada Land Inventory (Statistics Canada, 1966) at a scale of 1:125,000, updated from cadastral survey data to eliminate urbanized areas. Where data were derived from older sources, e.g. the area north of Vernon, land

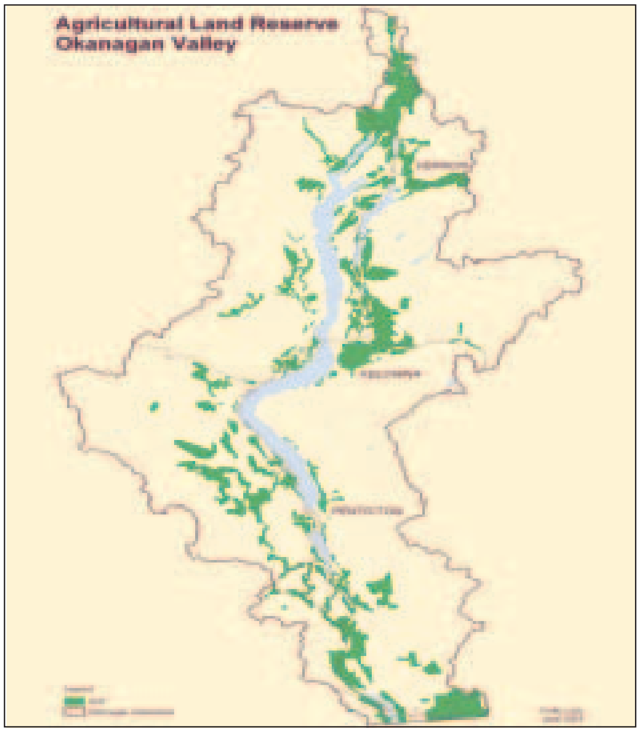


FIGURE 8.1

The Agricultural Land Reserve in the Okanagan Basin.

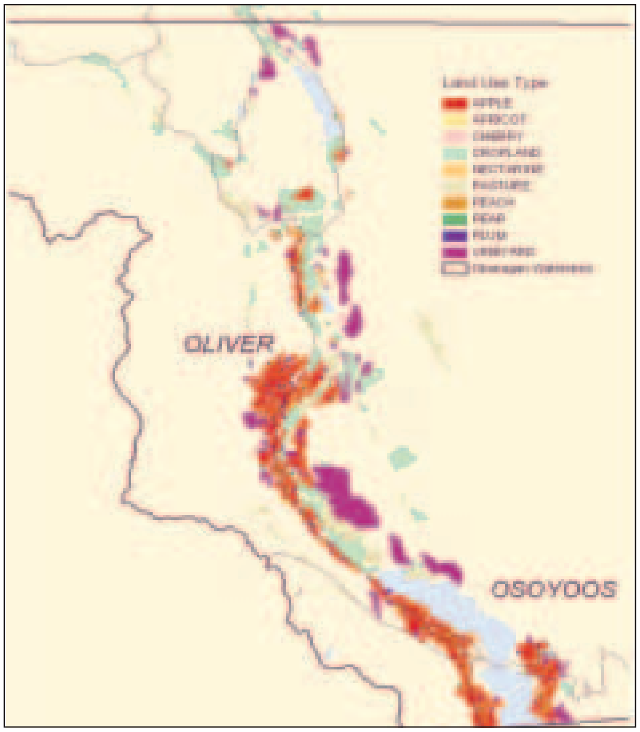


FIGURE 8.2

Agricultural land use in the Okanagan basin; Zone A Oliver/Osoyoos.

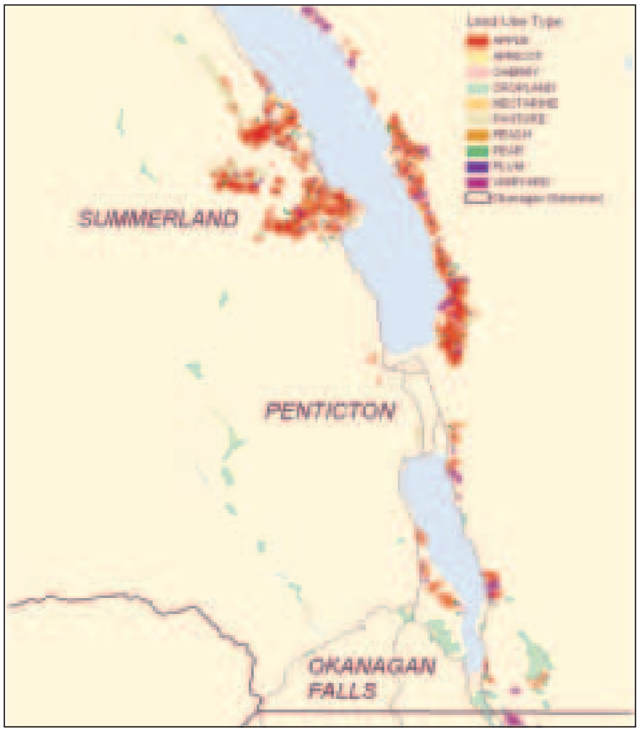


FIGURE 8.3

Agricultural land use in the Okanagan basin; Zone B Okanagan Falls/Summerland

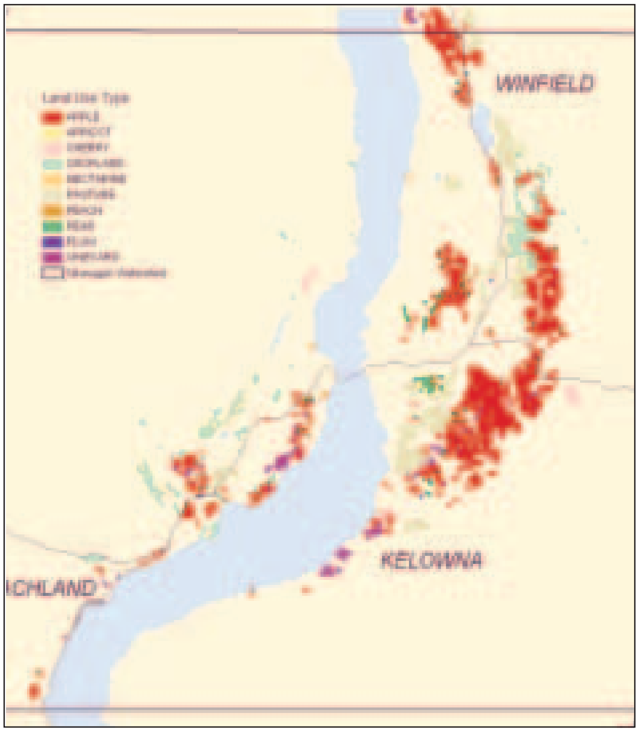


FIGURE 8.4

Agricultural land use in the Okanagan basin; Zone C Kelowna/Winfield

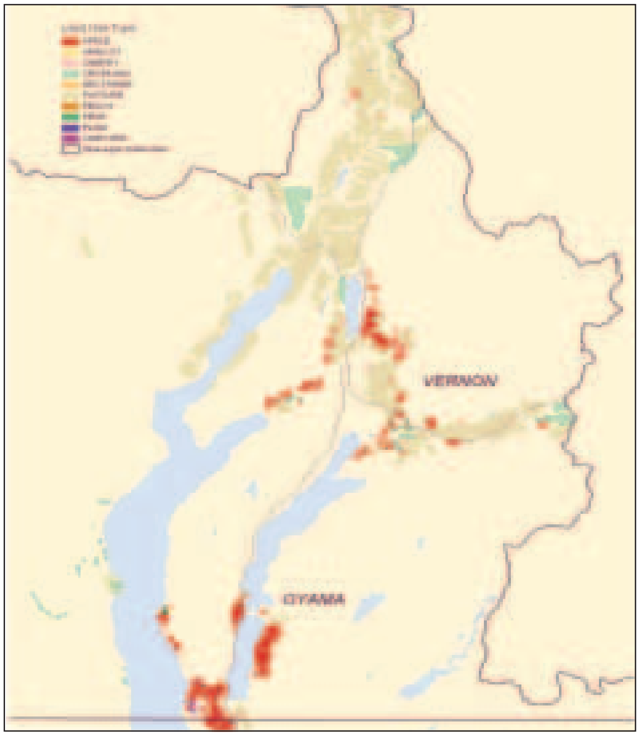


FIGURE 8.5

Agricultural land use in the Okanagan basin; Zone D Oyama/Vernon.

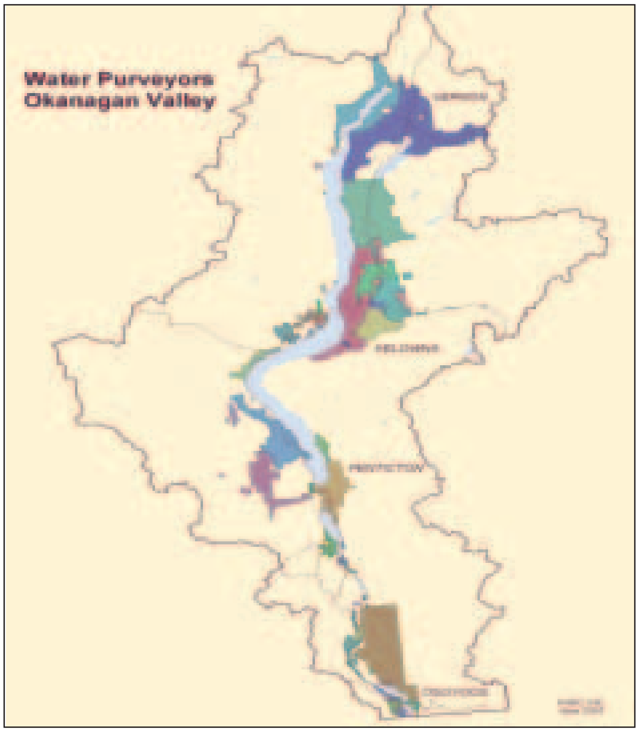


FIGURE 8.6

Areas served by major Water Purveyors in the Okanagan Basin.

use boundaries were verified by ground-truthing and re-drawn as necessary. In order to examine the interaction of land use distribution and water requirements, boundaries of water purveyor districts were digitised and added as a layer to the GIS (Fig. 8.6).

8.2.2 Land use distribution

The total area of irrigated land mapped for the Okanagan Basin was 27,739 ha. Around 48% of the land was mapped as irrigated pasture and forage; 28% as tree fruits, 6% as wine grapes and 16% as other crops (Fig. 8.7). Municipal effluent is used for irrigation near Vernon and applied to approximately 2% of the total irrigated land. Crop profiles vary within the basin, which may have implications for the management of water supply, particularly in the future. In the north, as exemplified by the Greater Vernon Water Utility, pasture/forage and field crops predominate and apples are the major horticultural crop (Fig. 8.7). More complex crop profiles exist in the central (e.g. Lakeview Irrigation District) and southern (e.g. Town of Oliver Waterworks) parts of the basin, as the climate there is more suitable for less winter-hardy species such as cherries, peaches, apricots and wine grapes. Some water purveyors have very specialised land use. For example, in the past few years there has been a major expansion in the wine grape industry, particularly in the Oliver/Osoyoos area as is indicated in the land use composition for the Osoyoos Indian Band. Land use distribution graphs for the major water purveyors in the basin are given in Appendix Chapter 8A.

8.3 Climate data

Recently, there has been considerable discussion about how the scale of climate change scenarios affects the modelling of impacts on agriculture and hydrology (e.g. Mearns, 2003; Payne *et al.*, 2004). Giorgi *et al.* (2001) indicated that high resolution scenarios probably would provide more realistic responses than coarse scale scenarios particularly in mountainous regions. At present, there is no suitable regional climate model (RCM) available for S. British Columbia to allow dynamical downscaling from GCMs to a finer spatial scale (~50 km x 50 km). Statistical downscaling (SDSM) of GCM output to station data for the region, while successful for temperature, did not provide reliable estimates of precipitation (see Chapter 5) and was thus considered not to be useful for hydrology modelling. In order to maintain consistency amongst all components of the study, the 'delta' method of perturbing 61-90 normals station data with average monthly changes in temperature from GCM output was

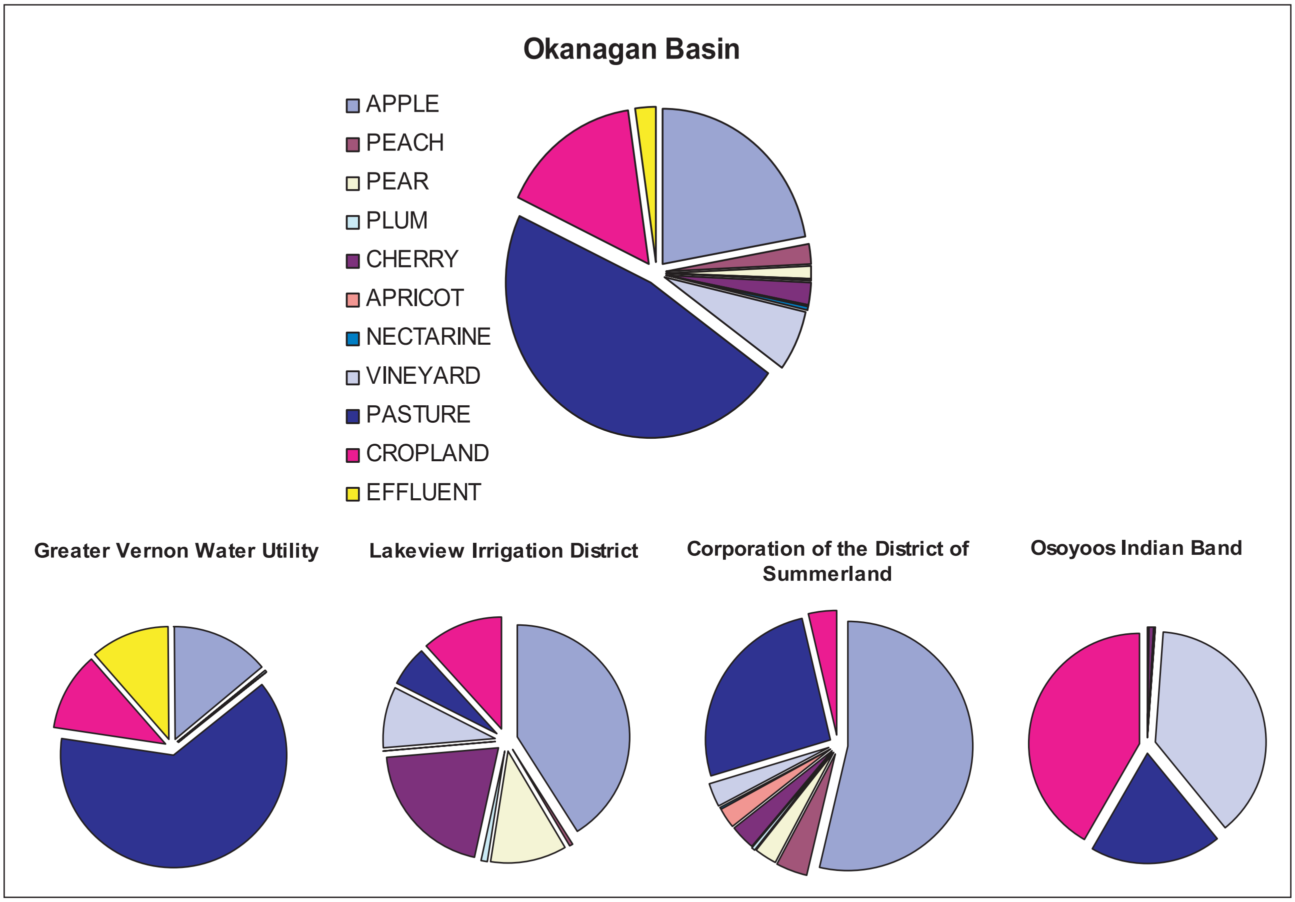


FIGURE 8.7

Land use distribution in the Okanagan Basin and for selected water purveyors.

used to determine climate change scenarios. Rainfall was not included in estimates of crop water demand. Rainfall events are sparse and contribute little plant available water, the latter defined as rainfall >5mm (Van der Gulik, T. W., 1999). Within the growing season (March – October), the number of days per month, with precipitation above 5mm, ranged from 1.1 to 3.9 going from south to north in the basin (Table 8.1). Historic and future crop water demand for the whole basin, was estimated for 1961-90 climate normals, and climates produced from perturbing 1961-90 data by output from GCM scenarios (see Chapter 5). Potential inter-annual variability was assessed for selected sub-watersheds from historic data.

8.3.1 Downscaling and Transformations of Climate Data for basin – wide estimates

For basin-wide crop water demand estimates, thirty year normal weather station climate data were spatially extrapolated using PRISM (Parameter-elevation Regressions on Independent Slopes Model) to an

TABLE 8.1

Monthly totals of 'days with precipitation of 5mm/day or greater' for selected weather stations in the Okanagan Basin (Canadian Climate Normals 1971-2000)

MONTH	OSOYOOS W.	PENTICTON A.	KELOWNA A.	VERNON COLDSTREAM RANCH	ARM-STRONG N.
Jan	0.66	0.43	0.47	0.22	0.38
Feb	1.1	0.63	0.33	0.56	0.50
Mar	1.1	0.97	0.83	0.93	1.8
Apr	1.7	1.7	1.6	1.8	2.5
May	2.5	2.3	2.8	3.2	3.5
Jun	2.1	2.2	2.9	3.9	3.9
Jul	1.3	1.8	2.6	2.8	3.4
Aug	1.6	2.3	2.4	3.2	3.1
Sept	1.1	1.6	2.2	2.6	2.9
Oct	1.2	1.1	1.5	2.1	2.7
Nov	1.7	1.1	1.0	1.5	1.9
Dec	1.1	0.57	0.50	0.46	0.45
Total	17.2	16.8	19.1	23.2	26.9

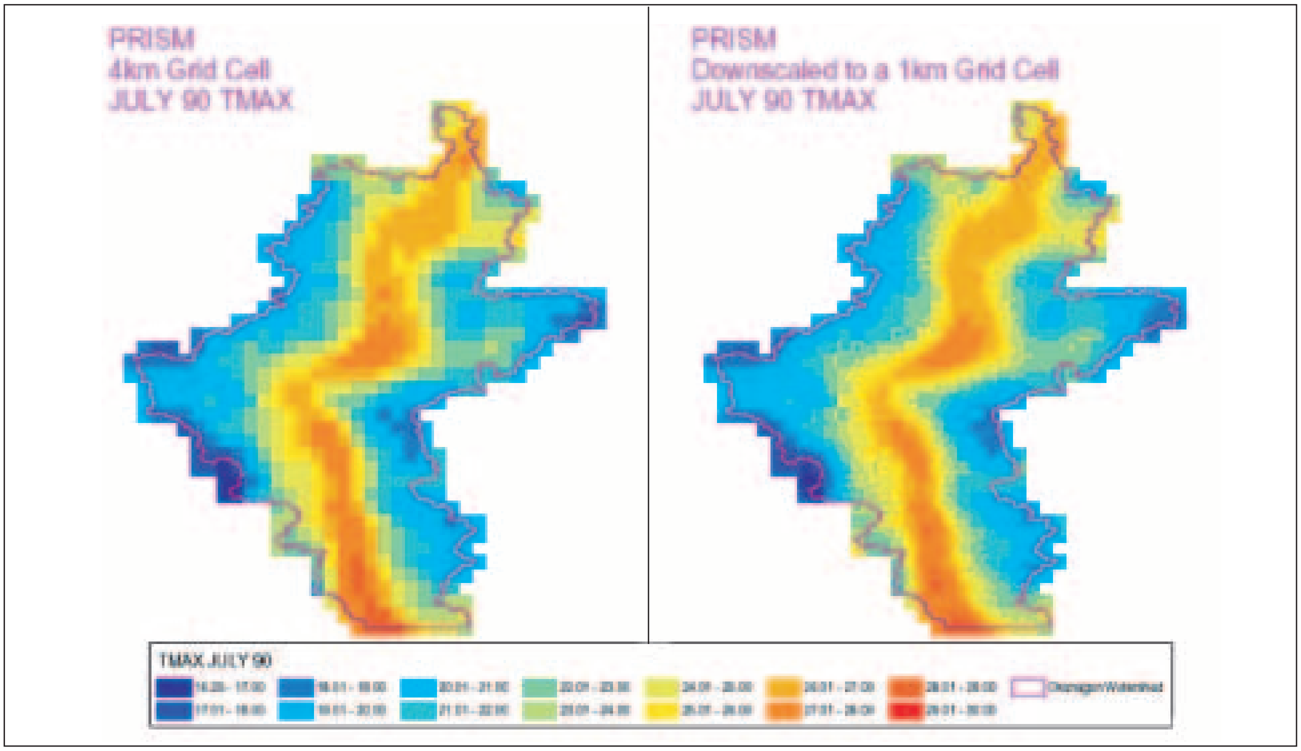


FIGURE 8.8

Rescaling of PRISM from a 4 x 4 km grid to a 1 x 1 km grid.

approximate 1 km x 1 km grid. PRISM is an expert system that uses point data and a digital elevation model (DEM) to generate gridded estimates of climate parameters (Daly *et al.*, 1994). In a previous study (Neilsen *et al.*, 2001), it was noted that the spatial downscaling of temperature data based on the original 4 x 4 km grid-cell output from PRISM, likely underestimated temperatures in crop use polygons because of the large elevation changes within the 4 x 4 km grid cells. This was based on observed differences between PRISM estimates and weather station temperatures. In consultation with Chris Daly (personal commun.), the 4 x 4 km gridded data set has been re-scaled to a 1 x 1 km grid by calculating local average lapse rates based on existing grid cell temperature and elevation data. Data from the 24 nearest neighbour cells were pooled to calculate lapse rates. A sample output for July 1990 max temperature is given in Fig. 8.8. 1961-90 monthly normals for maximum and minimum monthly temperature within each PRISM cell were perturbed using GCM scenario climate output. In order to account for uncertainty associated with GCM output, data were selected for a range of GCMs and emissions scenarios as recommended in the IPCC Third Assessment Report (2001).

A second transformation of scenario data involved the derivation of daily minimum and maximum temperature values during the growing season from PRISM monthly climate data (Tmax, Tmin). Daily mean temperature estimates were required to calculate growing degree day accumulations and daily maximum temperature was required to calculate evapotranspiration. Each monthly average was assigned to the middle of the month. For climate change scenarios, monthly data were perturbed by deviations (bias) in monthly maximum and minimum temperatures derived from GCM output. In order to assure a smooth transition between months a smoothing algorithm was defined which redistributes the discontinuities between perturbation factors and monthly temperatures throughout the month according to the method of Morrison *et al.* (2002). A cubic spline was fitted through the monthly temperatures for the 1961-90 normals case and through monthly temperatures + the bias for GCM output to interpolate to daily temperature values (Fig. 8.9). The monthly biases were assumed to be valid on the 15th day of each month. Since a cubic spline fits through the monthly values exactly, it was necessary to adjust the interpolated daily values such that the calculated mean monthly value was equivalent to the total monthly bias.

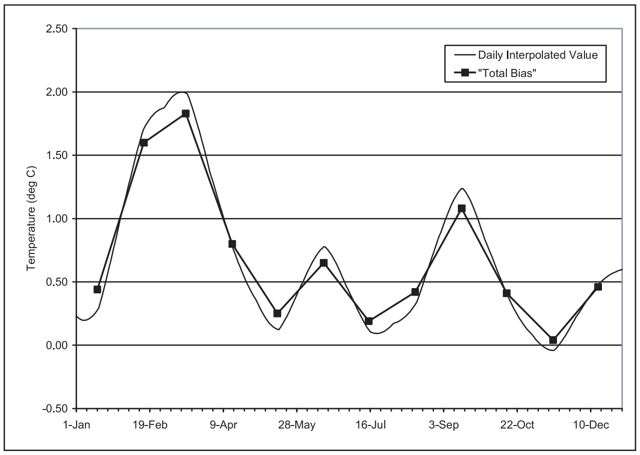


FIGURE 8.9

Monthly "total bias" and interpolated daily bias.

A bias adjustment was added to the daily values assuming a triangular distribution such that the greatest bias adjustment occurred mid-month, thus ensuring a smooth transition in daily temperature values between months (Fig. 8.10).

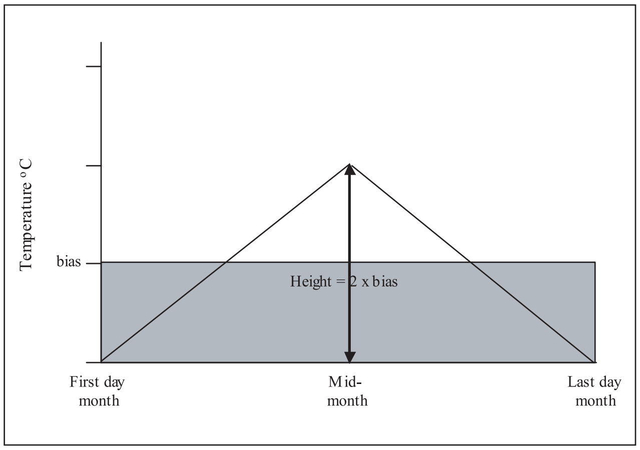


FIGURE 8.10

Triangular distribution applied to daily bias values for each month. Bias represents the difference between the calculated mean monthly value (based on interpolated daily values) and the monthly value ("total bias").

8.3.2 Downscaling and transformations of climate data for estimates of inter-annual variability

For selected sub-basins, daily maximum and minimum temperature data for the nearest climate station for all the years between 1961-90 were perturbed by monthly GCM output. Extrapolation of station data within the sub-basin was determined from relationships derived for 1) the climate station and the PRISM cell in which it was located and 2) the climate station PRISM cell and individual PRISM cells. Thus a 30-year climate record was synthesized for each PRISM grid cell using 1961-90 data from a local climate station, adjusted for monthly biases including:

- Monthly bias between climate station and PRISM cell temperature
- Monthly temperature bias between climate station PRISM cell and other PRISM cells
- Monthly GCM climate scenario adjustments

The monthly bias values between 1) climate station and PRISM cell, were determined by comparing monthly mean values for the climate normals for 1961-90 for climate station and the Prism cell in which it was located. Monthly temperature biases between 2) the climate station PRISM cell and other PRISM cells were derived from the 1 km^2 gridded PRISM climate normals (1961-90) described above. All three monthly biases were combined additively to produce a total bias for each month. A cubic spline was fitted through the total monthly bias to interpolate to daily bias values (Fig. 8.9) and smoothed using a triangular adjustment (Fig. 8.10).

8.4 Crop water use

8.4.1 Estimating potential evapotranspiration (PET)

Limitations in the climate data (only rainfall and temperature data were available for PRISM) meant that simple relationships were required to estimate potential ET. Algorithms to estimate daily potential evapotranspiration during the growing season (JD92 - JD306) were developed from daily maximum temperature (T_{max}), day of the year (JD) and the latitude (LAT) of the site. The relationship was developed between data collected at the Summerland CDA Environment Canada weather station and data from an electronic atmometer (Etgage Company. Loveland CO.) at the same site ($R^2 = 0.58$). Atmometer data had previously been shown to correlate well with measured sap flux (Fig. 8.11) and Penman-Monteith estimates of PET from the same weather station (Fig. 8.12). A potential evapotranspiration (PET) value was calculated for each PRISM cell as:

$$PET = -3.26 + 0.210\ T_{max} + 0.058Q_O$$

The solar energy (MJ m^{-2}) reaching the top of the atmosphere (Q_O) was calculated from day of the year and latitude (Allen *et al.*, 1998).

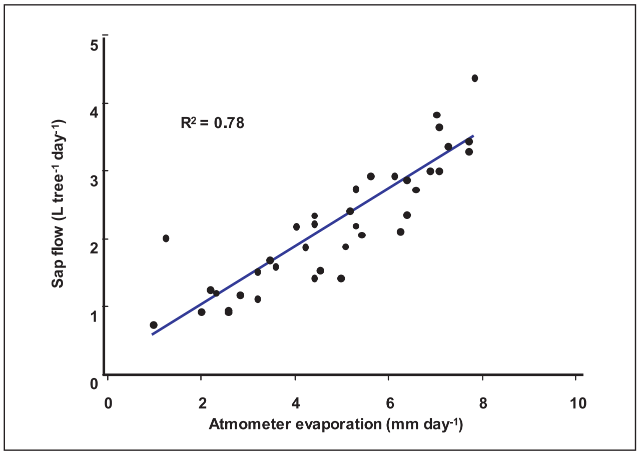


FIGURE 8.11

Relationship between measured sap flow and potential PET estimated by an atmometer for two-year old apple trees at maximum canopy development

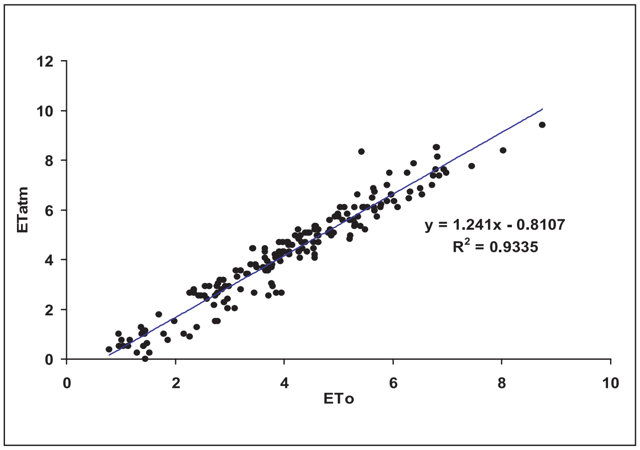


FIGURE 8.12

Relationship between estimated Penman-Monteith ET_o and atmometer ET at Summerland CDA weather station.

Estimates of maximum and minimum daily temperature and potential evapotranspiration, combined with equations for estimating seasonal crop coefficients (Kc) and growing season length discussed below, allow a first estimate of crop water use.

8.4.2 Seasonal Crop Coefficients

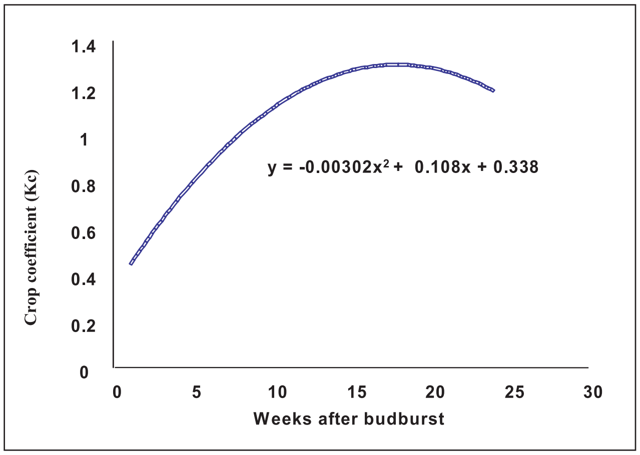


FIGURE 8.13

Seasonal crop coefficient (Kc) curves derived for mature deciduous fruit trees in the Okanagan Basin from water balance measurements in a lysimeter (mm water use/mm evaporation)

The crop coefficient is the ratio of actual crop water use to estimated evapotranspiration. It varies with canopy size and for perennial crops increases to a maximum both over the growing season and as the plant matures. In general, crop coefficient maxima for fruit trees are close to the Penman reference (grass) ET_O (1.0) despite the potential for greater transpiration in response to the increased wind speed and boundary layer conductance resulting from tree height. This has been attributed to the diurnal pattern of stomatal conductance in which stomatal closure occurs mid-afternoon regardless of water demand (Jarvis, 1985). Maximum mid-season crop coefficients (based on Penman-Monteith ET_O) range from 0.9 - 0.95 for apricot, peach, pear and plum and from 0.95 - 1.0 for apple and cherry under clean cultivated conditions (Fereres and Goldhammer, 1990). These may be expected to be 20-30% higher under a cover crop (Doorenbos and Pruitt, 1977).

Water balance data from the Summerland lysimeter, have indicated that a maximum crop coefficient for drip irrigated apple is around 1.25 mm ET/mm evaporation measured using an Etgage atmometer (Fig. 8.13). Initially, this crop coefficient curve for maximum canopy development, was used to model actual water demand in all tree fruits. However, changes in temperature projected for 2050's and 2080's scenarios required a crop coefficient curve adapted to a longer growing season. For the purpose of the current climate change study, seasonal crop coefficient curves for tree fruit and grapes (Figs 8.14 and 8.15) were derived from generalised curves based on those published by Doorenbos and Pruitt (1977). Water use for pasture, forages and other field crops was not modified by seasonal crop coefficients and was thus characterised by calculated PET values.

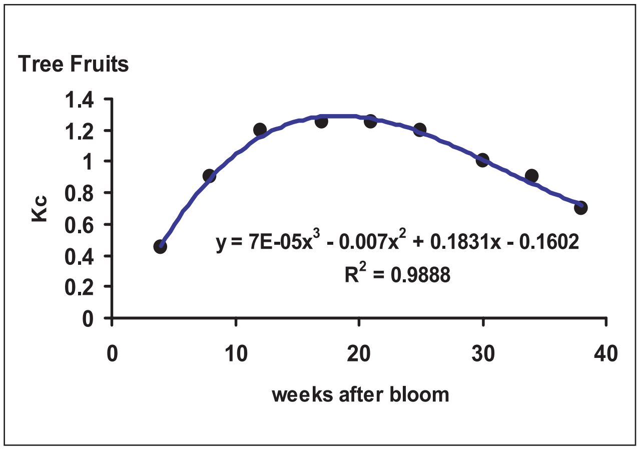


FIGURE 8.14

Seasonal crop coefficient (Kc) curves for tree fruits derived from Doorenbos and Pruitt (1987) (mm water use/mm evaporation)

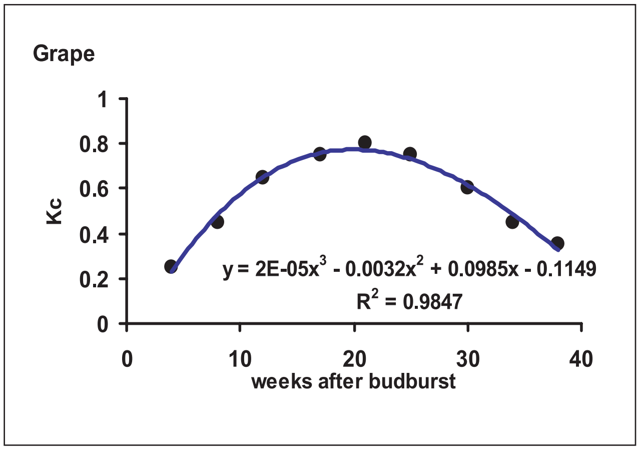


FIGURE 8.15

Seasonal crop coefficient (Kc) curves for grape derived from Doorenbos and Pruitt (1987) (mm water use/mm evaporation)

8.4.3 Length of growing season

In addition to the effects of elevated PET, total demand for water by crops is also determined by the length of the growing season. Previously (Neilsen *et al.*, 2001), the start of the growing season for apple was determined by the start of accumulation of growing degree day base 10°C (GDD10). This was considered to correspond with the timing of full bloom in apple, which coincides with the time of rapid canopy development and hence the onset of demand for water for transpiration. For all other crops, the start of the growing season was based on previously observed average differences between their dates of full bloom and that of apple. The timing of bud break in deciduous trees is a complex issue, and is related not only to genetic factors and increases in photoperiod and air temperature in the spring, but also to the magnitude and duration of cold temperatures experienced in the winter (Kramer and Koslowski, 1979). For the current study, we examined the relationships between degree day accumulations and bloom date in a complete and well recorded, set of data collected between 1937 and 1964 at the Summerland Research Centre. The advantages of these data were that they were 1) collected on the same trees over the period, 2) collected by the same individual, 3) there was a range of species at one location 4) collected for phenological studies. Regression analysis indicated that the relationship between the bloom dates of apple and start of accumulation of GDD10 was better than that of all other species with either GDD5 (Figs. 8.16) or GGD 10 (Figs. 8.17). Regression analysis also indicated that there were strong relationships between the date of apple bloom and the date of bloom for other species (Figs. 8.18), although this was less well established for apricot and peach than for pear, cherry and plum. It is not surprising that there are strong relationships among bloom dates for different species in any given year as all are responding to similar ranges of conditions. Consequently, a combination of the equation for GDD10 and apple bloom, and the relationships derived for apple and other species, was used for assessing the start of the growing season for each tree fruit crop. The start of the growing season in grapes has similarly been related to the start of GDD10 accumulation (Association of British Columbia Grape Growers. 1984) and for pasture and perennial forages the start of the growing season to the start of GDD5 accumulation. The end of the growing season was determined as the end of accumulation of GDD5.

8.4.4 Model assumptions

1. Growing degree days were accumulated using the following conventions: Start GDD accumulation after five consecutive days of mean temperature above the base temperature; End GDD accumulation after last occurrence of five consecutive days of mean temperature above the base temperature
2. To determine maximum demand, all orchards were considered mature.
3. All tree fruits were considered to be under sprinkler irrigation and an ‘efficiency factor’ was built into the equation (75%) (British Columbia Sprinkler Irrigation Manual 1989).

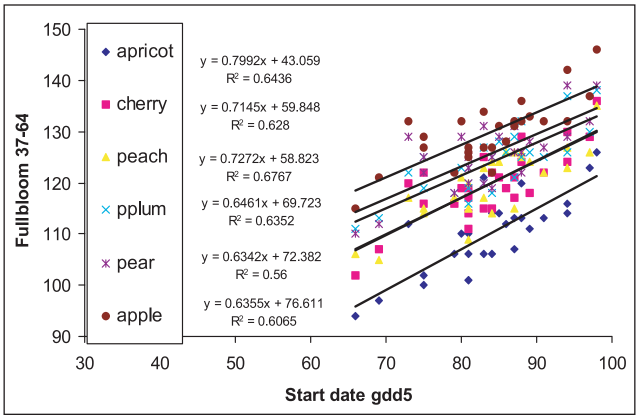


FIGURE 8.16

Relationship between timing of full bloom and the start of GDD5 accumulation

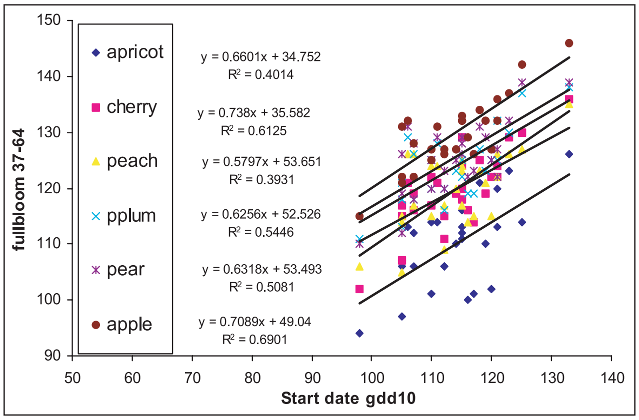


FIGURE 8.17

Relationship between timing of full bloom and the start of GDD10 accumulation

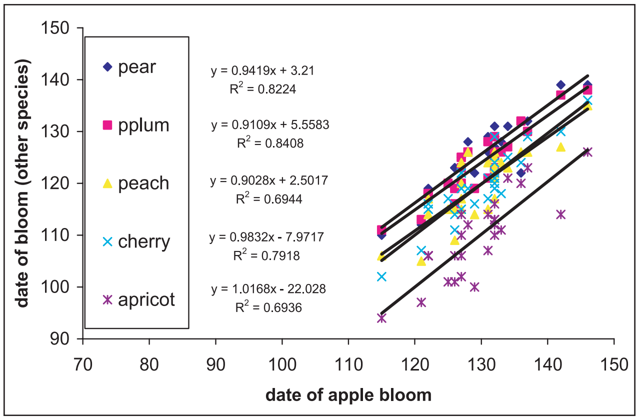


FIGURE 8.18

Relationships among timing of full bloom in apple and in other species

4. In all cases, daily crop water demand was calculated until evaporative demand ceased in the fall.

5. There were no effects of elevated CO_2 concentration on transpiration (see below)

Under experimental conditions, increases in plant growth in response to elevated concentrations of atmospheric CO_2 have been widely reported (Oechel and Strain, 1985; Drake *et al.*, 1997; Curtis and Wang, 1998; Norby et al, 1999; Ward and Strain, 1999). The ratio of intercellular CO_2 to ambient CO_2 remains relatively constant (Morison, 1998) even under conditions of elevated CO_2 concentration (Drake *et al.*, 1997). To maintain this relationship, reduced stomatal conductance (g_s) is an adaptive response to the biochemical limitations of mesophyll demand. Consequently, it has been hypothesised and demonstrated, that under experimental conditions of elevated CO_2, reduction in g_s can lead to reduced transpiration and water use. There have been some reports that increased leaf area, under conditions of elevated CO_2, may offset reduction in transpiration of individual leaves (Kerstiens *et al.*, 1995) although Drake *et al.*, (1997), in reviewing the literature, found little evidence to support this assertion.

A wide range of plant responses to the doubling of atmospheric CO_2 predicted to occur sometime in this century have been reported and this poses a problem for incorporation of effects into models. Morison (2001) noted that "the many attempts to derive a 'typical' value for the reduction of g_s in response to elevated CO_2 have varied widely if not wildly", ranging from a 40% reduction for herbaceous agricultural and horticultural crops, with large variation (Morison, 1987) and a 30-40% reduction for tree species, with an overall range of 0-70% (Eamus and Jarvis, 1989). More recently, Drake *et al.* (1997) suggested a change in g_s of 20% for woody species. Curtis and Wang (1998) used meta-analysis of data from many disparate experiments to summarise effects of elevated CO_2 on g_s in trees and found an 11% reduction, which was not statistically significant. Using the same analytic procedure, but separating long and short term studies, Medlyn *et al.* (2001) determined an average g_s of 21% for tree species.

The majority of these studies have been carried out on either herbaceous agronomic crops (mostly annuals) and natural grassland and forest species. There have been few studies of elevated CO_2 effects on transpiration losses for tree fruit and vine crops typical of the Okanagan basin. That is, for plants which are acclimated to conditions of high seasonal evaporative demand (high temperatures, low relative humidity), with unlimited water supply through irrigation and for which foliar and fruiting sinks for carbon are highly managed through control of crop load and pruning. Centritto *et al.*, (1999, 2002) found that one and two year-old peach (*Prunus persica)* and cherry (*Prunus avium)* seedlings grown in pots had higher carbon assimilation rates under conditions of elevated CO_2 than under current atmospheric concentrations, but no decrease in stomatal conductance, total water uptake and leaf area.

Taking into consideration the inconclusive findings in the literature in general, and the specific findings of Centritto *et al.*, described above, potential effects of elevated CO_2 on crop water use are not included in the crop water demand model designed for the current project. However, the caveat that crop water demand scenarios may be subject to this added uncertainty is acknowledged.

8.4.5 Modelling Crop Water Demand

ARC Macro Language programming within ArcInfo™ was used to assemble climate scenarios and land use coverage. PRISM grid data for the twelve mean monthly maximum and minimum temperatures were overlain with the agricultural land use coverage. This procedure created a database that described climatic conditions, over the year, for each unique land unit (polygon). The centroids of latitude and longitude for each polygon were added to the database and the values converted to radians, a necessary input for the calculation of ET. Visual Basic programming was used with MS Access™ to perform daily time-step calculations of crop water demand and for query and summary of annual, monthly or daily values of PET, growing degree days base 5 °C and 10 °C and volume of water demand. These data can be summarised by land unit, at the grid, local authority or regional scale. Additional queries were also developed to summarize weighted mean values for these attributes by crop type.

8.5 Crop water demand Scenarios – Okanagan Basin

8.5.1 Verification

Estimates of crop water demand derived from the model for the 1961-90 normals climate data were compared with annual irrigation requirements determined previously for the Okanagan basin (Van der Gulik, 1989, 1999). The modelled values increased from north to south and related well to expected values (Table 8.2). Average values for historic climate data (1961-90), indicated modelled irrigation demand for the Okanagan Basin to be around 200 $m^3 \times 10^6$ (Fig. 8.19).

TABLE 8.2

Estimates of crop water use for 1961-90 normals data and recommended irrigation requirements

REGION	REPRESENTATIVE WATER PURVEYOR	[z] IRRIGATION REQUIREMENTS (MM)	ESTIMATED CROP WATER DEMAND (MM)
N. Okanagan	Greater Vernon Water Utility	559	648
Central Okanagan	S. E. Kelowna Irrigation District	660	653
S. Central Okanagan	Corp. District of Summerland	686	725
S. Okanagan	Oliver	864	839

[z] Derived from BCMAFF Sprinkler and Trickle Irrigation manuals

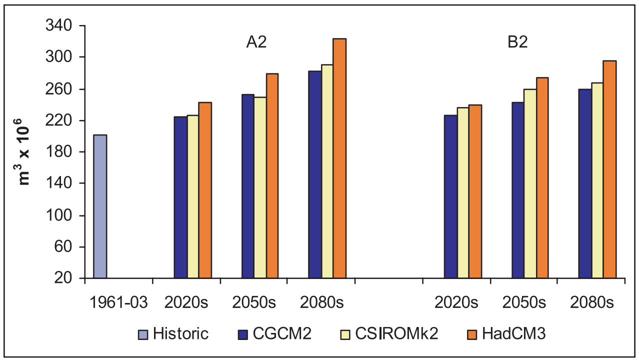


FIGURE 8.19

Estimated average annual crop water demand for the Okanagan Basin under historic conditions and six climate scenarios at three time slices.

8.5.2 Annual demand

Crop water demand scenarios were created for the whole basin in response to climate change scenarios from three Global Climate Models each with two emissions scenarios. All models showed an increase in annual crop water demand over the next 100 years (Fig. 8.19). However, the magnitude of the change varied over time and between GCMs and emission scenarios, ranging from 12-61%. The greatest increases occurred under the HadCM3 model, and the least under the CGCM2 model scenarios with the CSIROMk2 being intermediate. This is consistent with the range of summer temperatures estimated from the three models (see Figure 5.4) as the crop water demand model is mainly dependent on the effects of temperature on both ET and growing season length. Under the high emissions scenario (A2) there was little difference between scenarios for CGCM2 and CSIROMk2, which demonstrated a 12% increase between historic (1960-91) and 2020s crop water demand and a 24% and 40-48% increase for 2050s and 2080s respectively. For the HadCM3 model, demand increased by 20% in the 2020s, 38% in the 2050s and 61% in the 2080s. Under low emission scenarios (B2), modelled crop water demand was similar to the A2 scenarios for the 2020s and 2050s time-slices, but lower by the end of the century. In addition, under B2 scenarios there was more distinction between the CGCM2 and CSIROMk2 estimates, the latter being higher than the former. This is the result of higher temperature increases predicted for the summer months under B2 scenarios for the CSIROMk2 model compared the CGCM2 model (see Figure 5.4). In the 2020s and 2050s time-slices, the B2 scenarios were also higher than the A2 scenarios for the CSIROMk2 model. The HadCM3 produced the highest crop water demand at all three time slices. The lack of difference between high and low emissions scenarios in the earlier part of the century is the effect of different emissions scenarios for CO_2 and SO_2. Under A2 scenarios, the warming expected under high CO_2 emissions is offset by the cooling caused by the accompanying high SO_2 emissions (Albritton *et al.*, 2001). Under B2 scenarios, lower CO_2 and SO_2 are projected to lead to a larger near-term warming.

8.5.3 Annual Supply

The Land and Water BC water licence database was queried for water licences for irrigation purposes in the Okanagan Basin. There are 1201 water licensees of which there are 10 large, 7 medium and 34 small publicly owned water purveyors, as well as 3 large and 1147 small private ones (Figure 8.20). The three major sources of water are the Okanagan river and lake-system main stem, tributary streams and groundwater. Surface water diversion is regulated under the water act and is more carefully monitored than groundwater, which currently is unregulated. The majority of water supply for irrigation comes from headwaters diversions and high elevation in-stream storage basins. These systems are less costly because they use gravity to pressurize water systems. The remainder is pumped from lakes and streams. Approximately 75% of irrigation water is supplied by the former method and 25% by the latter (Agrodev, 1994). Modelled demand for the 1961-90 period (200 $m^3 \times 10^6$), was less than the current total licensed allocation for irrigation (323.7 $m^3 \times 10^6$) estimated from the Land and Water BC water licence database. Irrigation accounts for approximately 78% of the total basin licensed water allocation. The current total allocation for irrigation is greater than the 286 $m^3 \times 10^6$ reported in the Okanagan Basin Study (O'Riordan, 1971). A re-estimate of the basin's water supply in 1994, indicated that there were 63 $m^3 \times 10^6$ of water per year available from Okanagan Lake in excess of current allocation (Obedkoff, 1994). Current data suggest that much of that excess has been allocated for agricultural purposes. The demand for agricultural water use projected over this century under climate change scenarios (Fig. 8.19) ranged from 225-324 $m^3 \times 10^6$, indicating that unless increased demand is accompanied by increased supply in response to changing climates, further availability of water allocation for agriculture will be unlikely.

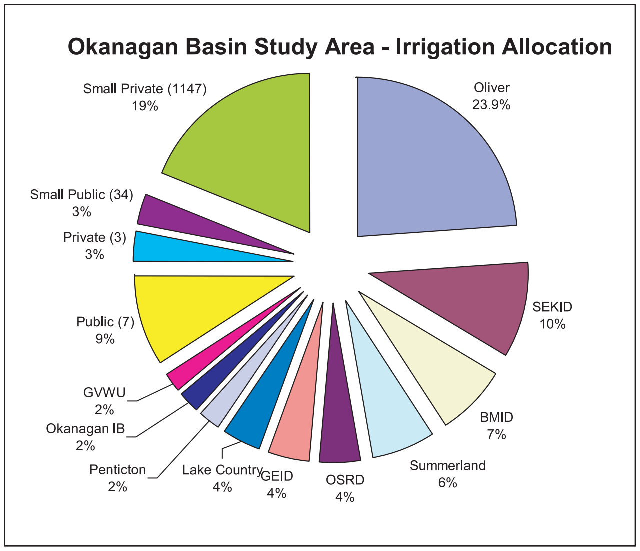


FIGURE 8.20

Water licensees for irrigation purposes in the Okanagan basin.

Major water users in the Okanagan are listed in Appendix Chapter 8B. Projected water demand under climate change was compared to water licence allocations for major water purveyor/users (Table 8.3). In general, the majority of purveyors technically have sufficient allocation to meet increased average demand. Water purveyors 14, 19 and 27 (Penticton, Glenmore Ellison and Lake Country) potentially have average crop water demands that are close to licence allocations. However, as will be discussed in Chapter 9, annual variation in demand may lead to water shortages in some years, and the frequency of those occurrences is likely to increase over the current century. The licensed allocation for irrigation purposes for the area

TABLE 8.3

Licensed water allocation and estimated demand for selected public water purveyors and private licensees in the Okanagan Basin.

PURVEYOR+	AREA (KM^2)	ALLOCATION (M^3 X 10^6)	1961-1990 NORMALS DEMAND (M^3 X 10^6)	EMISSIONS SCENARIO	CGCM2-2020S DEMAND	CGCM2-2050S DEMAND	CGCM2-2080S DEMAND	CSIROM2-2020S DEMAND	CSIROM2-2050S DEMAND	CSIROM2-2080S DEMAND (M^3 X 10^6)	HADCM3 2020S DEMAND	HADCM3-2050S DEMAND	HADCM3-2080S DEMAND
2	11.987	22.8	8.17	A2	9.24	10.66	12.11	9.35	10.53	12.74	10.22	12.05	14.23
				B2	9.37	10.24	10.96	9.86	11.06	11.47	10.05	11.85	12.90
4	0.3434	0.45	0.25	A2	0.28	0.32	0.36	0.28	0.32	0.38	0.31	0.36	0.42
				B2	0.28	0.31	0.33	0.31	0.33	0.34	0.30	0.35	0.38
5	0.8046	1.29	0.33	A2	0.38	0.44	0.51	0.38	0.44	0.54	0.42	0.50	0.59
				B2	0.38	0.42	0.45	0.42	0.46	0.48	0.41	0.49	0.53
14	5.217	7.98	3.32	A2	3.80	4.39	5.01	3.85	4.37	5.32	4.23	5.00	5.91
				B2	3.85	4.23	4.52	4.09	4.59	4.76	4.15	4.91	5.34
15	9.780	20.98	7.10	A2	8.07	9.13	10.31	8.10	9.16	10.86	8.80	10.18	11.94
				B2	8.11	8.79	9.35	8.69	9.54	9.82	8.68	10.03	10.86
16	0.7541	1.868	0.62	A2	0.69	0.78	0.87	0.70	0.78	0.90	0.75	0.85	0.99
				B2	0.70	0.75	0.79	0.74	0.81	0.83	0.74	0.84	0.90
18	2.584	13.6	1.50	A2	1.73	2.04	2.34	1.77	2.02	2.52	1.96	2.37	2.83
				B2	1.76	1.96	2.11	1.87	2.14	2.23	1.92	2.33	2.55
19	6.876	13.2	4.88	A2	5.52	6.31	7.13	5.57	6.26	7.51	6.06	7.07	8.33
				B2	5.58	6.06	6.46	5.92	6.56	6.77	5.98	6.98	7.56
20	35.734	6.55*	26.11	A2	29.04	32.44	36.24	28.99	31.79	37.02	31.20	35.78	41.78
				B2	29.25	31.30	33.24	30.13	33.19	34.19	30.87	35.32	38.12
23	2.214	2.47	1.85	A2	2.04	2.27	2.53	2.04	2.25	2.59	2.18	2.46	2.85
				B2	2.05	2.19	2.32	2.15	2.34	2.40	2.15	2.44	2.61
24	1.632	4.44	1.10	A2	1.26	1.44	1.63	1.26	1.44	1.73	1.38	1.62	1.91
				B2	1.27	1.38	1.47	1.36	1.50	1.55	1.36	1.59	1.74
25	0.2388	1.51	0.21	A2	0.23	0.25	0.28	0.23	0.25	0.28	0.24	0.27	0.31
				B2	0.23	0.24	0.26	0.24	0.26	0.27	0.24	0.27	0.29
27	10.939	12.4	6.85	A2	7.85	9.18	10.54	7.98	9.13	11.21	8.81	10.54	12.54
				B2	7.97	8.82	9.46	8.50	9.62	9.98	8.66	10.35	11.30
28	0.2677	4.41	0.16	A2	0.19	0.22	0.25	0.19	0.22	0.27	0.21	0.25	0.30
				B2	0.19	0.21	0.23	0.21	0.23	0.24	0.21	0.25	0.27
31	7.271	6.43	5.06	A2	5.61	6.24	6.96	5.61	6.20	7.16	5.99	6.81	7.87
				B2	5.63	6.02	6.38	5.90	6.44	6.61	5.92	6.72	7.22
32	1.457	1.84	1.05	A2	1.17	1.33	1.51	1.18	1.34	1.61	1.29	1.50	1.77
				B2	1.18	1.28	1.37	1.27	1.40	1.44	1.27	1.48	1.61
38	11.51	31.9	7.52	A2	8.66	10.01	11.51	8.79	10.10	12.34	9.71	11.48	13.65
				B2	8.77	9.68	10.33	9.55	10.57	10.96	9.53	11.28	12.32
42, 43	12.63	60.12	9.32	A2	10.58	12.04	13.66	10.68	12.12	14.51	11.63	13.52	15.85
				B2	10.63	11.60	12.36	11.51	12.63	13.01	11.43	13.31	14.41
44, 45	6.01	17.21	9.01	A2	5.31	6.00	6.80	5.32	5.79	6.15	5.34	6.08	7.24
				B2	5.32	5.79	6.15	5.79	6.32	6.49	5.71	6.61	7.14
47,48	1.775	5.06	0.71	A2	0.82	0.95	1.10	0.83	0.96	1.18	0.91	1.08	1.29
				B2	0.83	0.92	0.98	0.90	1.01	1.04	0.90	1.06	1.16
50	2.454	6.31	1.61	A2	1.84	2.11	2.40	1.86	2.11	2.54	2.04	2.40	2.83
				B2	1.86	2.04	2.17	1.99	2.21	2.28	2.01	2.35	2.56

*Greater Vernon Water Utility also withdraws water from the Shuswap R. system.

+For a list of purveyor names. see Appendix 8A.

served by the Greater Vernon Water Utility (Purveyor 20) is considerably less than the modelled demand (Table 8.3). However, this purveyor has large water licences for irrigation purposes on the Duteau Creek - Aberdeen /Haddo Lake system (24.6 m^3 x 10^6) which is part of the Shuswap drainage system, plus other licences on Kalamalka Lake and Coldstream Creek which are not specified for irrigation. Nevertheless, the projected crop water demand for GVWU was large compared with Shuswap and Okanagan licensed allocations combined. This suggests that a model correction for precipitation input may be required for the N. Okanagan.

An estimate of how climate change scenarios might affect basin water supply can be derived from current and modelled Okanagan Lake inflows (Chapter 7). As a caveat, it should be noted that this is not a quantitative measure of total basin supply and thus cannot be used to calculate a water balance. Average net annual inflow into Okanagan Lake is estimated at 450 - 500 m^3 x 10^6 (B. Symonds, BCMWLAP, 2004). Average inflow (UBC watershed model) with no restrictions or withdrawals, for the 1961-90 period, was 840.3 m^3 x 10^6 and this remained constant or declined slightly for 2020 scenarios (86 – 105%), and decreased for 2050s scenarios to between 80%- 93% of current inflow and for 2080s scenarios to around 69-84% of current inflow. A comparison of modelled crop water demand and Okanagan Lake inflows indicated that climate scenarios, which lead to increased demand for irrigation water, also lead to decreased supply (Fig 8.21).

8.5.4 Regional and seasonal demand

Monthly distribution of water demand was plotted for several water purveyors, representative of different geographic regions. The north Okanagan is represented by Greater Vernon Water Utility (GVWU); the central Okanagan by South East Kelowna Irrigation District (SEKID); the south-central Okanagan by the Corporation of the District of Summerland (Summerland) and the south Okanagan by the Town of Oliver Waterworks (Oliver). Water demand differed among scenarios and between regions (Figs. 8.22-8.25). In general, the effects of scenarios for each month followed the patterns of relative magnitude established for annual demand i.e. the HadCM3 model produced higher projections of demand than CSIROMk2 or CGCM2. For all models, the size of demand increased in every month relative to historic requirements (1961-90), thus increasing the need for irrigation water not only mid-season but also at the beginning and end of the growing season.

Projections of seasonal distribution of demand differed among models. CGCM2 produced scenarios, with demand increasing rapidly to a peak in July, declining slightly in August and rapidly after that until the end of October (Figs. 8.22-8.25). The HadCM3 model produced scenarios with relatively less demand earlier in the season a peak in August and greater demand in July, August and September than the other two models. The CSIROMk2 scenarios were intermediate between the other two. For each water purveyor, differences in the distribution of water demand among models were largely related to the magnitude of projected changes in monthly maximum temperature (Fig. 5.4). For example, CGCM2 and CSIROMk2 had smaller changes in temperature in May than in April, which was opposite to HadCM3. However, CSIROMk2 and HadCM3 had their largest temperature increases in the summer, whereas CGCM2 projected the highest increases in the spring.

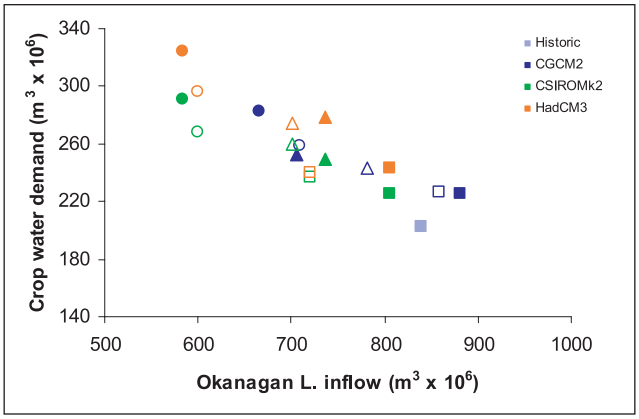


FIGURE 8.21

Comparison of estimated demand for irrigation water in the Okanagan Basin and estimated inflow into Okanagan Lake under historic conditions and six climate scenarios at three time slices: 2020s (■), 2050s (▲), 2080s (•). Filled symbols are A2 scenarios and open symbols are B2 scenarios.

8.5.5 Crop effect on demand

The length of the potential irrigation season differed among water purveyors, starting earlier for GVWU and Summerland (March/April), than for SEKID and Oliver. These differences are likely due to differences in crop profile (Appendix C). GVWU and Summerland both have a sizeable area of irrigated hay and pasture, whereas Oliver and SEKID have little pasture and mainly tree fruits. The effect of crop on potential water demand is illustrated in Figs. 8.26-8.29, which depict modelled, average annual water demand for a hypothetical hectare of land situated at the Summerland CDA weather station. From model predictions for the

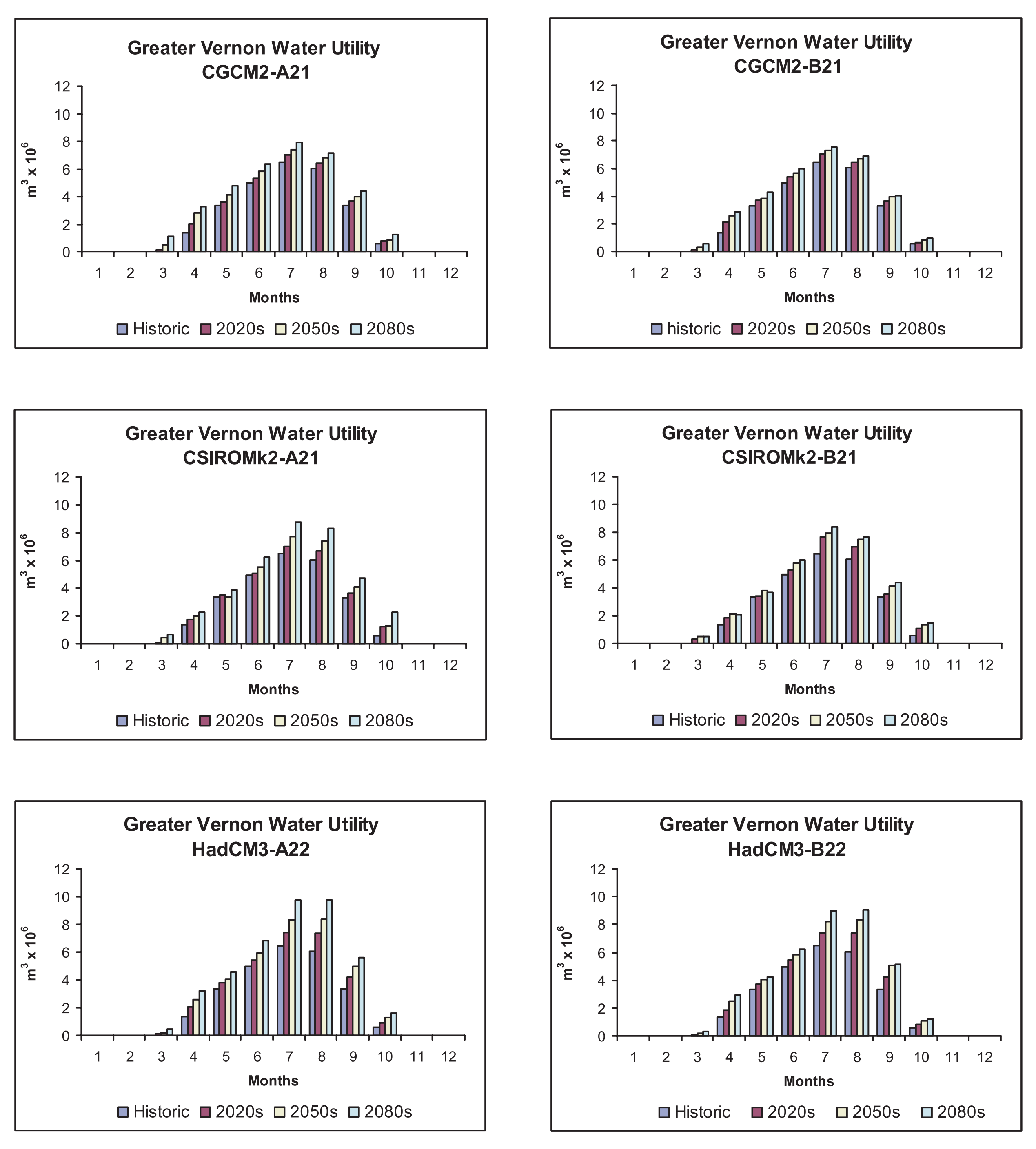


FIGURE 8.22

Monthly distribution of irrigation demand in response to climate change scenarios for the Greater Vernon Water Utility.

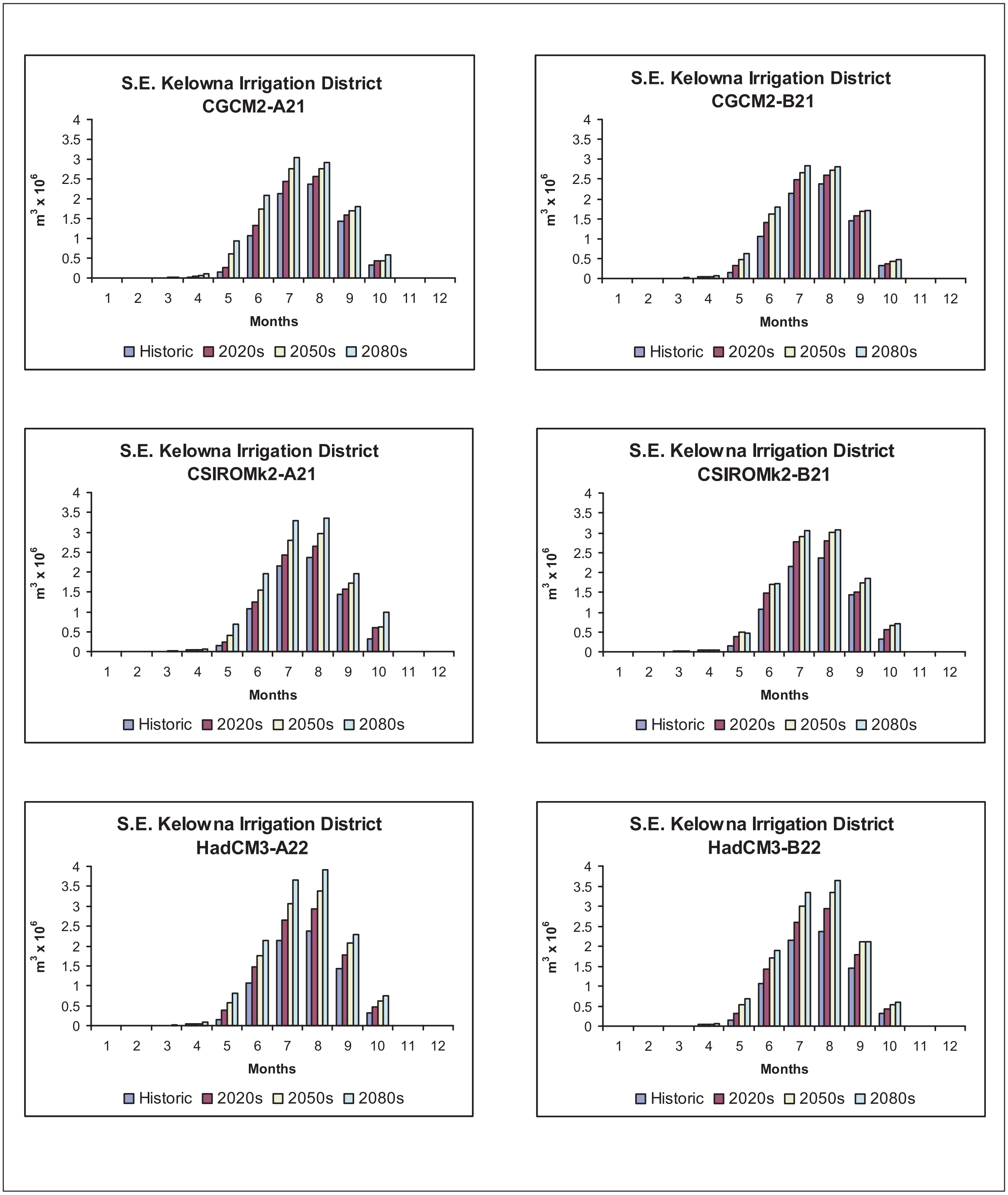


FIGURE 8.23

Monthly distribution of irrigation demand in response to climate change scenarios for the S.E. Kelowna Irrigation District.

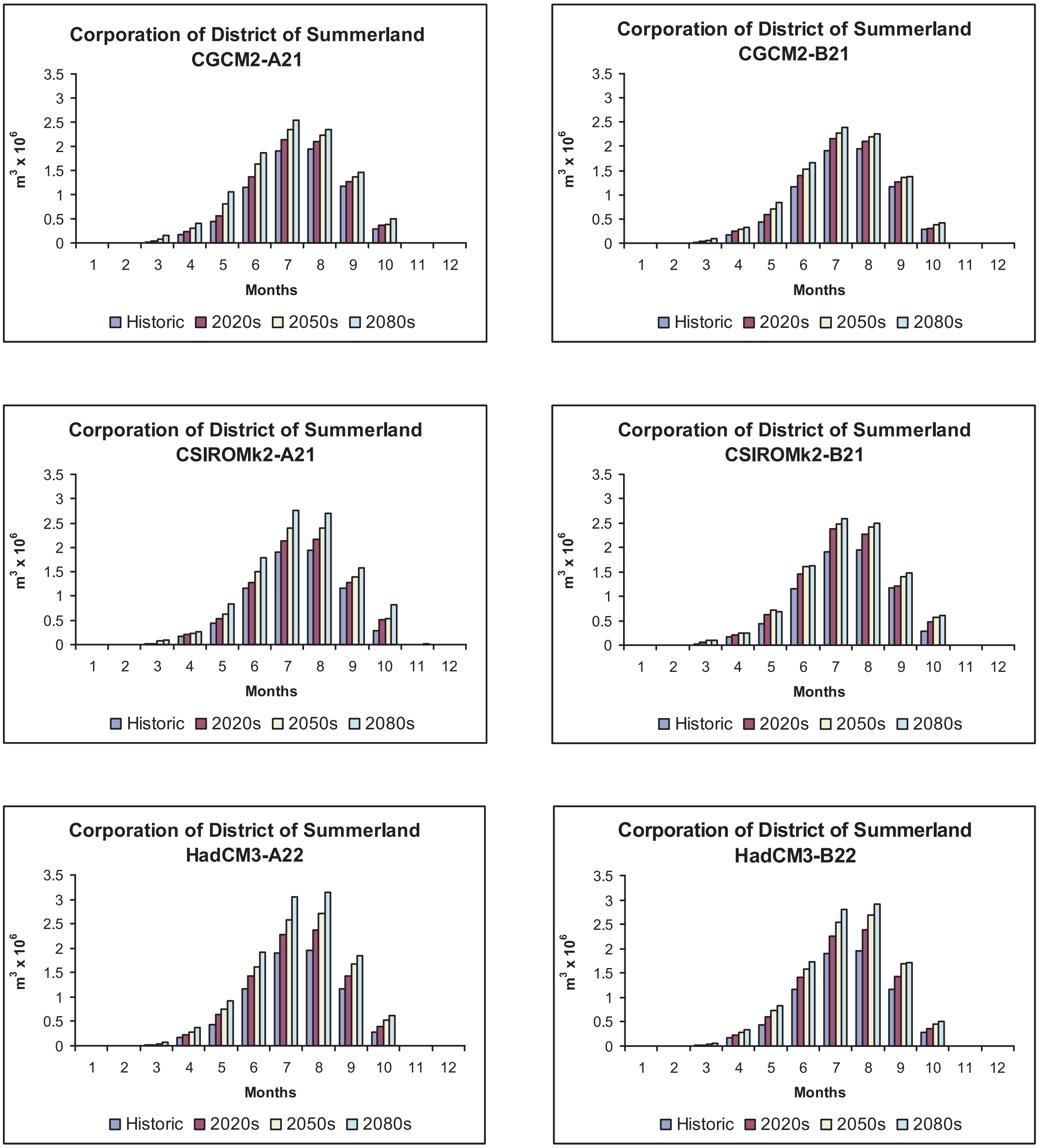
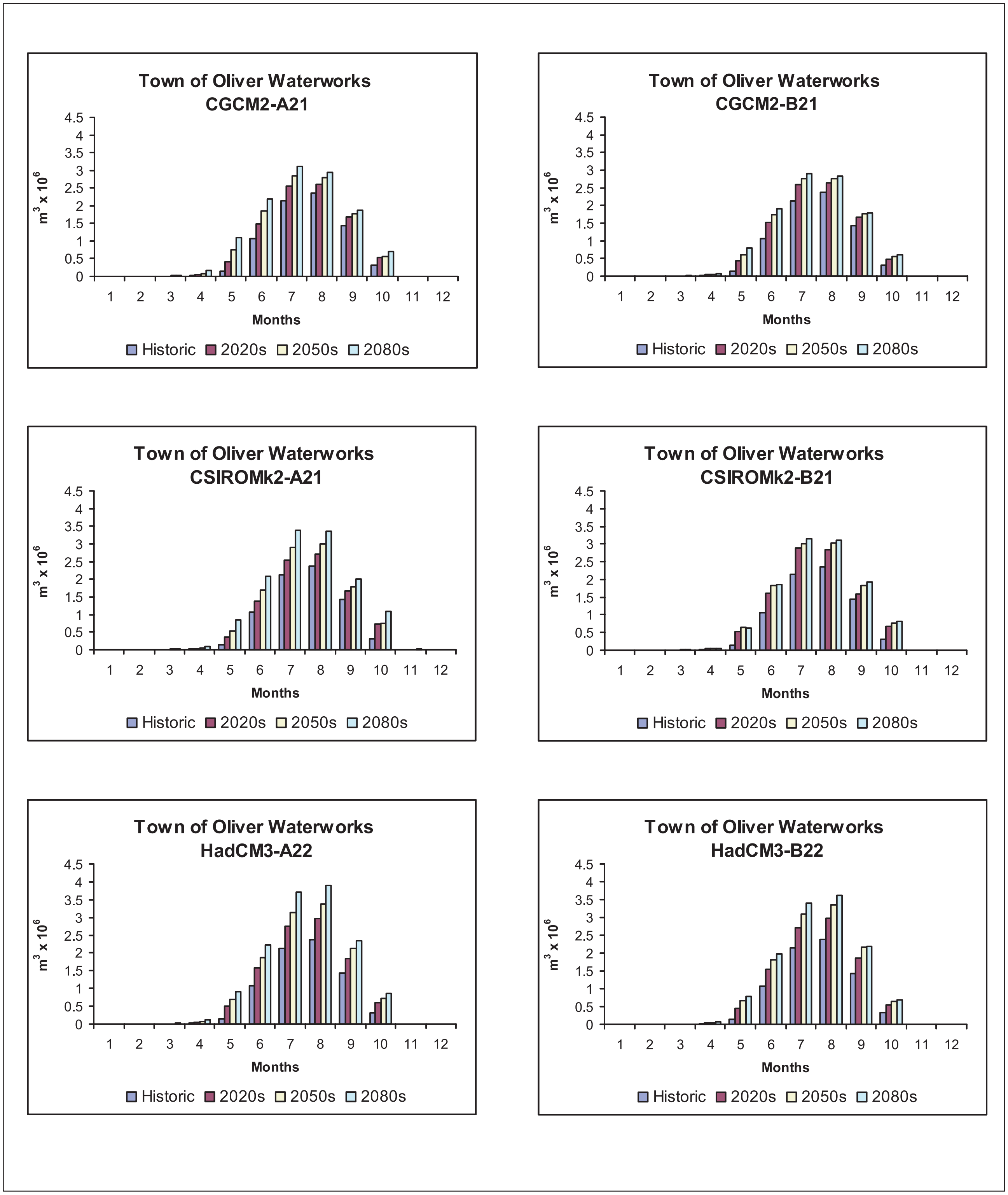


FIGURE 8.24

Monthly distribution of irrigation demand in response to climate change scenarios for the Corporation of the district of Summerland



Town of Oliver Waterworks CGCM2-A21

Town of Oliver Waterworks CGCM2-B21

Town of Oliver Waterworks CSIROMk2-A21

Town of Oliver Waterworks CSIROMk2-B21

Town of Oliver Waterworks HadCM3-A22

Town of Oliver Waterworks HadCM3-B22

FIGURE 8.25

Monthly distribution of irrigation demand in response to climate change scenarios for the Town of Oliver Waterworks

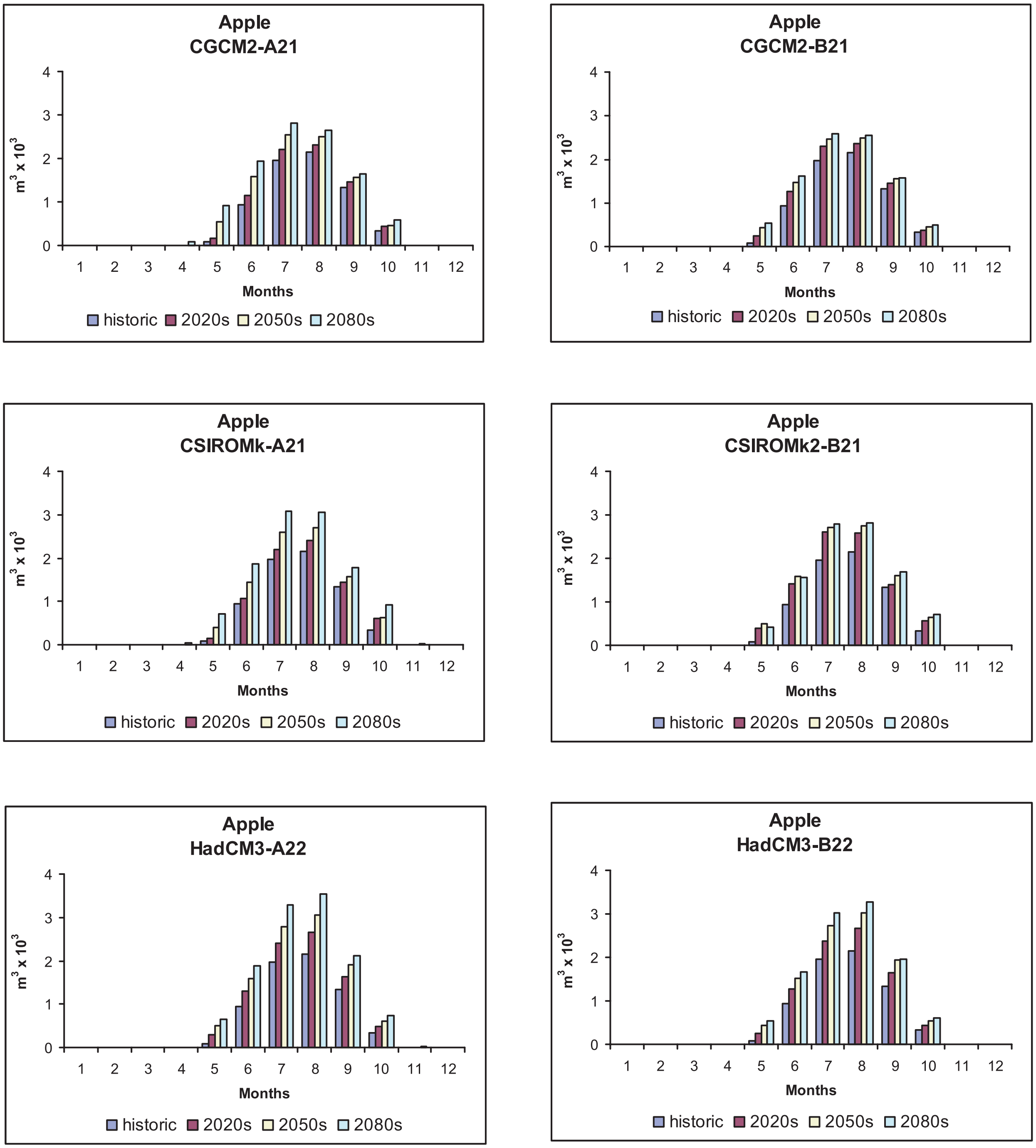


FIGURE 8.26

Monthly distribution of irrigation demand in response to climate change scenarios for apple based on 1 ha model at Summerland CDA weather station

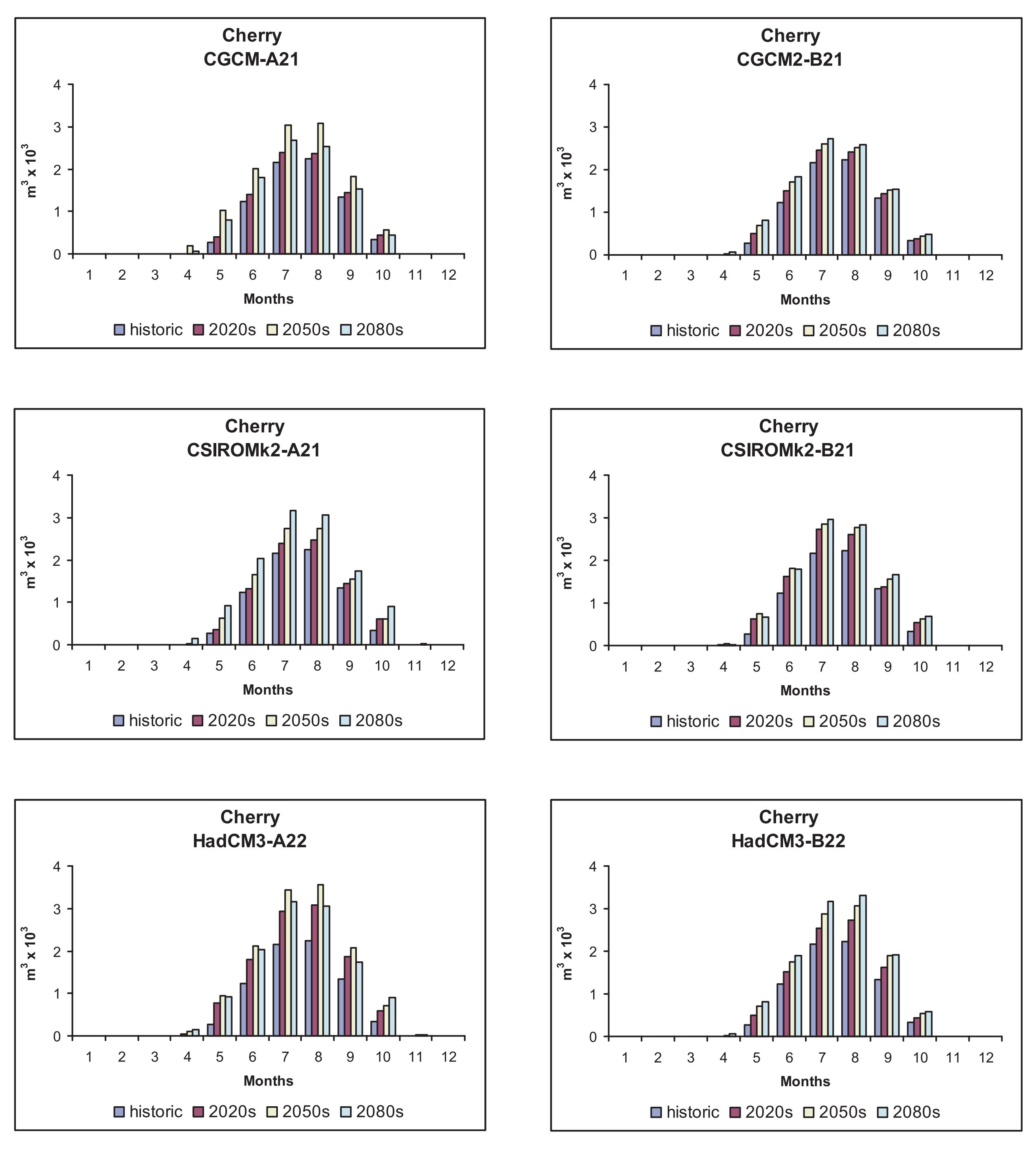
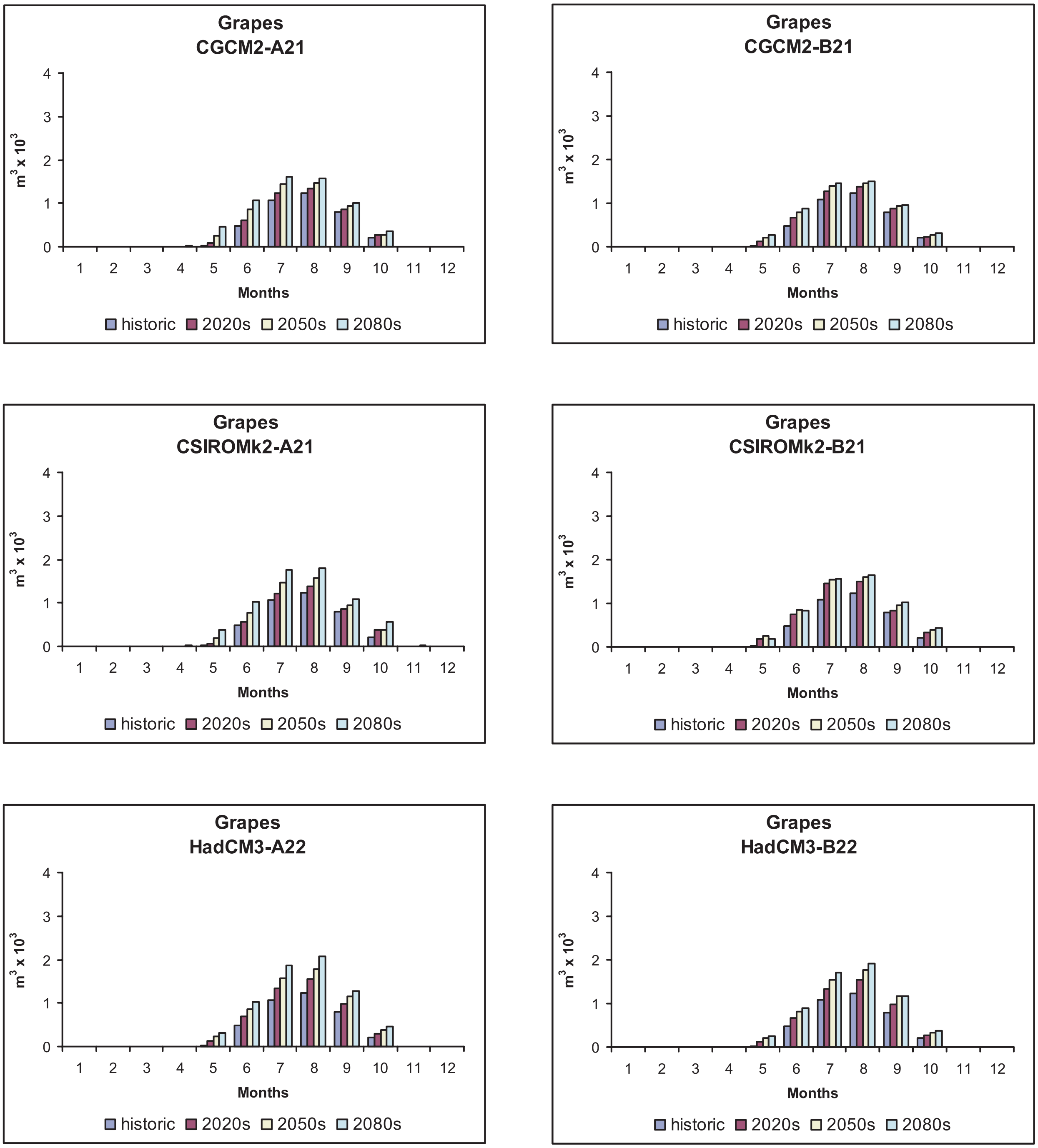


FIGURE 8.27

Monthly distribution of irrigation demand in response to climate change scenarios for cherry based on 1 ha model at Summerland CDA weather station


Grapes CGCM2-A21

Grapes CGCM2-B21

Grapes CSIROMk2-A21

Grapes CSIROMk2-B21

Grapes HadCM3-A22

Grapes HadCM3-B22

FIGURE 8.28

Monthly distribution of irrigation demand in response to climate change scenarios for grapes based on 1 ha model at Summerland CDA weather station

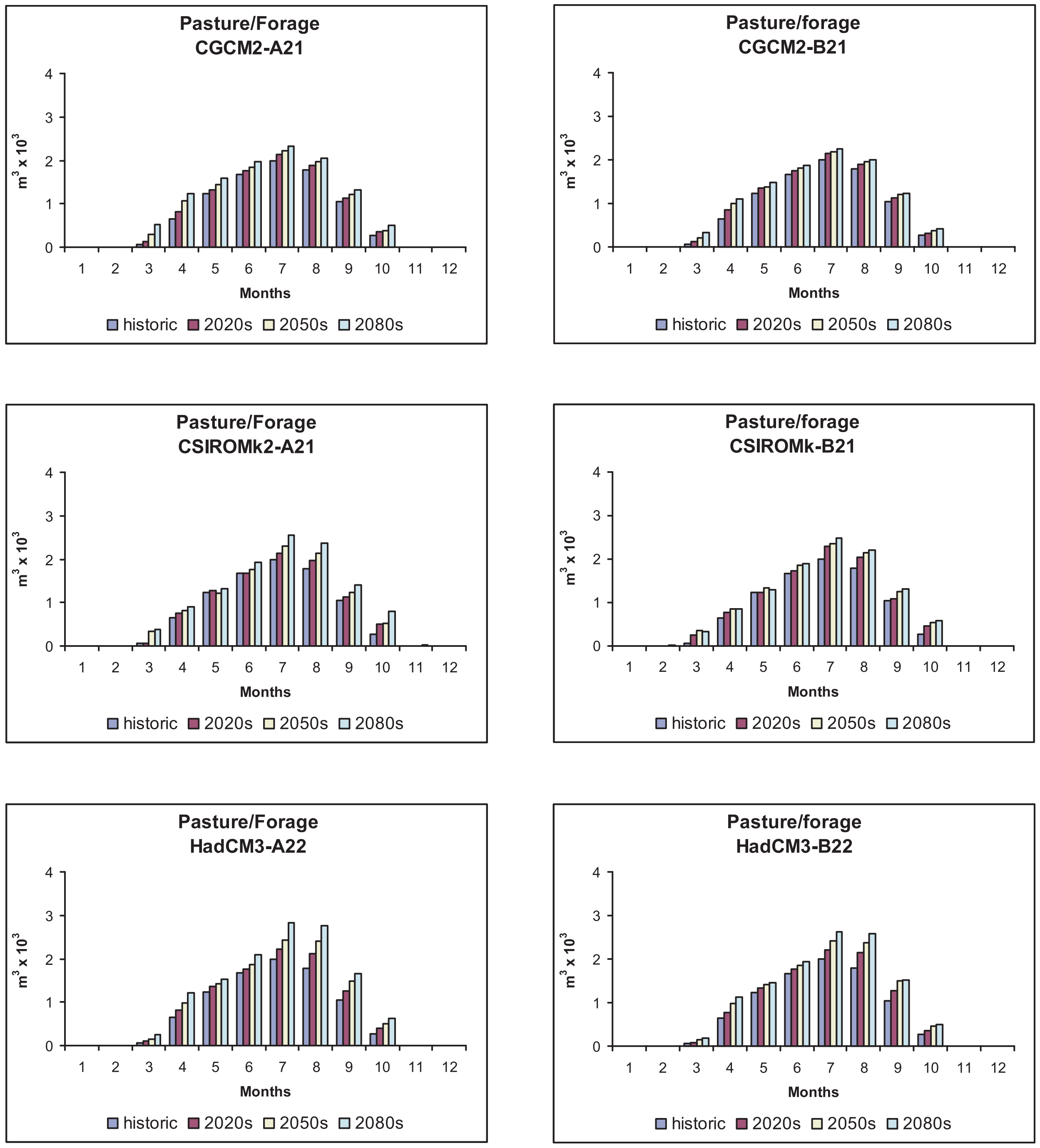


FIGURE 8.29

Monthly distribution of irrigation demand in response to climate change scenarios for pasture/forage based on 1 ha model at Summerland CDA weather station

1961-90 historic period, the largest total amount of water was required for pasture (Fig. 8.29) and the least (44%) for grapes (Fig. 8.28). Apple (Fig. 8.26) required approximately 78% of the amount needed for pasture, and cherry (Fig. 8.27) slightly more (87%). The low irrigation demand for grapes resulted from a shorter growing season and lower crop requirements during peak ET. In contrast, pasture and forage, being cooler season crops had a longer growing season with high demand. Tree fruits had a shorter growing season than pasture, but peak demand was higher. Under conditions of future water shortage, crop profile may have a bearing on potential adaptation strategies. Some crops, e.g. row crops, tree fruits and grapes are suitable for efficient micro-irrigation systems, which can lead to a considerable reduction in water use (Van der Gulik, 1999). The most efficient irrigation method currently available for pasture/forages is the drop tube pivot system. However, such systems require level terrain to function effectively and may not be suitable for application in some parts of the Okanagan Basin. Water savings in fruit and row crops may also be made through the use of mulches to reduce evaporation from the soil surface and savings can be made for all crops if irrigation is scheduled to meet demand; an example for apple is given in Neilsen *et al.* (2002). Procedures for scheduling different types of irrigation systems are outlined in Van der Gulik (1989, 1998).

8.5.6 Effects of climate change scenarios on the length of the growing season and potential ET

In contrast to annual crops, many of which have a determinate growing season, most temperate perennial crops do not stop growing or transpiring until limited by temperature and/or radiation. Consequently, demand for water has two components –evaporative demand and length of the growing season. The percentage change in both components was calculated for apple and pasture/forage at Summerland in response to climate scenarios (Fig. 8.30). For apple the growing season was projected to lengthen 5-10% in the 2020s, 10-20% in the 2050s and 15-30% in the 2080s depending on GCM scenario. For pasture/forage the growing season was projected to lengthen 5-10% in the 2020s, 8-20% in the 2050s and 13-35% in the 2080s depending on GCM scenario. Projected increases in potential evaporation in response to climate change were thus dependent both on increased temperature and increases in the length of the growing season. For apple, increases in ET ranged from 11-20% for the 2020s, 19-36% for the 2050s and 26-58% for the 2080s. Similarly, for pasture/forage, increases in ET ranged from 10-15% for the 2020s, 17-31% for the 2050s and 23-51% for the 2080s. For both pasture/forage and apples, the change in potential ET was greater than change in the length of the growing season particularly for HadCM3-A2 scenarios, which projected higher summer temperatures than the other two models. For apple, (Fig. 8.26) monthly increases in demand in response to climate change scenarios were relatively evenly distributed from the beginning of the season to mid-season, and less from mid to end of the growing season. Thus, the effect of increased ET likely contributed more to the overall change in crop water demand than the length of the growing season. For pasture, increases in demand were high at the beginning of the season under CGCM2 but high mid- to late season under CSIROMk2 and HadCM3 (Fig. 8.29), suggesting that both changes in the length of the growing season and changes in ET would be important in determining demand. In terms of water management, increased demand, particularly late in the growing season, may be difficult to meet from current storage and in-stream withdrawal allocations.

8.6 Limitations

There are some limitations to the estimates of crop water demand presented in this report. Because of the infrequency of effective precipitation during the growing season at most locations (Table 8.1) water demand estimates were not corrected for precipitation. The majority of the climate scenarios that were used indicated that precipitation would increase in the winter months and either remain the same or decrease in the summer months (Figure 5.4). Thus, although increased winter precipitation may contribute to soil moisture storage, delaying the need for irrigation in the spring, it seems unlikely that a significant portion of crop water demand would be met by summer precipitation. An exception to this may be the N. Okanagan, which currently receives more precipitation than the basin to the south. Future modelling should include precipitation, despite the high degree of uncertainty associated with precipitation estimates from GCMs (Albritton *et al.*, 2001). Given that the area covered by the Greater Vernon Water Utility receives the majority of its irrigation water from the Shuswap system, modelled demand for the Okanagan could be reduced by the amount determined for GVWU, i.e. by around 12.9%.

A second limitation is the possible effect of elevated CO_2 on stomatal conductance, resulting in reduced transpiration and demand for water. Although there is little direct, experimental evidence that fruit trees display reduced transpiration in response to elevated

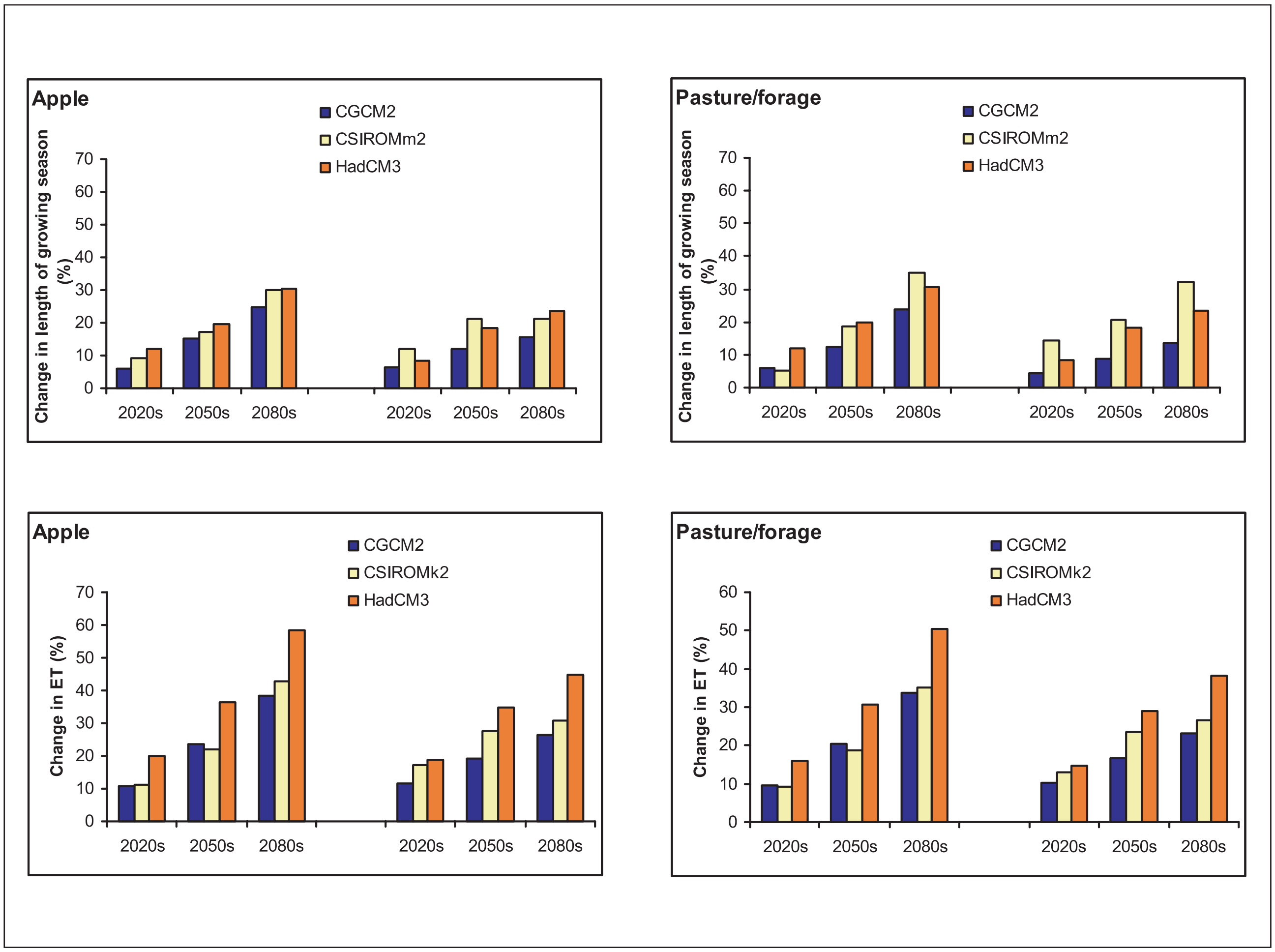


FIGURE 8.30

Estimated annual change in the evaporative demand and length of the growing season for apple and pasture/forage at Summerland in response to climate change scenarios. Values represented on the left hand side of the x axis are for the A2 emission scenarios, those to the right are for the B2 emissions scenarios.

CO_2 (Centritto *et al.*, 1999, 2002), there is more evidence that grasses and other annual C3 crops transpire less in elevated CO_2 atmospheres. Literature values suggest that such reductions in water demand may be as high as 20-30%, although a study of potential effects of climate change on US agriculture determined that field crops (corn, wheat, alfalfa) grown in the Pacific Northwest and western mountainous regions had relatively low reductions in transpiration by the end of the current century (approximately 8%) compared with other regions (Izzaurralde *et al.*, 2003). Given that the projected increases in water demand by the 2080's ranged between 40% and 60%, even a 20-30% decrease in transpiration due to elevated CO_2 would still leave the requirement for a substantial quantity of extra water to supply crop demand compared with current conditions.

8.7 Summary

Water for agriculture in the Okanagan Basin is supplied mainly from headwaters diversions and storage with some pumping from streams, lakes and groundwater. Shortages in recent years have highlighted conflicts between consumptive (agriculture) and in stream (fish, wildlife) uses of water. In the current study, a model was developed to determine potential effects of climate change on agricultural water demand. Based on inputs from a set of spatially gridded climate data, the model consists of estimates of water demand for different crops whose distribution has been mapped throughout the basin. Model output was assembled on a spatial basis at basin or sub-basin level in a GIS. Model runs for present day climate conditions (1961-90) yielded crop water demands that were similar to historic estimates of irrigation requirements in the Okanagan basin. An average annual total demand of 200 $m^3 \times 10^6$ was estimated for the whole basin.

A range of possible climate outcomes from Global Climate Models and emissions scenarios resulted in increases for basin water demand ranging from 12-20% in the 2020s, 24-38% in the 2050s to 40-61% in the 2080s. The beneficial effects of low emissions scenarios were not seen until the end of the century. Annual licensed water allocations appear sufficient to meet changes in average annual demand for most water purveyors, although a few apparently have insufficient allocations to meet projected demand. However, water availability may become problematic. Comparisons with modelled Okanagan lake inflows for the same set of scenarios, suggested that scenarios with high demand tended to be those with low supply. Moreover, these results are for averages of 30 year periods of climate data and do not take into account variation from year to year.

All models projected increases in peak demand and increases in demand at each end of the growing season. Subtle differences in seasonal crop water demand projections were due to both variability associated with GCMs, emissions scenarios and with crop profile. The growing season was potentially lengthened by 30-35% at the end of the century for all crops and was longest for pasture/forage and shortest for grapes. The combination of long growing season and responsiveness to changes in potential ET caused pasture/forage crops to have the highest demand for water. Increases in potential ET are likely more important to the total increase in crop water demand than length of the growing season, but high demand in the Fall may be more problematic in terms of water supply, particularly if coupled with projected low stream flows. Adaptation by producers to increased demand may include adoption of conservation irrigation practices and, where appropriate, planned deficit irrigation. These responses would be technically more feasible for tree fruit, grape and vegetable production systems than for pasture/forage. However, given the increases in projected future demand, any current water savings achieved through increased efficiency of irrigation should probably not be diverted into other uses, but rather 'banked' to support agriculture, a major driver of the region's economy.

There are some limitations to the findings of this study. Projected increases in demand may be lower than modelled if the elevated concentrations of atmospheric CO_2, which are driving global warming, also lead to reduction in plant transpiration. Some studies suggest that transpiration may be reduced by as much as 20% by the end of the century, although there is not consensus on the applicability of these predictions to all crops. The absolute amount of total water demand is lower than reported as some of the N. Okanagan requirements are met by water diverted from the Shuswap system. However, the percentage change in demand will remain the same.

8.8 Acknowledgements

Bill Taylor and Mark Barton provided the climate and climate change scenario data and participated in many discussions regarding downscaling and climate variability.

Dave Hutchinson (Environment Canada – PYR) wrote much of the crop water model code and helped in both spatial and temporal interpolation of data.

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chapter 9

Risk Assessment and Vulnerability - Case Studies of Water Supply and Demand

Denise Neilsen, Walter Koch, Wendy Merritt, Grace Frank, Scott Smith, Younes Alila, Jeff Carmichael, Tina Neale and Rachel Welbourn

9.1 Introduction

In the previous chapter, the potential effects of change in average climate on crop water demand were assessed and discussed. However, extreme climate events present a greater challenge to agriculture, to communities and to their ability to cope (IPCC, 2001). One of the major risks facing Okanagan agriculture is the occurrence and frequency of drought. In production systems that are entirely dependent on irrigation, drought is defined by the inability to provide an adequate water supply to maintain an economic return. There are two components to drought in this case; high demand and low supply. It might be expected that the most dramatic effects will occur when high demand and low supply are combined.

The risks associated with drought are determined by the severity and frequency of occurrence of drought conditions. Forecasting when droughts may occur is not feasible. It is, however, possible to examine the historical record and determine how frequently periods of high water demand and low supply have occurred, and under climate change scenarios, to determine the likelihood of such combinations in the future. In the current study, a first approximation of the inter-annual variability in demand has been determined using crop water modeling described in Chapter 8 applied to historical climate and future climate scenarios. Similar estimates have been made for hydrologic scenarios, i.e. annual stream flow in response to current and future climates (Chapter 7) and we attempt to compare the two. Both approaches have the limitation that the inter-annual variability in climate data from 1961-1990 is imposed on future climates and it is possible that that this variation will not remain constant. Construction of annual variation in future climate has been attempted through the use of weather generator models (Semenov and Barrow, 1997) but techniques were not available to extend such model output to the spatially distributed climate data based on multiple climate stations and topography that was used in the current study.

Community vulnerability to the effects of drought is determined by the limitations in the water supply system, both in terms of water withdrawal rights and the ability to store water. Communities in which agriculture is the dominant economic activity may be inherently more vulnerable to drought than those with a more diverse tax and income base. Jones (2000), examined the risk of climate change to agricultural viability in an irrigated production system in S. Australia. Risk was determined as the probability of exceeding known water supply thresholds. In the current study we will define risk thresholds associated with licensed limits on demand and hydrological limits on supply for two case studies; the Trout Creek watershed which supplies the District of Summerland and the Ellis and Penticton Creek watersheds which supply the City of Penticton.

9.2 Case studies of demand/supply

9.2.1 *Corporation of the District of Summerland -Trout creek*

There are approximately 980 ha of irrigated agricultural land in the area covered by the Corporation of the District of Summerland water licence. Around 54% of the land is in apple production, 25% in pasture and the remainder in other tree fruits and grapes (Fig. 9.1). Trout Creek supplies about 90% of the water to 4,100 domestic, 269 commercial and 1,151 irrigation connections in the District of Summerland. Within the Trout Creek watershed there are eight reservoirs which are used to store water and regulate flow. Water is diverted from the stream into a balancing reservoir and from there, through a chlorinator, where flow rates are recorded and then into the municipal system. There is no separation of supply so that all the water used for commercial and irrigation purposes flows through the same distribution system as domestic water. In an average year, total Trout Creek flows are estimated to be around 84.1 $m^3 \times 10^6$ of which 2.5 $m^3 \times 10^6$ would be withdrawn for commercial and domestic use

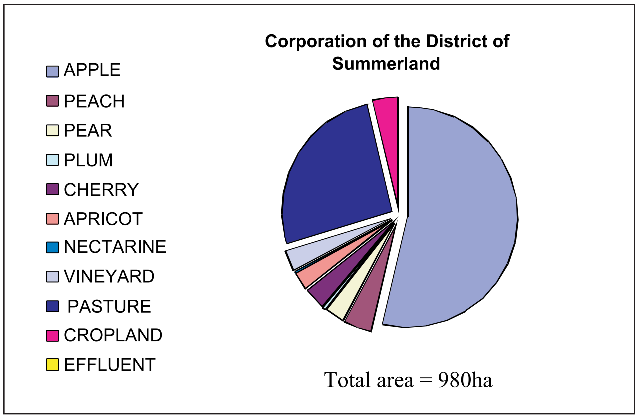


FIGURE 9.1

Land use in the District of Summerland

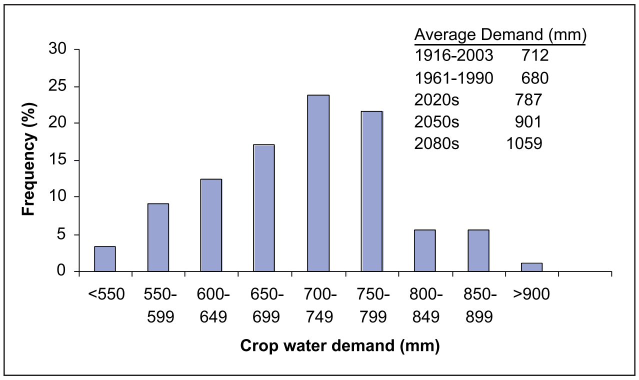


FIGURE 9.2

Frequency of modeled crop water demand for hypothetical hectare of apple at Summerland based on climate data from historical record 1916-2002. Average future demand based on CGCM2-A2 scenarios

(A. Reeder personal communication). Currently, the maximum allowable demand for irrigation is equivalent to 10.5 m^3 x 10^6, which is equivalent to the highest demand in the recent past (2002). This value is about half of the licensed allocation for irrigation of 20.93 m^3 x 10^6. Total flow requirements are met both by dam storage and unregulated flow below the dam. Currently, 2003-2004, there is a conflict between withdrawal requirements to meet increased demands and in-stream requirements for fish. The purpose of this study is to determine agricultural water needs for irrigation under current and future climates.

9.2.1.1 Historic variation in crop water demand

The variation in historic demand for water use has been estimated from modeling crop water demand for a hypothetical hectare of apples located at the Environment Canada climate station at Summerland (Summerland CDA/Summerland CS). Historic data from 1916-2003 were input into the crop water demand model described in Chapter 8. Between 1916 and 2003, the water demand ranged from 680 to 915 mm, with an average of 712mm (Figure 9.2). Using PRISM cell based estimates for 1961-1990 climate normals and data adjusted by the 'delta' method using CGCM2-A2 output for 2020, 2050 and 2080 time-slices, the average estimated crop water use was 679, 787, 902 and 1059 mm respectively. It should be noted that the average for the 1961-1990 normal data was considerably lower than the average calculated for 1916-2003 daily data. These estimates indicate that, within the next 100 years, 'average' water demand, is likely to meet and exceed the most extreme demand experienced in the historical record. If the variation in climate continues to follow a distribution similar to that observed between 1916-2003, the highest crop water demand (900 mm) exceeded 1% of the time in the historical record, would potentially be exceeded 46% of the time by the 2050s.

9.2.1.2 Historic water use

Crop water demand, for the area covered by the Corporation of the District of Summerland water supply system, was modeled using daily data for selected years from the Summerland CDA/CS climate station, incorporating the spatial scaling biases described in Chapter 8. Modeled demand for the years 1961-2003 indicated that above average years were concentrated in the period from 1985 to the present (Fig. 9.3). There is too much variation however to identify a significant positive trend ($r^2 = 0.135$; $p>0.05$). Historic modeled demand was compared to irrigation consumption measured by the water purveyor from

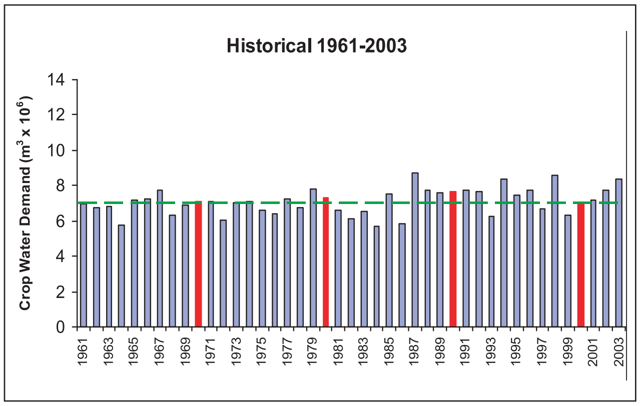


FIGURE 9.3

Modeled irrigation consumption for the Corporation of the District of Summerland 1977-2003. Dashed line is 1977-2003 average

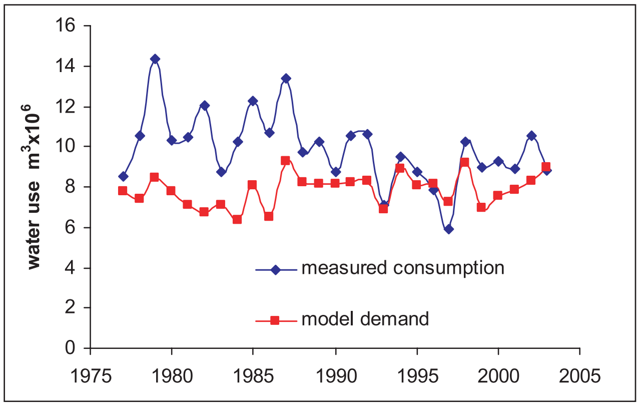


FIGURE 9.4

Comparison of measured consumption and modeled crop water demand for the Corporation of the District of Summerland 1977-2003

1977 to 2003 (Fig. 9.4). Modeled demand did not reflect measured consumption before 1992 very well. There are several possible explanations for this. Firstly, there was a downward trend in irrigation consumption from 1977 to the present. This was largely due to changes in irrigation technology from, chronologically, less efficient movable irrigation pipes and overhead sprinklers to under tree sprinklers to micro irrigation systems. In addition, Summerland agricultural activity is dominated by apple growing (Fig. 9.1) and there was a large change in production practices for apple after 1992 in response to orchard renewal programs sponsored by the Okanagan Valley Tree Fruit Authority. At that time, more extensive orchard systems with widely spaced trees were replaced by high density plantings. This type of orchard structure was more suitable for efficient micro-irrigation systems. In a survey undertaken 2000-2001, around 30% of apple orchards in the S. Okanagan used micro-irrigation systems (unpublished data, Sterile Insect Release Program). Modeled demand, after 1992, showed a much closer fit to consumption (Fig. 9.4). The decline in measured consumption between 2002 and 2003 was likely the result of stage three drought restrictions, early irrigation shutoff and a concerted community effort to conserve water after August 1st.

9.2.1.3 Future water demand

Crop water demand scenarios were created in response to climate change scenarios from three Global Climate Models each with two emissions scenarios. Future demands are based on daily temperature records from Summerland CDA/CS which have been perturbed by average increases generated from 30 year GCM output. In this exercise, land use remained constant. The model output for crop water demand is compared with an irrigation demand threshold of 10 m^3 x 10^6 based on peak measured consumption since 1990 (Fig. 9.4). Patterns of variability from year to year were similar, but not identical for crop water demand derived from historical data and CGCM2-A2 scenarios (Fig. 9.5). This is expected given that each year is perturbed by a constant value within a given scenario time-slice. The number of years when the demand threshold might be exceeded, increased over time, to around eighteen years out of thirty by the 2080s. For the lower emissions scenarios (B2), differences in response compared with the high emissions scenarios (A2) only became evident by the end of the century (Fig 9.5). Estimates of demand varied among GCMs (Figs. 9.6, 9.7), with the most extreme responses occurring in the HadCM3-A2 scenarios, so that by the 2080s, demand exceeded the threshold in every year.

9.2.1.4 Future water supply

Water supply estimates were derived from annual model outputs from the UBC watershed model for Trout Creek

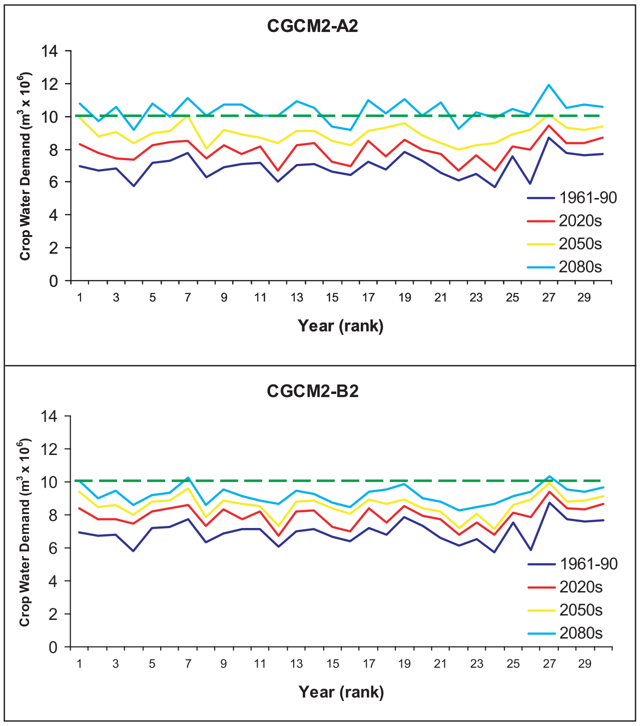


FIGURE 9.5

Modeled annual crop water demand in Summerland for 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to CGCM2-A2 and -B2 scenarios. Green dashed line is maximum allowable annual demand.

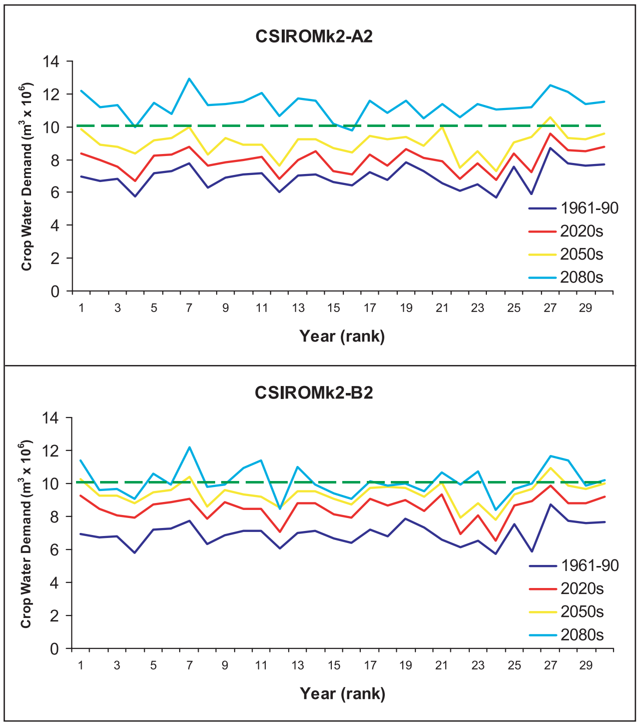


FIGURE 9.6

Modeled annual crop water demand in Summerland for 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to CSIROMk2-A2 and -B2 scenarios. Green dashed line is maximum allowable annual demand.

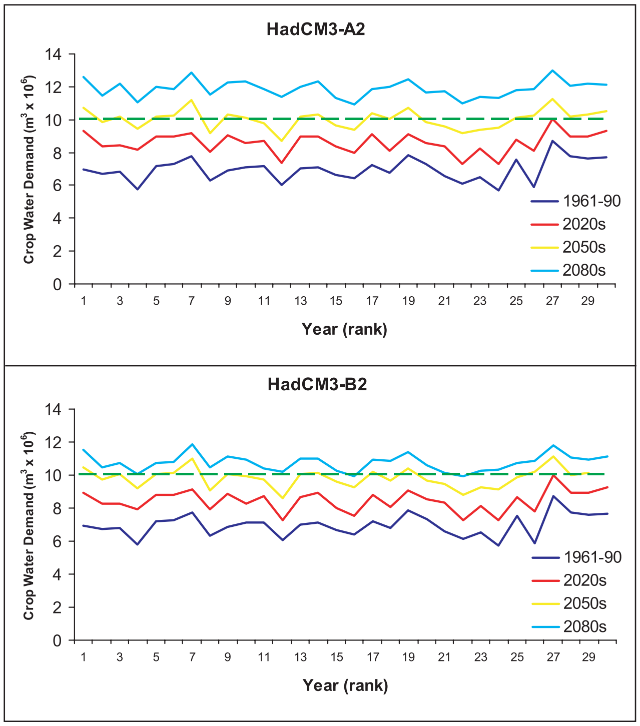


FIGURE 9.7

Modeled annual crop water demand in Summerland for 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to HadCM3-A2 and -B2 scenarios. Green dashed line is maximum allowable annual demand.

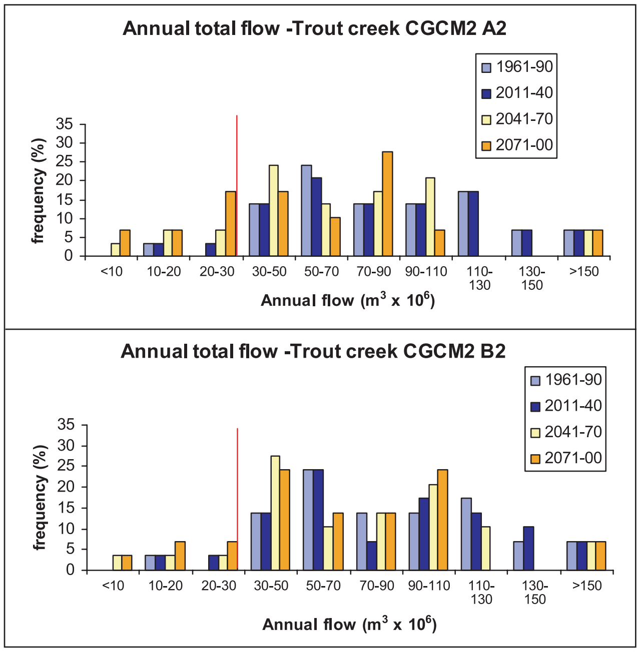
that were obtained using the methodology outlined in Chapter 7. As with crop water demand modeling, thirty years of climate data, 1961-90 were perturbed by ‘delta’ values for temperature and precipitation from three GCMs and two emissions scenarios for three time slices 2020s, 2050s and 2080s. From historical patterns, average unrestricted flow in Trout Creek has previously been estimated as 2.65m^3/sec. (Northwest Hydraulic Consultants, 2001). Modeled unrestricted flow at the mouth of Trout Creek, using the UBC watershed model, averaged 2.83 m^3/sec for the period 1961-90. Similar unrestricted flows were projected for the 2020s in CGCM2 scenarios and the HadCM3-A2 scenario, but were slightly higher in the HadCM3-B2 scenario and were lower in CSIROmk2 scenarios (Table 9.1). Reductions in flow were projected for the 2050s and 2080s in all model scenarios.

A drought threshold of 30.3 m^3 x 10^6 (36% of average annual flow) has been proposed for Trout Creek (Associated Engineering, 1997). Currently, four drought stages are recognized which are linked to restrictions on water supply. Under stage one, agricultural water supply is reduced by 5% compared to

TABLE 9.1

Modeled average daily flow for Trout Creek in response to 1961-90 historic climate data and climate change scenarios

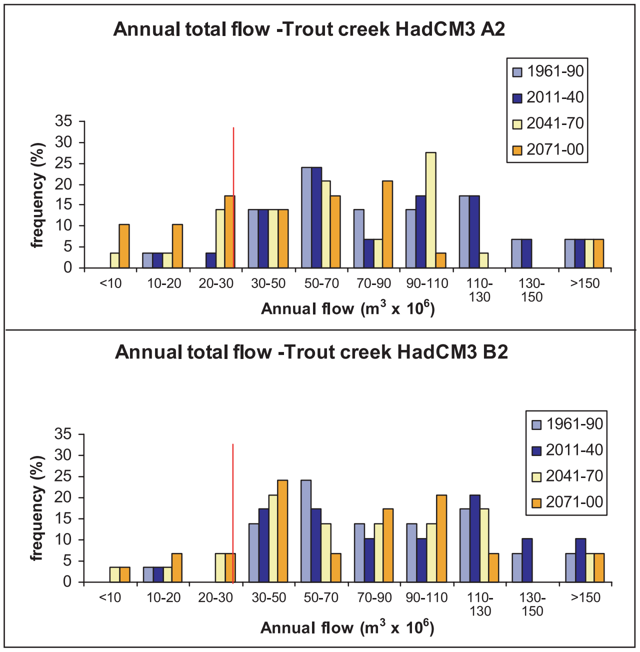
1961-90 M3/SEC		CGCM2 2020	CGCM2 2050	CGCM2 2080	CSIROMK2 2020	CSIROMK2 2050	CSIROMK2 2080	HADCM3 2020	HADCM3 2050	HADCM3 2080
		M3/SEC								
2.86	A2	2.83	2.11	1.89	2.58	2.02	1.28	2.81	2.21	1.73
	B2	2.83	2.45	2.14	2.12	2.06	1.41	3.03	2.48	2.31


Annual total flow -Trout creek CGCM2 A2

Annual total flow -Trout creek CGCM2 B2

FIGURE 9.8

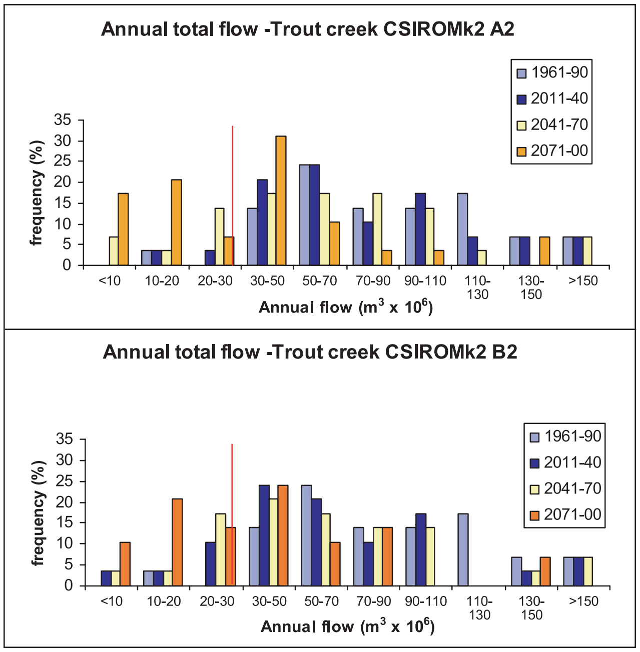
Frequency distribution of total annual flow in Trout Creek modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to CGCM2 scenarios. Vertical red line is the drought threshold.


Annual total flow -Trout creek HadCM3 A2

Annual total flow -Trout creek HadCM3 B2

FIGURE 9.10

Frequency distribution of total annual flow in Trout Creek modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to HadCM3 scenarios. Vertical red line is the drought threshold.


Annual total flow -Trout creek CSIROMk2 A2

Annual total flow -Trout creek CSIROMk2 B2

FIGURE 9.9

Frequency distribution of total annual flow in Trout Creek modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to CSIROMk2 scenarios. Vertical red line is the drought threshold.

estimates of full demand; under stages two and three early and late season watering are restricted and under stage four there is no irrigation. Domestic watering and fish flow restrictions are imposed with increasing severity from stage one to four. Frequency distributions for total annual unrestricted flow were plotted for each of the GCM scenarios and compared to modeled historic unrestricted flows (1961-90) (Figs. 9.8-9.10). Between 1961-1990, there was only one occurrence of modeled, unrestricted flow lower than the drought threshold. For high emissions (A2) scenarios, there was a slight increase in the frequency of drought by the 2020s (~6.8% of years); a larger increase, (17-24%) depending on GCM by the 2050s and an even larger (31-44%) frequency for the 2080s. The CSIROMk2 model provided the driest A2 (Fig. 9.9) scenarios whereas CGCM2-A2 (Fig. 9.8) and HadCM3-A2 (Fig. 9.10) were relatively similar. For low emissions (B2) scenarios, there were only slight increases in drought frequency for CGCM2 and HadCM3 in the 2020s; modest increases (10-14%) in the 2050s and a 17% frequency in 2080. Thus for these two GCMs, B2 scenarios produced fewer extreme events than A2 scenarios. In contrast, the CSIROMk2-B2 scenarios produced more drought years in the 2020s and similar event frequencies in the 2050s and 2080s, when compared to A2 scenarios (Fig. 9.9). Potential

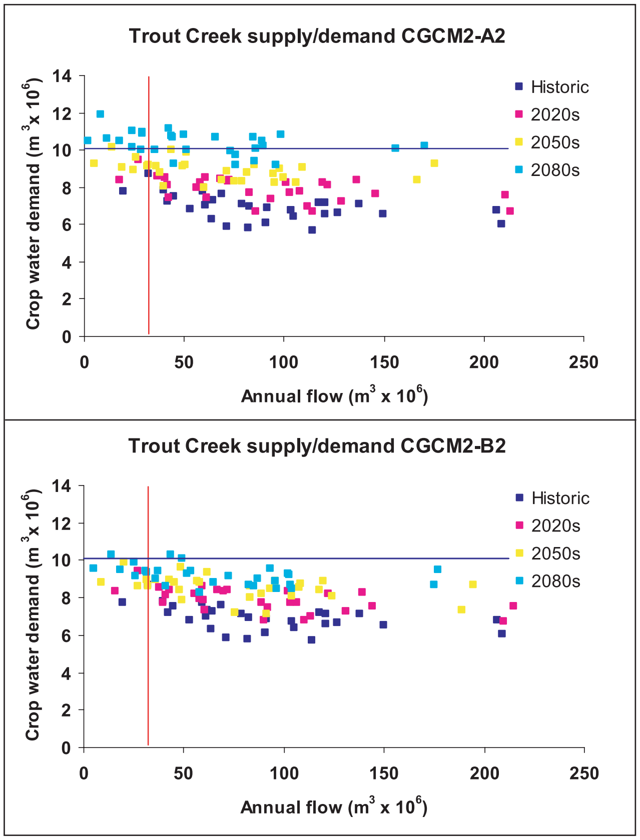


FIGURE 9.11

Relationship between total annual flow in Trout Creek and crop water demand in Summerland modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to CGCM2 scenarios. Vertical red line is the drought threshold. Blue horizontal line is the maximum annual demand.

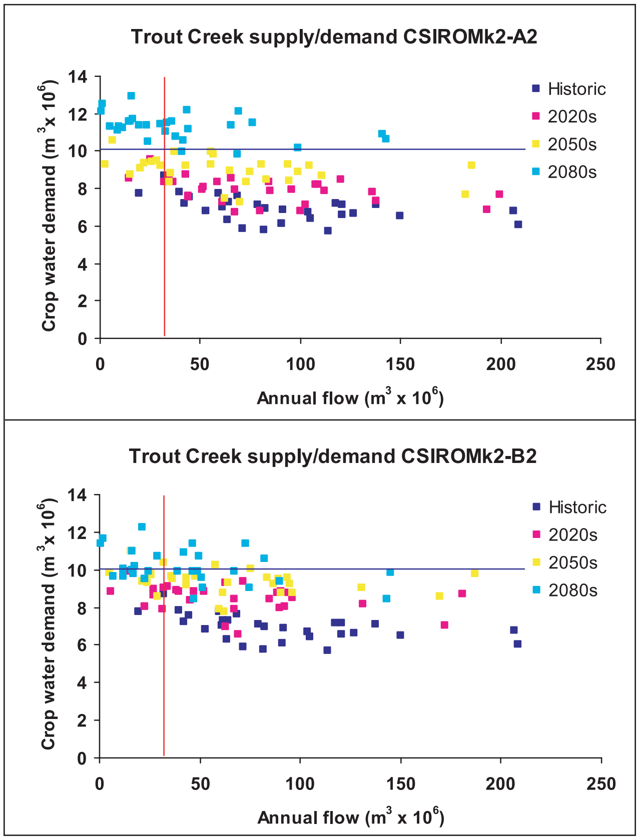


FIGURE 9.12

Relationship between total annual flow in Trout Creek and crop water demand in Summerland modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to CSIROMk2 scenarios. Vertical red line is the drought threshold. Blue horizontal line is the maximum annual demand.

benefits from low emissions relative to high emissions scenarios, in reducing green house gas concentrations in the atmosphere and thus warming, are likely to be reduced in the early part of the century as the warming expected under high CO_2 emissions is offset by the cooling caused by the accompanying high SO_2 emissions (Albritton and Filho 2001).

The effects of low supply are likely to be exacerbated if coupled with high demand. These 'worst case' scenarios are identified in Figs. 9.11 – 9.13, where the demand limit is defined by the 'peak' demand value of 10.1 m^3 x 10^6 and the supply limit by the drought threshold of 30.3 m^3 x 10^6. The lowest risk of not being able to meet demand occurs in the lower right hand quadrant of the diagrams. The majority of points fell within this quadrant for historic, 2020s and 2050s scenarios, but, with exception of CGCM2-B2, the majority of points fell outside of this quadrant for the 2080s data. The highest risk is associated with points found in the upper left hand quadrant of the diagrams (Figs. 9.11 – 9.13). There were no instances of high risk in the historic (1961-90) data. High emissions (A2) scenarios resulted in a greater frequency of high risk outcomes for HadCM3 in the 2050s (1 year in 6) and for all GCMs by the 2080s (1 year in 4 to 1 year in 2). Incidence of 'high risk' response for low emissions scenarios was less than under high emissions.

The increased demand and low supply scenarios outlined above suggest that it is unlikely the existing infrastructure will be sufficient, even if conservation measures could save 30-40% of water used. The ability of the water system to supply demand in the future will be dependent on the availability of effective water storage which is presently around 9.1 m^3 x 10^6. Recent data

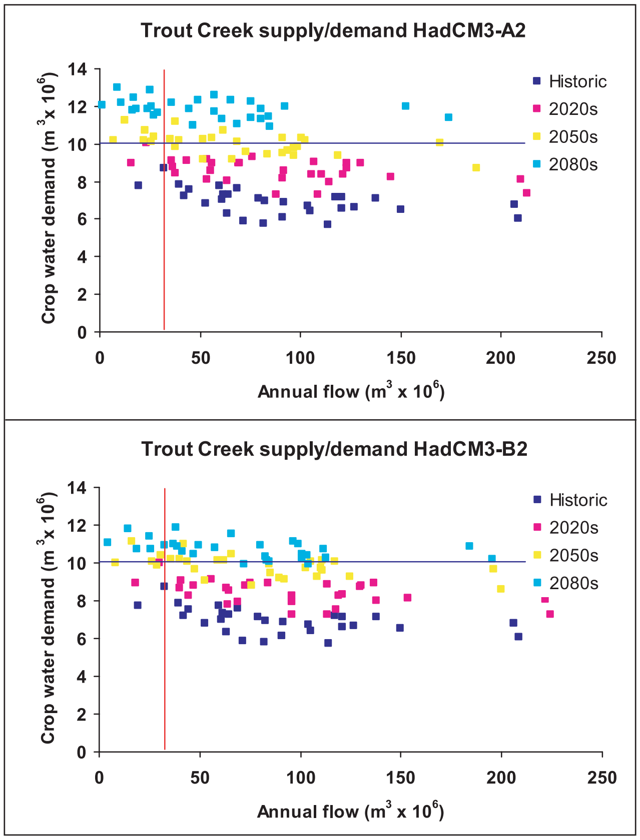


FIGURE 9.13

Relationship between total annual flow in Trout Creek and crop water demand in Summerland modeled from historic climate data 1961-1990 and for thirty year periods centred on 2020s, 2050s and 2080s in response to HadCM3 scenarios. Vertical red line is the drought threshold. Blue horizontal line is the maximum annual demand.

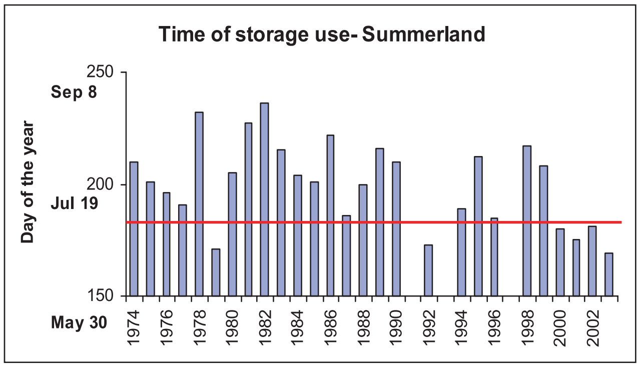


FIGURE 9.14

Actual start time of water use from storage in the Trout Creek system in Summerland 1974 to 2003. Horizontal red line indicates July 1st.

suggest that years of high demand and early snow melt result in early use of stored water and potential water shortages. Between 1974-2003, early use of stored water (before July 1st) occurred 6 times, five of them since 1992 (Fig. 9.14). In the current study, an investigation of the timing of demand with respect to supply and consequent effects on the timing of water use from storage was not possible as flow requirements for fish habitat have not yet been determined.

9.2.1.5 Summary

It is apparent that the existing water infrastructure, which provides around 9.1 m^3 x 10^6 of effective storage, will be unable to meet demands in years of extreme future climate. The frequency with which crop water demand, that is higher than the current demand threshold of 10.1 m^3 x 10^6, (2002 measured water use) occurs, increased over the century in response to all climate change scenarios. Similar increases in response to climate change scenarios, were determined for the occurrence of hydrological drought, defined as 36% of unrestricted flow. The highest risk to the Trout Creek system would occur if high demand years coincided with low supply years. High emissions (A2) scenarios resulted in a frequency of high risk outcomes for HadCM3 in the 2050s (1 year in 6) and for all GCMs by the 2080s (1 year in 4 - 1 year in 2). Incidence of 'high risk' response for low emissions (B2) scenarios was less than under high emissions.

9.2.2 City of Penticton – Penticton and Ellis Creeks

There are approximately 522 ha of irrigated agricultural land in the area covered by the City of Penticton water licence. Around 54% of the land is in apple production, 14% in grapes, 13% pasture and the remainder in other tree fruits and crops (Fig. 9.15). The City of Penticton has a more versatile system for supplying irrigation water than Summerland, in that the irrigation and domestic water supply systems are separate and because there are two separate water systems, north and south based on Penticton and Ellis Creeks respectively. The north irrigation area is much larger than the south area and although both have a crop profile dominated by apple and other tree fruits, apple has less importance in the south.

The Penticton Creek system consists primarily of two dams: Greyback dam, which holds approximately 12.335 m^3 x 10^6 of live storage and Penticton #1 dam which holds approximately 1.60 m^3 x 10^6. Greyback and Penticton #1 dams are the main source of water for the City of Penticton's domestic and north irrigation system. Water flows from Penticton #1 into Greyback Dam and from there into Penticton Creek, and finally

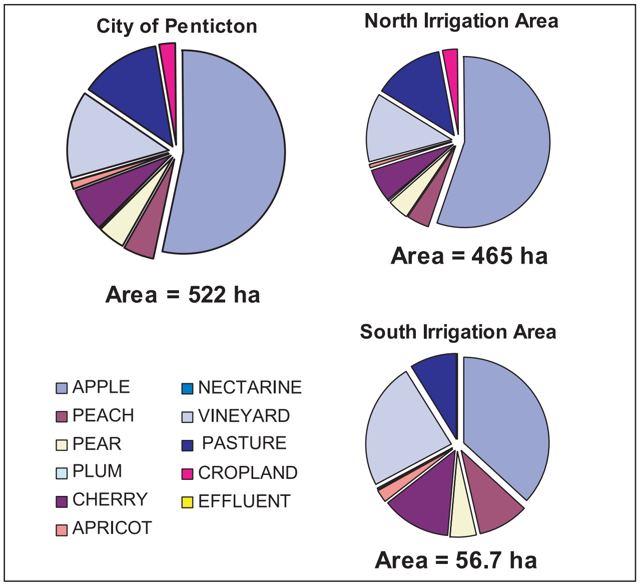


FIGURE 9.15

Agricultural land use in the City of Penticton.
(see Chapter 8 for data sources)

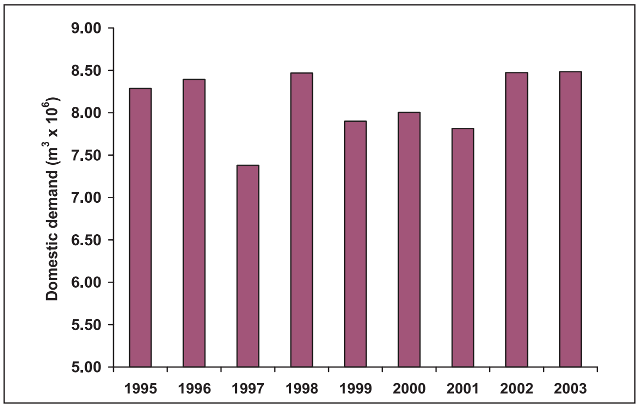


FIGURE 9.16

Measured domestic water demand for the City of Penticton, 1995-2003.
(Source: City of Penticton Public Works Department)

into the city's two intakes- the "Campbell Mountain Diversion Dam" and the "Penticton #2 Dam". Water diverted for irrigation purposes is not treated. The remaining system functions as a dual source domestic water supply. Water can be gravity fed from Penticton Creek or pumped up from Okanagan Lake and blended with the creek water. The quantity of total domestic water supply is metered during treatment and ranged from 7.82 to 8.48 m^3 x 10^6 between 1995-2003 (Fig. 9.16). The Ellis Creek system consists of the Ellis #4 dam of 0.80 m^3 x 10^6 and the Ellis #2 dam of 0.45 m^3 x 10^6. This system is used exclusively to serve the Ellis Irrigation System to the south east portion of Penticton. Both drain into Ellis Creek and to the Ellis Creek Diversion Dam. There are no recorded flow data available for irrigation demand for either system.

9.2.2.1 *Modeled historic crop water demand*

In the absence of measured irrigation flow values, the best estimates of crop water demand for Penticton are modeled from daily temperature records from Summerland CDA/CS. For the area served by Penticton Creek (north irrigation area), the demand for the 1961-1990 period ranged from 2.24 to 3.60 m^3 x 10^6 with the highest occurring in 1987. Between 1961 and 2003, the highest demand, 3.69 m^3 x 10^6, occurred in 1998. For the area served by Ellis Creek (south irrigation area) the demand for the 1961-2003 period ranged from 0.25 to 0.44 m^3 x 10^6, with the highest occurring in 1987. Together, this represents just under half of the amount of water diverted for domestic use.

9.2.2.2 *Modeled future crop water demand*

Crop water demand scenarios were created in response to climate change scenarios from three Global Climate Models each with two emissions scenarios. Future demands are based on daily temperature records from Summerland CDA/CS which have been perturbed by average increases generated from 30 year GCM output. In this exercise, land use remained constant. On average, future demand for both irrigation areas was higher than historic demand for all GCM scenarios (Table 9.2). For the north irrigation area, modeled average demands eventually exceeded the 1961-90 maximum demand (3.60 m^3 x 10^6) depending on climate change model and scenario; by the 2050s for both CGCM2 and CSIROMk2 high emissions (A2) and by the 2020s for both HadGCM3 scenarios and the CSIROMk2 low emissions scenario. For the south irrigation area, modeled average demands equaled or exceeded 1961-90 maximum demand (0.44 m^3 x 10^6) by the 2050s for both CGCM and CSIROMk2 scenarios and the HadCM3 low emissions (B2) scenario, and by the 2020s for the HadCM3 high emissions (A2) scenario.

Currently, there are no system based caps on the volume of irrigation demand for the City of Penticton, other than the licenced allocation of 7.97 m^3 x 10^6. Consequently the model output for crop water demand was compared to thresholds of 3.60 and 0.44 m^3 x 10^6 for the north and south irrigation areas respectively, based on peak demand estimated from model data for 1961-1990. These thresholds are not equivalent to the system based cap for Summerland detailed above, as there have been no volume restrictions required for irrigation supply in the City of Penticton up to this

TABLE 9.2

Modeled crop water demand for the areas served by Penticton Creek and Ellis Creek in response to 1961-90 historic climate data and climate change scenarios.

	1961-90		CGCM2			CSIROMK2			HADCM3		
			2020S	2050S	2080S	2020S	2050S	2080S	2020S	2050S	2080S
	M³ X 10⁶					M³ X 10⁶					
Penticton Creek	2.87	A2	3.32	3.79	4.46	3.36	3.83	4.89	3.65	4.34	5.23
		B2	3.34	3.64	3.92	3.62	4.03	4.37	3.60	4.26	4.69
Ellis Creek	0.34	A2	0.40	0.45	0.54	0.40	0.46	0.59	0.44	0.52	0.62
		B2	0.40	0.44	0.46	0.43	0.48	0.52	0.43	0.51	0.56

point. Patterns of variability from year to year were similar, but not identical for crop water demand derived from historical data and CGCM2 scenarios (Fig. 9.17). This is expected given that each year is perturbed by a constant value within a given scenario time-slice. For the high emissions (A2) scenario, the number of years when the 1961-90 demand threshold might be exceeded, increased over time, from six years out of thirty by the 2020s to thirty years out of thirty by the 2080s. For the lower emissions scenarios (B2), the number of years when the 1961-90 demand threshold might be exceeded were slightly lower than for A2 scenarios, ranging from four years out of thirty by the 2020s to twenty-six years out of thirty by the 2080s. Estimates of demand varied among GCMs (Figs. 9.18, 9.19), with the most extreme responses occurring in the HadCM3-A2 scenarios, so that by the 2050s, demand exceeded the threshold in every year. Similar responses were seen for the south irrigation area supported by Ellis Creek (Figs. 9.20-9.22).

9.2.2.3 Comparison of modeled future crop water demand and supply

Water supply estimates were derived from annual model outputs from the UBC watershed model for Penticton and Ellis creeks for historic and future climate conditions. As described above, thirty years of climate data, 1961-90 were perturbed by 'delta' values for temperature and precipitation from three GCMs and two emissions scenarios for three time slices 2020s, 2050s and 2080s. Modeled unrestricted flow at the mouth of Penticton and Ellis Creeks, using the UBC watershed model, averaged 0.84 m^3/sec and 0.55 m^3/sec respectively for the period 1961-90. For both watersheds, similar unrestricted flows were projected for the 2020s in CGCM2 scenarios, the HadCM3 scenarios, and the CSIROMk2 high emissions (A2) scenario but were lower for the CSIROMk2 low emissions (B2) scenario (Table 9.3). Reductions in flow were projected for the 2050s and 2080s in all model scenarios.

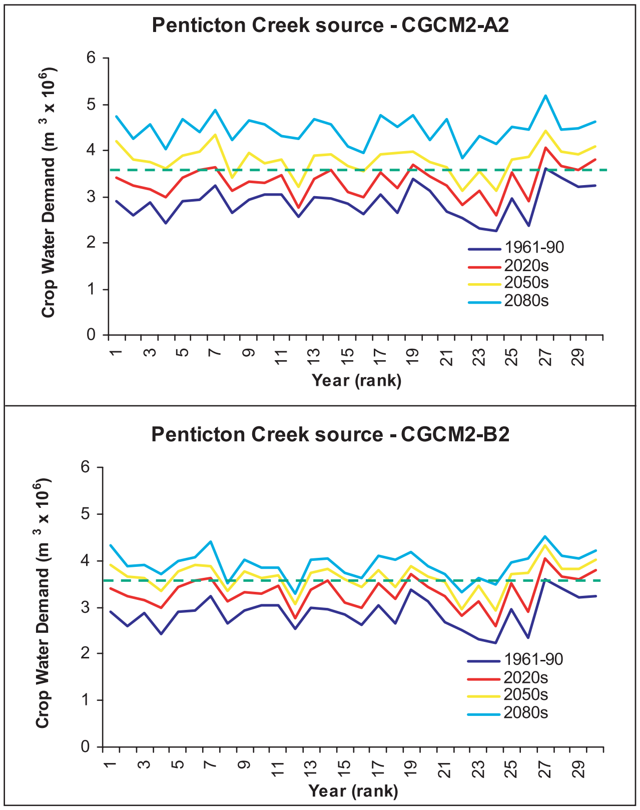


FIGURE 9.17

Modeled annual crop water demand for the north irrigation area served by Penticton Creek for 1961-1990 and for thirty year periods centred on the 2020s, 2050s 2080s in response to CGCM2-A2 and –B2 scenarios. Green dashed line is maximum demand from 1961-90.

Annual estimates of flow were plotted against estimates of crop water demand to determine 'worst case' scenarios where low supply coincided with high demand (Figs. 9.23-9.28). The demand limits were defined as the 'peak' values of 3.60 and 0.44 m^3 x 10^6 derived from 1961-1990 modeled crop water demand for the north and south irrigation areas respectively.

TABLE 9.3

Modeled average daily flow for Penticton Creek and Ellis Creek in response to 1961-90 historic climate data and climate change scenarios.

			CGCM2			CSIROMK2			HADCM3		
	1961-90		2020S	2050S	2080S	2020S	2050S	2080S	2020S	2050S	2080S
	M^3/SEC					M^3/SEC					
Penticton Creek	0.84	A2	0.81	0.59	0.48	0.77	0.55	0.29	0.79	0.62	0.45
		B2	0.80	0.68	0.59	0.60	0.64	0.35	0.84	0.69	0.61
Ellis Creek	0.55	A2	0.52	0.35	0.27	0.49	0.32	0.15	0.51	0.39	0.26
		B2	0.51	0.42	0.35	0.36	0.37	0.18	0.55	0.43	0.38

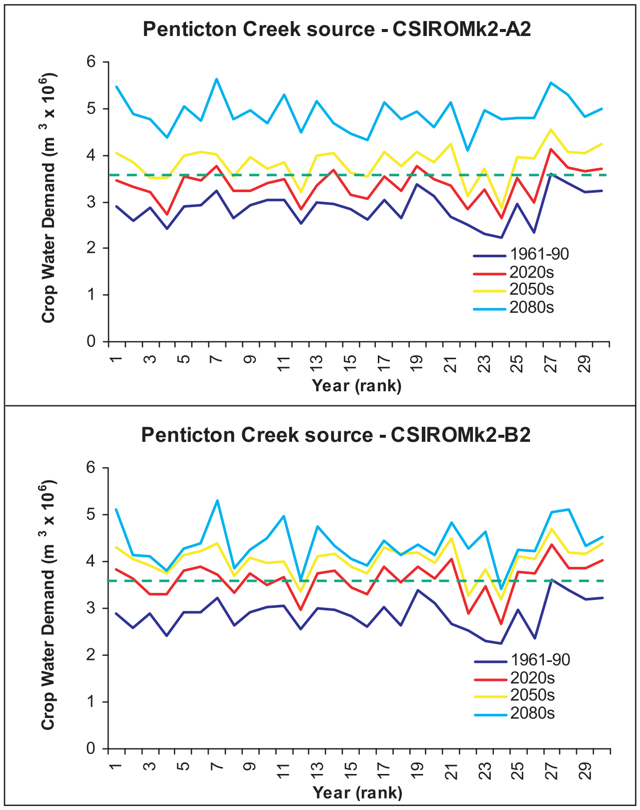


FIGURE 9.18

Modeled annual crop water demand for the north irrigation area served by Penticton Creek for 1961-1990 and for thirty year periods centred on the 2020s, 2050s 2080s in response CSIROMk2-A2 and –B2 scenarios. Green dashed line is maximum demand from 1961-90.

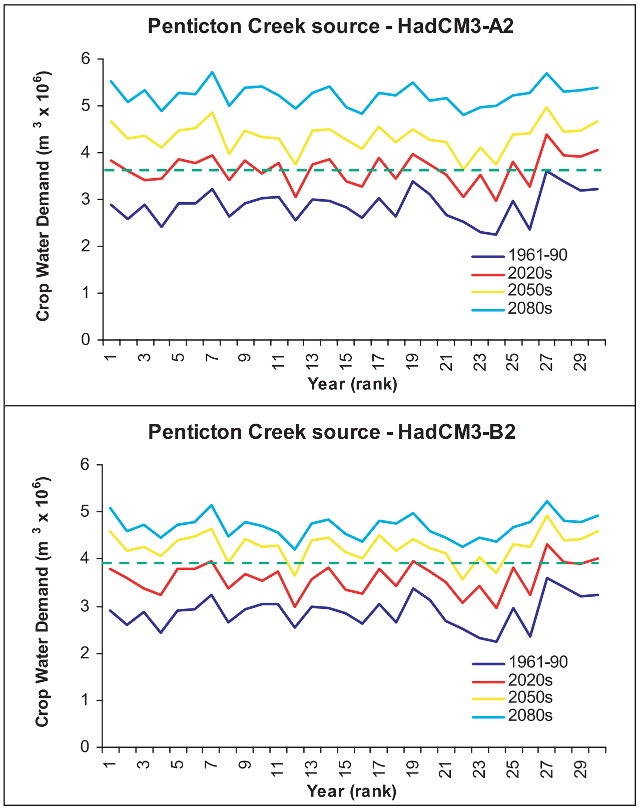


FIGURE 9.19

Modeled annual crop water demand for the north irrigation area served by Penticton Creek for 1961-1990 and for thirty year periods centred on the 2020s, 2050s 2080s in response HadCM3-A2 and –B2 scenarios. Green dashed line is maximum demand from 1961-90.

The supply limit was determined as minimum total annual flow derived from UBC watershed model output for 1961-1990 for Penticton and Ellis Creeks respectively. The lowest risk of not being able to meet demand occurs in the lower right hand quadrant of the diagrams. For Penticton Creek, the majority of points fell within this quadrant for historic and 2020s scenarios for CGCM2 and CSIROMk2-A2 (Figs. 9.23-9.25). The majority of points fell outside of this quadrant for all other scenarios. The highest risk is associated with points found in the upper left hand quadrant of the diagrams. By definition, there were no

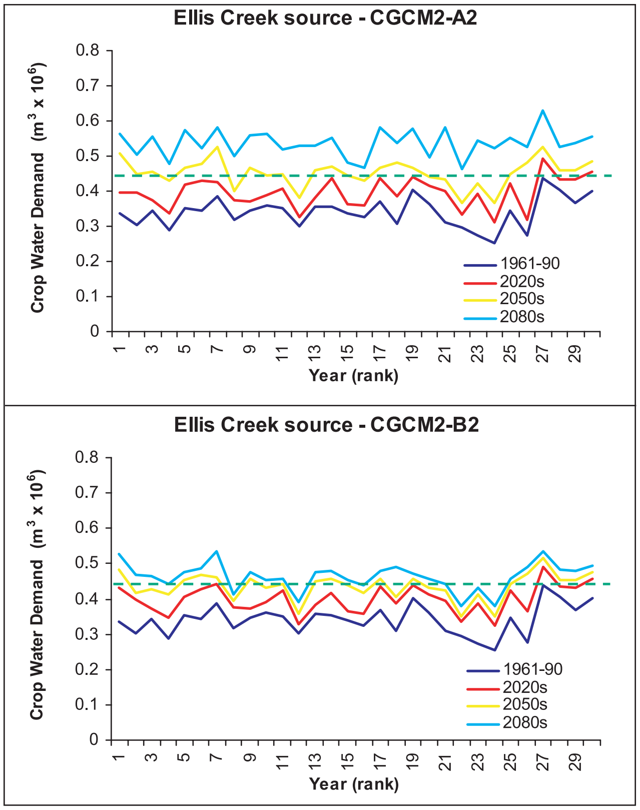


FIGURE 9.20

Modeled annual crop water demand for the south irrigation area served by Ellis Creek for 1961-1990 and for thirty year periods centred on the 2020s, 2050s 2080s in response to CGCM2-A2 and –B2 scenarios. Green dashed line is maximum demand from 1961-90.

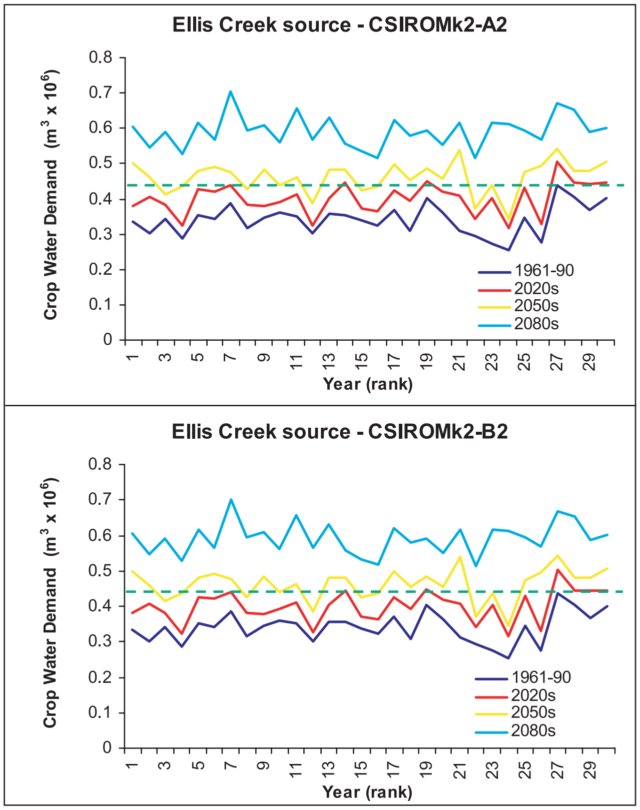


FIGURE 9.21

Modeled annual crop water demand for the south irrigation area served by Ellis Creek for 1961-1990 and for thirty year periods centred on the 2020s, 2050s 2080s in response to CSIROMk2-A2 and –B2 scenarios. Green dashed line is maximum demand from 1961-90.

instances of high risk in the historic (1961-90) data. For all three global climate models, high emissions (A2) scenarios resulted in a greater frequency of high risk outcomes in the 2050s (1 year in 6 to 1 year in 10) and by the 2080s (1 year in 2 to 1 year in 3) than low emissions scenarios. For all scenarios, there were some potential outcomes in which demand was greater than annual supply, mostly for the 2080s time slice. Given that Penticton Creek is also a major source of domestic water, this suggests that a greater dependence on lake water supply would likely ensue under some projected extreme conditions. The frequency of high and low risk outcomes for Ellis Creek was similar to that of Penticton Creek (Figs. 9.26-9.28). However, in contrast to Penticton Creek, there were few potential outcomes where demand was greater than total annual supply for Ellis Creek and it is apparent that in the short to mid-term there may be available extra capacity in the south irrigation system.

9.2.2.4 Summary

In contrast to the Trout Creek/Summerland water supply system, Penticton's water demand is dominated by domestic requirements. Modeled irrigation requirements for the combined north and south irrigation systems for the period 1961-2003 suggest that currently, irrigation requires just below half the amount of water required for domestic needs. The frequency with which modeled annual irrigation demand exceeded the most extreme years in the reference period of 1961-1990 increased for all models and scenarios throughout the century. Similarly, for both Penticton and Ellis Creeks, there was an increased frequency of years with flow below the minimum modeled for the reference period, in response to climate change scenarios. Consequently, for both north and south irrigation systems, there was increased risk of high demand coinciding with low supply over time.

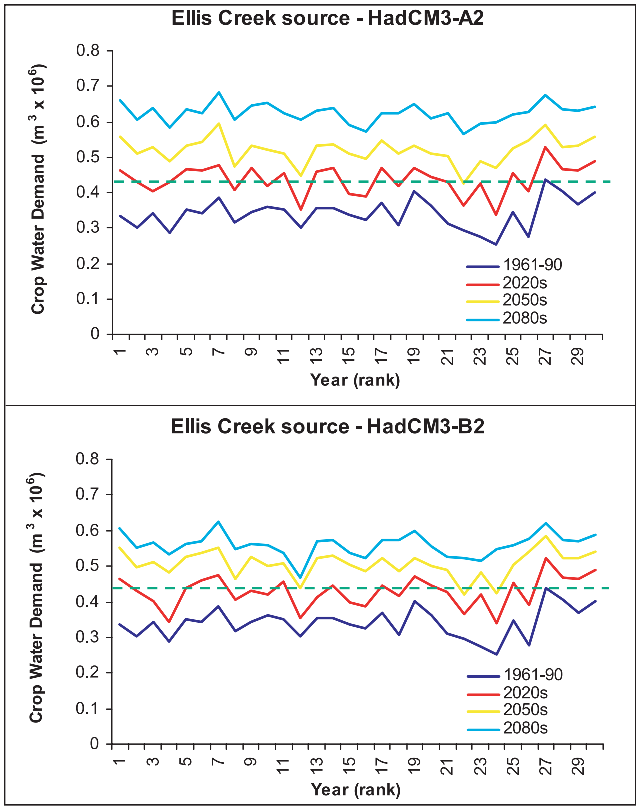


FIGURE 9.22

Modeled annual crop water demand for the south irrigation area served by Ellis Creek for 1961-1990 and for thirty year periods centred on the 2020s, 2050s 2080s in response to HadCM3-A2 and –B2 scenarios. Green dashed line is maximum demand from 1961-90.

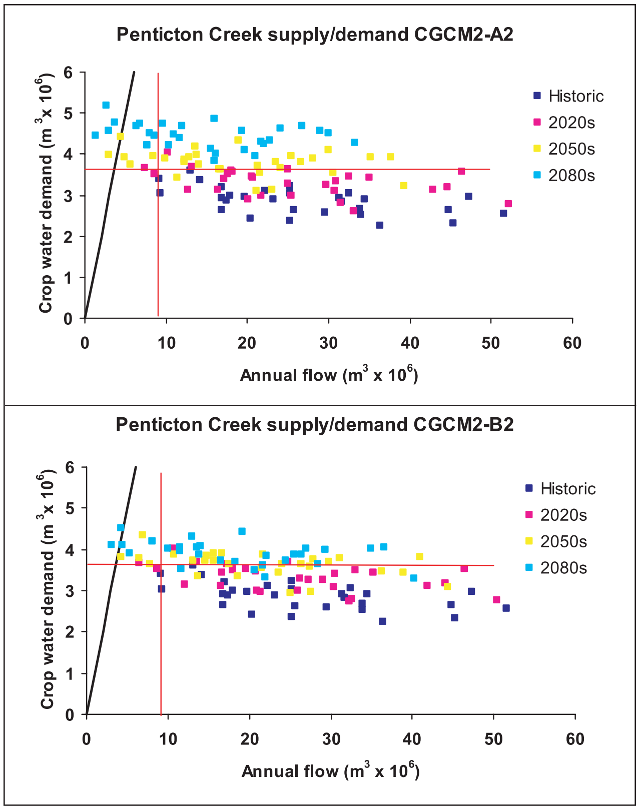


FIGURE 9.23

Relationship between total annual flow in Penticton Creek and crop water demand in Penticton modeled from historic climate data, 1961-90, and for thirty year periods centred on 2020s, 2050s and 2080s in response to CGCM2 scenarios. The vertical red line represents the lowest flow and the horizontal red line the highest demand for 1961-90 data. The sloped black line represents equal supply and demand.

For all three global climate models, high emissions (A2) scenarios resulted in an increased frequency of these high risk outcomes; in the 2050s, between1 year in 10 and 1 year in 6 and by the 2080s, between1 year in 3 and 1 year in 2. High risk outcomes were fewer under low emissions (B2) scenarios. In some, very extreme years, there is a potential for demand to be greater than supply.

9.2.3 City of Penticton: Residential Water Demand Scenarios: Climate Change, Demographic and Housing Preference Changes

Climate change is expected to lead to higher summer maximum temperatures, as indicated elsewhere in this report. Among many other effects, analysis has taken place on the degree to which this may affect residential outdoor water use, in the context of other socioeconomic patterns that also affect demand. It is important to consider each of these effects. An analysis that projected residential water demand usage based only on population growth without accounting for housing preferences would tend to underestimate future water demand. Likewise, an analysis of climate change-induced increases in water usage that neglected population and housing patterns would be a less valuable outcome.

Historical analysis and projections have been created that represent three principal patterns of change in the Okanagan region, using the city of Penticton as a case study. The three patterns considered were 1) population change, 2) changes in preferred dwelling types, and 3) climate change induced temperature change.

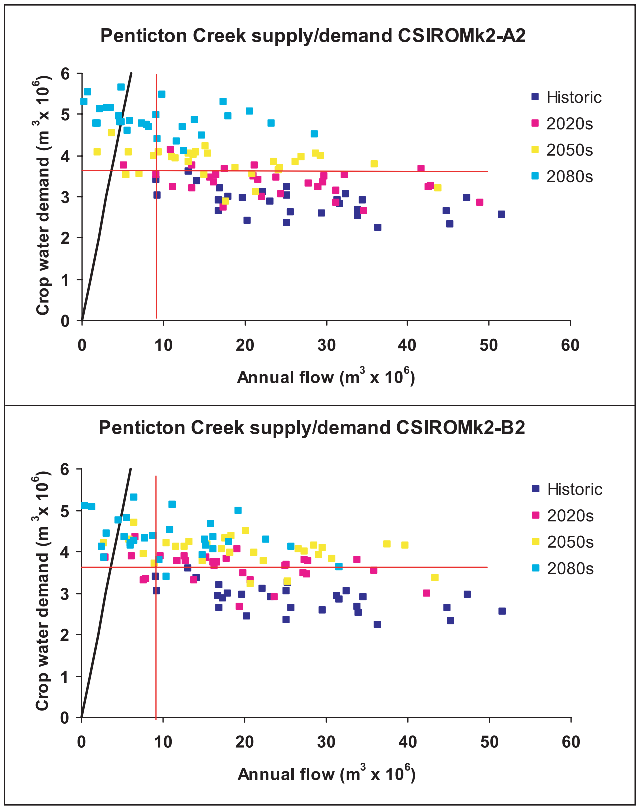


FIGURE 9.24

Relationship between total annual flow in Penticton Creek and crop water demand in Penticton modeled from historic climate data, 1961-90, and for thirty year periods centred on 2020s, 2050s and 2080s in response to CSIROMk2 scenarios. The vertical red line represents the lowest flow and the horizontal red line the highest demand for 1961-90 data. The sloped black line represents equal supply and demand.

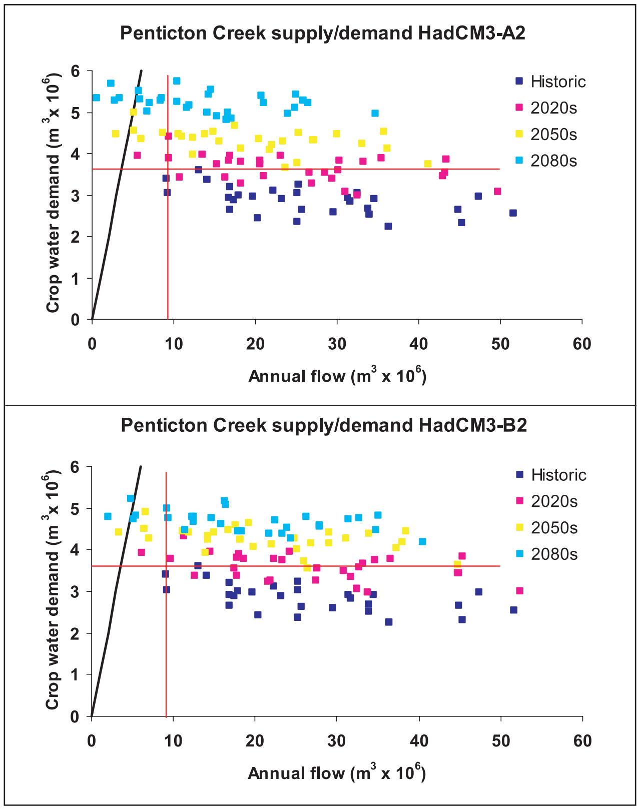


FIGURE 9.25

Relationship between total annual flow in Penticton Creek and crop water demand in Penticton modeled from historic climate data, 1961-90, and for thirty year periods centred on 2020s, 2050s and 2080s in response to HadCM3 scenarios. The vertical red line represents the lowest flow and the horizontal red line the highest demand for 1961-90 data. The sloped black line represents equal supply and demand.

9.2.3.1 Population Change

Past and future projected population growth data were gathered from the City of Penticton, from BC Stats and from the Census of Canada. Changes in the number of residents demanding service from the existing water provision utility are one important factor that must be included in a comprehensive analysis of estimated future water demand.

Demographic projections for the Okanagan region indicate that the population will grow by 63 percent between 2001 and 2050 – particularly residents aged 50 to79. This is a combination of a “Baby Boomer” bulge in this age set, together with expected new residents from the same age class. Two alternate scenarios were also created, in order to explore the degree to which population growth affects future water demand issues.

9.2.3.2 Dwelling Types Patterns

Past information on the number of dwelling types were collected from the Census of Canada. Housing types recorded in the Census of Canada are:

1. Single-detached house
2. Semi-detached house
3. Row house
4. Apartment or flat in a detached duplex
5. Apartment in a building that has five or more storeys

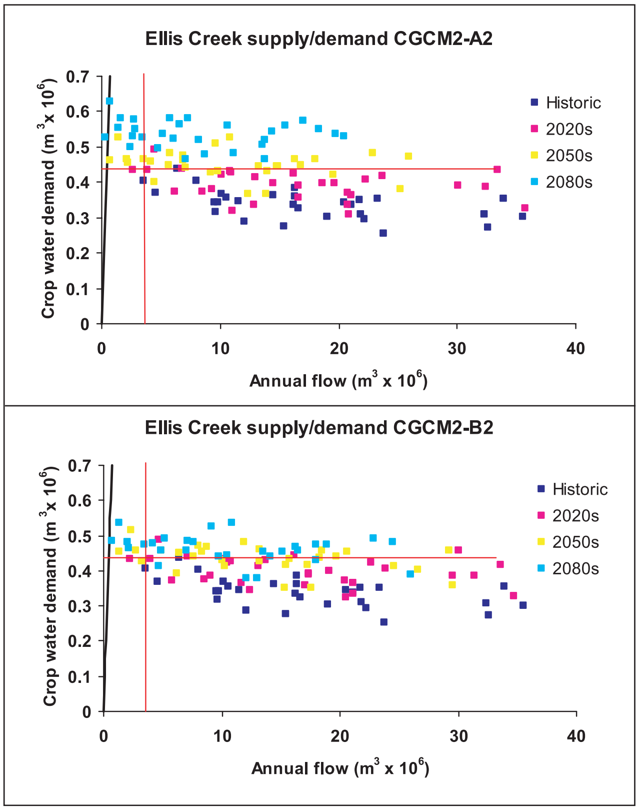


FIGURE 9.26

Relationship between total annual flow in Penticton Creek and crop water demand in Penticton modeled from historic climate data, 1961-90, and for thirty year periods centred on 2020s, 2050s and 2080s in response to CSIROMk2 scenarios. The vertical red line represents the lowest flow and the horizontal red line the highest demand for 1961-90 data. The sloped black line represents equal supply and demand.

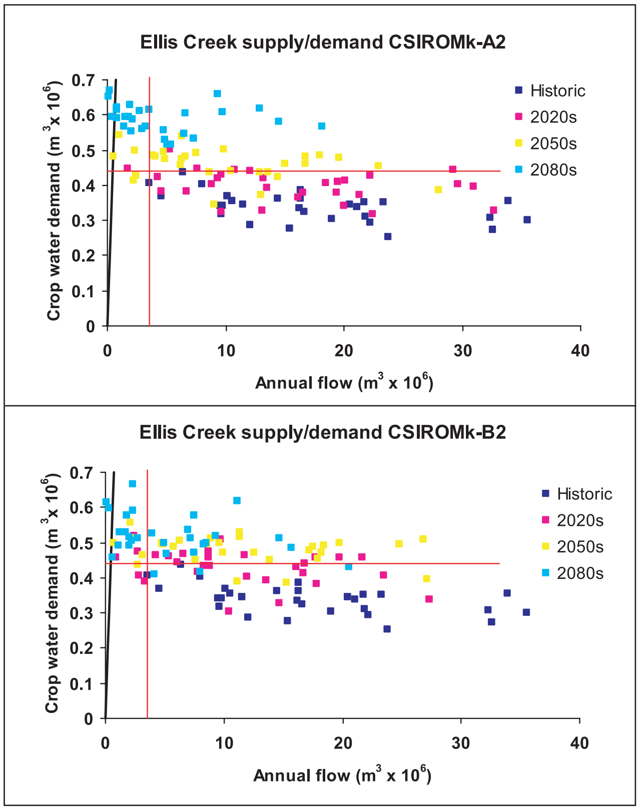


FIGURE 9.27

Relationship between total annual flow in Penticton Creek and crop water demand in Penticton modeled from historic climate data, 1961-90, and for thirty year periods centred on 2020s, 2050s and 2080s in response to HadCM3 scenarios. The vertical red line represents the lowest flow and the horizontal red line the highest demand for 1961-90 data. The sloped black line represents equal supply and demand.

6. Apartment in a building without direct ground access in a building that has fewer than five storeys
7. Apartment with direct ground access in a building that has fewer than five storeys
8. Other single-attached house
9. Mobile home
10. Other movable dwelling

Definitions for these housing types can be found at Structural Type of Dwelling: http://www.statcan.ca/english/census2001/dict/dwe013.htm (Accessed May 28, 2004).

Future projections on the prevalence of specific dwelling types were collected from a series of reports prepared by The Real Estate Foundation of BC and The Canadian Land Centre for each regional district in British Columbia. The projections used for each case study area are based on those published for the regional district as a whole, since sub-regional projections were not available.

The principal focus of the projections is on differences in expected new construction of ground-oriented and apartment housing, and correspondingly different water use patterns between these dwelling types, as households in ground-oriented dwellings use more water than households in apartments. The Urban Futures Institute defines ground-oriented dwellings to include single-detached house, semi-detached house, apartment or flat in a detached duplex, row house, other single-attached house, mobile home and other movable dwelling.

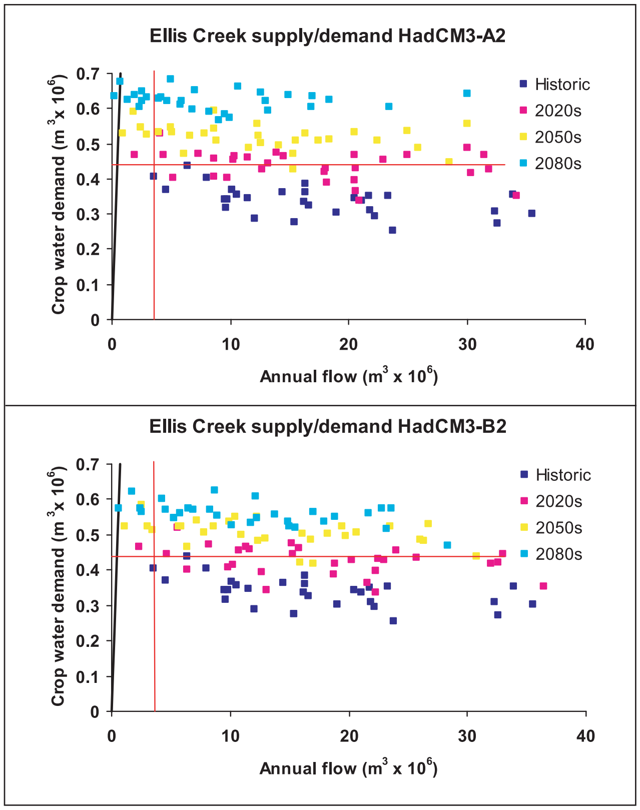


FIGURE 9.28

Relationship between total annual flow in Ellis Creek and crop water demand in Penticton modeled from historic climate data, 1961-90, and for thirty year periods centred on 2020s, 2050s and 2080s in response to HadCM3 scenarios. The vertical red line represents the lowest flow and the horizontal red line the highest demand for 1961-90 data. The sloped black line represents equal supply and demand.

Apartments are defined to include the remaining three categories.

Projections of future water demand based on demand for housing types has two advantages over simple per-capita projections:

1. Allows demographic trends to be incorporated into the analysis

2. Allows adaptation strategies based on zoning bylaws to be explored

The reports, which study the relationship between age and structure type, indicate that as people in the Okanagan region age, they are more likely to be live in ground-oriented dwellings. Demand for apartments increases from age 50 to 85, however even at age 85, a person in the Regional District of Okanagan Similkameen is 1.4 times more likely to live in a ground-oriented dwelling than an apartment (The Real Estate Foundation of BC and The Canadian Land Centre. 2001). Ground oriented dwellings typically have lawns and gardens, which require water for aesthetic and maintenance purposes. This outdoor water use comprises a significant added water demand to indoor use (e.g. sinks, toilets, showers, appliances). Only indoor use generally takes place in apartment dwellings.

9.2.3.3 Climate Change Temperature-Induced Effects

Summer temperatures have been shown to affect outdoor residential water use (see, for example, Cohen, 1985 and 1987). The relationship between summer temperatures and residential water use has been examined in this case study by regression analysis on the correlation between summer daily maximum temperature and total residential/commercial water use per household through the city's water delivery system, using monthly totals for the time period 1998-2003 (see Figure 9.29). Indoor and commercial usage are relatively constant, and have been removed in order to isolate the relationship between temperature and outdoor use. The graph has a positive horizontal intercept, indicating that outdoor water use generally does not take place below certain temperatures. The slope gives the relationship between outdoor residential water use per household and maximum daily temperature as 0.0049ML per °C.

This coefficient was combined with climate change estimates from three different climate models (CGCM2-HadCM3 and CSIROMk2) under two scenarios of global greenhouse gas emissions from the IPCC's SRES

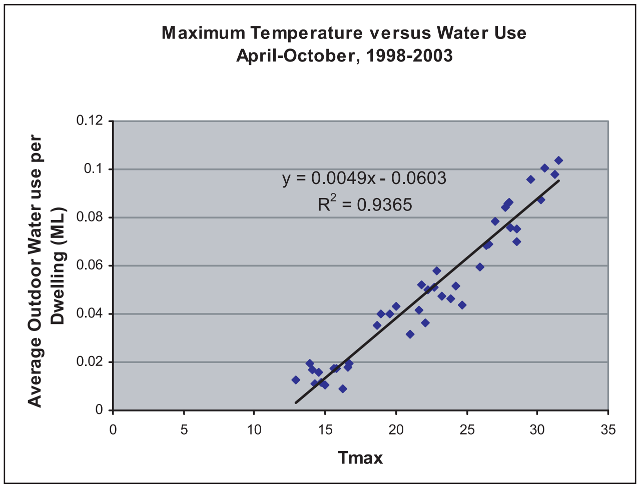


FIGURE 9.29

Relationship between Maximum Temperature and Monthly Water Use series for the period 2010-2069 (see Chapter 5 for detail on the methods used to generate these data). Changes in maximum monthly temperatures during the years 2004 to 2009 were linearly interpolated between those of 2003 (the actual record) and 2010 (the first year for which the climate change models used estimate maximum temperature). The 2004 to 2069 record of estimated maximum monthly temperatures were then used to estimate monthly residential outdoor water use, based on the relationship derived above. Note that outdoor water use changes only apply to households living in dwellings that use water outdoors.

9.2.3.4 Baseline Water Use

Water use data for all serviced customers (residential and commercial) for the city of Penticton was collected for the period 1998 to 2003 on a monthly basis. These data were then analyzed to separate indoor and outdoor use, and coefficients for indoor and outdoor water use per household were created for all relevant housing types discussed above for each summer month. 'Summer' in this analysis refers to the period during which outdoor use takes place, which was determined to be between April to October.

9.2.3.5 Methodology

Three different population projection scenarios were considered. Population projections from BC Stats were used as a "Medium Growth" scenario. Population projections from the City of Penticton's Official Community Plan 2002 were used as a "High Growth" scenario. The "Low Growth" scenario uses a growth rate that is half the rate of that in the "Medium Growth" scenario.

Dwelling type projections were independently generated, based on growth rates estimated by the BC Stats growth projection for Okanagan Similkameen Regional District from 2001-2031, and converted to shares of housing by dwelling type. For each of the three growth scenarios, population was then allocated into the dwelling types on the basis of these shares. Household sizes were assumed to be constant across dwelling types.

Future indoor and outdoor water use for each dwelling type was then estimated for the period 2002 to 2069, without accounting for climate change effects, for the purpose of comparison. The number of households in each dwelling type was multiplied by the per household water use in each case.

The per household outdoor water use coefficient was then revised to account for climate change temperature-induced effects, using the relationship derived above, for each year during the period 2002 to 2069. Future outdoor water use for each dwelling type was then estimated for the same period, using the same method just described.

9.2.3.6 Results

This study is not complete, allowing only initial results to be presented. Initial results have been generated for six different climate scenarios, as well as a scenario in which

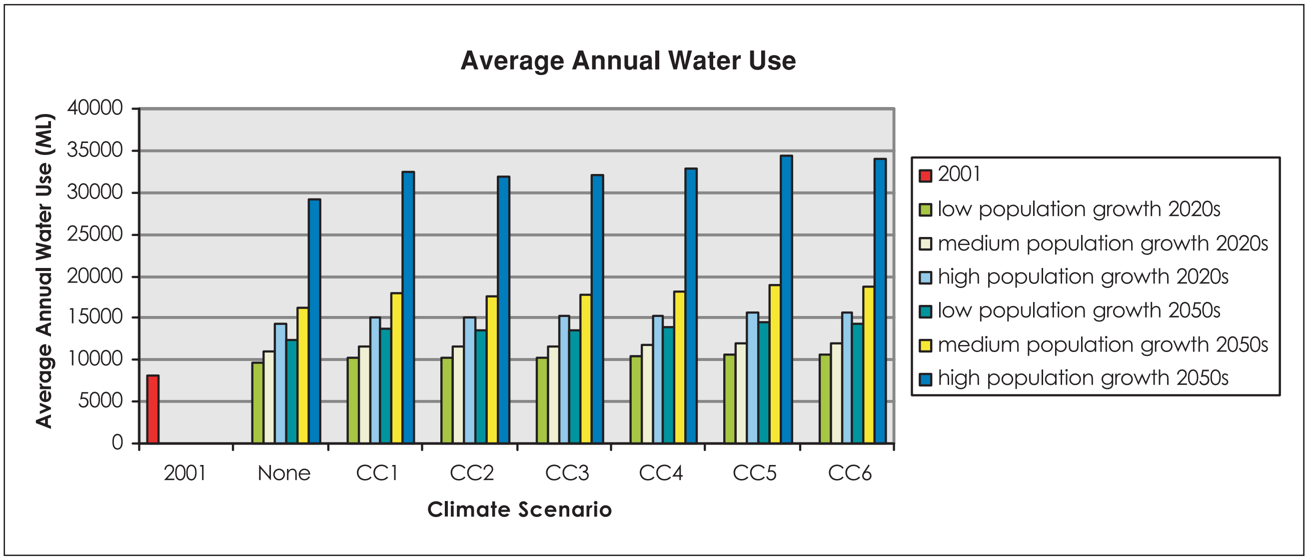


FIGURE 9.30

Average annual water use for the City of Penticton under various climate and growth scenarios.

climate change has not been taken into account. Each of these seven scenarios has been combined with each of three population growth scenarios, and annual water use during the period from 2001 to 2069 has been estimated. Figure 9.30 and Table 9.4 through Table 9.9 summarize the results. There are three pairs of tables, for each of the three population scenarios. Each pair indicates estimated annual use for 2001, 2010 to 2039 (the 2020s), and 2040 to 2069 (the 2050s). The first table in each pair gives average annual use over each period, as well as the minimum annual use and maximum annual use over each period. The second table in each pair gives the corresponding percentage growth in use relative to year 2001 for each of the future periods.

TABLE 9.4

Annual Water Use: Low Population Growth Scenario

	2001	2010-2039			2040-2069		
Climate Scenario		*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
None	8,026	8,623	9,705	10,871	10,958	12,336	13,821
CC Scenario 1 (CGCM2-A21)	8,026	8,886	10,243	11,967	11,895	13,664	15,908
CC Scenario 2 (CGCM2-B21)	8,026	8,907	10,266	11,991	11,686	13,436	15,660
CC Scenario 3 (CSIROmk2-A21)	8,026	8,911	10,271	12,001	11,765	13,526	15,759
CC Scenario 4 (CSIROmk2-B21)	8,026	9,014	10,384	12,121	12,037	13,829	16,096
CC Scenario 5 (HadCM3-A22)	8,026	9,231	10,622	12,380	12,641	14,485	16,804
CC Scenario 6 (HadCM3-B22)	8,026	9,178	10,564	12,317	12,543	14,377	16,685

TABLE 9.5

Increase in Use Relative to 2001: Low Population Growth Scenario

		2010-2039			2040-2069		
Climate Scenario		*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
None		7.4%	20.9%	35.4%	36.5%	53.7%	72.2%
CC Scenario 1 (CGCM2-A21)		10.7%	27.6%	49.1%	48.2%	70.2%	98.2%
CC Scenario 2 (CGCM2-B21)		11.0%	27.9%	49.4%	45.6%	67.4%	95.1%
CC Scenario 3 (CSIROmk2-A21)		11.0%	28.0%	49.5%	46.6%	68.5%	94.4%
CC Scenario 4 (CSIROmk2-B21)		12.3%	29.4%	51.0%	50.0%	72.3%	100.5%
CC Scenario 5 (HadCM3-A22)		15.0%	32.3%	54.3%	57.5%	80.5%	109.4%
CC Scenario 6 (HadCM3-B22)		14.4%	31.6%	53.5%	56.3%	79.1%	107.9%

TABLE 9.6

Annual Water Use: Medium Population Growth Scenario

	2001	2010-2039			2040-2069		
Climate Scenario		*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
None	8,026	9,017	10,948	13,127	13,298	16,150	19,369
CC Scenario 1 (CGCM2-A21)	8,026	9,431	11,555	14,237	14,652	17,888	21,964
CC Scenario 2 (CGCM2-B21)	8,026	9,453	11,581	14,265	14,394	17,590	21,622
CC Scenario 3 (CSIROmk2-A21)	8,026	9,473	11,586	14,253	14,498	17,707	21,759
CC Scenario 4 (CSIROmk2-B21)	8,026	9,567	11,714	14,420	14,826	18,104	22,224
CC Scenario 5 (HadCM3-A22)	8,026	9,798	11,982	14,729	15,571	18,964	23,201
CC Scenario 6 (HadCM3-B22)	8,026	9,741	11,916	14,653	15,450	18,821	23,037

TABLE 9.7

Increase in Use Relative to 2001: Medium Population Growth Scenario

		2010-2039			2040-2069		
Climate Scenario		*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
None		12.3%	36.4%	63.6%	65.7%	101.2%	141.3%
CC Scenario 1 (CGCM2-A21)		17.5%	44.0%	77.4%	82.6%	122.9%	173.7%
CC Scenario 2 (CGCM2-B21)		17.8%	44.3%	77.7%	79.3%	119.2%	169.4%
CC Scenario 3 (CSIROmk2-A21)		19.1%	45.6%	79.1%	82.2%	122.5%	173.5%
CC Scenario 4 (CSIROmk2-B21)		19.2%	45.9%	79.7%	84.7%	125.6%	176.9%
CC Scenario 5 (HadCM3-A22)		22.1%	49.3%	83.5%	94.0%	136.3%	189.1%
CC Scenario 6 (HadCM3-B22)		21.4%	48.5%	82.6%	92.5%	134.5%	187.0%

Water use appears to vary significantly across the three population scenarios in all cases. For example, in climate change scenario 5 (HadCM3-A22), annual water use more than quadruples between 2001 and 2040-2069 if population grows at 2.1 percent annually, but only increases by 80 percent in the low population growth scenario.

In all cases, climate change exacerbates the increases in water usage. However, the variations across climate scenarios appear to be moderate. For example, in the high population growth scenarios, usage growth relative to 2001 ranges from 297 to 328 percent. Figure 9.31 illustrates the variation across the climate scenarios under a high population growth scenario (the other two population scenarios are included in Appendix 9).

Climate change effects have been isolated from population growth in the interest of comparison. These results are shown if population were to remain at its current level, and at the same time changes in dwelling preferences were halted, then water use under each of the climate scenarios would be expected to rise to the levels given in the table under the four rightmost columns.

TABLE 9.8

Annual Water Use: High Population Growth Scenario

	2001	2010-2039			2040-2069		
Climate Scenario		*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
None	8,026	9,940	14,332	19,812	20,289	29,261	40,458
CC Scenario 1 (CGCM2-A21)	8,026	10,637	15,128	21,169	22,768	32,412	45,269
CC Scenario 2 (CGCM2-B21)	8,026	10,662	15,161	21,216	22,383	31,871	44,527
CC Scenario 3 (CSIROmk2-A21)	8,026	10,666	15,169	21,224	22,537	32,085	44,824
CC Scenario 4 (CSIROmk2-B21)	8,026	10,785	15,335	21,454	23,082	32,803	45,856
CC Scenario 5 (HadCM3-A22)	8,026	11,036	15,686	21,936	24,162	34,359	47,954
CC Scenario 6 (HadCM3-B22)	8,026	10,975	15,601	21,819	23,978	34,101	47,598

TABLE 9.9

Increase in Use Relative to 2001: High Population Growth Scenario

		2010-2039			2040-2069		
Climate Scenario		*Minimum*	*Average*	*Maximum*	*Minimum*	*Average*	*Maximum*
None		23.9%	78.6%	146.8%	152.8%	264.6%	404.1%
CC Scenario 1 (CGCM2-A21)		32.5%	88.5%	163.8%	183.7%	303.8%	464.0%
CC Scenario 2 (CGCM2-B21)		32.8%	88.9%	164.3%	178.9%	297.1%	454.8%
CC Scenario 3 (CSIROmk2-A21)		32.9%	89.0%	164.4%	180.8%	299.8%	458.5%
CC Scenario 4 (CSIROmk2-B21)		34.4%	91.1%	167.3%	187.6%	308.7%	471.3%
CC Scenario 5 (HadCM3-A22)		37.5%	95.4%	173.3%	201.1%	328.1%	497.5%
CC Scenario 6 (HadCM3-B22)		36.7%	94.4%	171.9%	198.7%	324.9%	493.0%

The increases in use between 2001 and 2010-2039 across climate scenarios vary measurably, ranging from 5.6 to 9.5 percent. Similar results emerge for increases in use between 2001 and 2040-2069, ranging from 9.1 to 17.8 percent. This may be contrasted with the increases in use associated with population projections (isolated from climate change effects). Use increase percentages between 2001 and 2040-2069 averages range from 54 to 265 percent across the three population scenarios.

According to these initial results, climate change is expected to have an additive effect to any population projection scenario. The degree to which the additive effects are significant in comparison with the degree to which population scenarios affect total use may be seen by examining shows four different population growth scenarios, each with and without a particular climate change scenario (HadCM3-A22), in order to illustrate the relative impact of climate change. (Other graphical representations based upon initial results are available in the Report Appendix.) The range of use varies

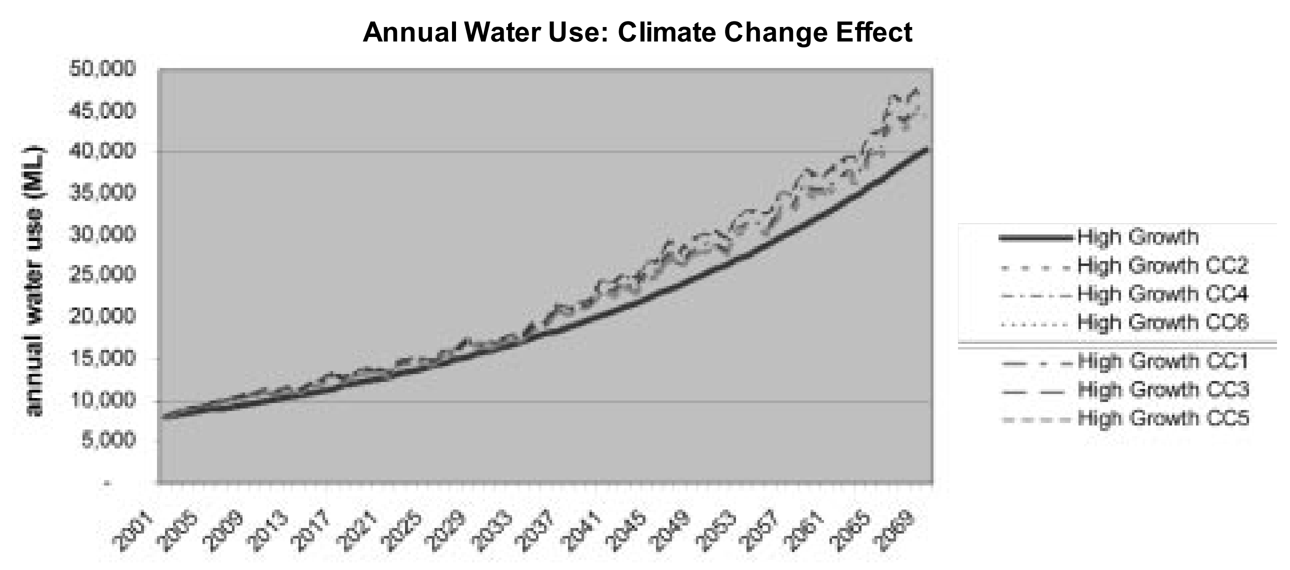


FIGURE 9.31

Multiple Climate Scenarios with High Population Growth Scenario

TABLE 9.10

Annual Water Use: Isolated Climate Change Effect

		NO POPULATION OR DWELLING CHANGES			
	2001	*2010-39*	*Increase as %*	*2040-69*	*Increase as %*
Climate Scenario					
CC Scenario 1 (CGCM2-A21)	8,026	8,476	5.6%	8,908	11.0%
CC Scenario 2 (CGCM2-B21)	8,026	8,495	5.8%	8,757	9.1%
CC Scenario 3 (CSIROmk2-A21)	8,026	8,499	6.8%	8,890	11.7%
CC Scenario 4 (CSIROmk2-B21)	8,026	8,593	7.1%	9,018	12.4%
CC Scenario 5 (HadCM3-A22)	8,026	8,791	9.5%	9,454	17.8%
CC Scenario 6 (HadCM3-B22)	8,026	8,743	8.9%	9,382	16.9%

markedly across the population projection scenarios, varying from about 8,000 million litres per year to over 25,000 million litres per year.

In each case, climate change effects are expected to increase use. The degree of impact appears to increase in absolute terms for scenarios with higher levels of population growth, as temperature effects are applied to increasing numbers of outdoor residential users. However, if the climate change effect is considered in comparison with the effects of population growth, based on the results in Table 9.10, a 9% increase from climate change (the lowest change among the climate scenarios) from 2001 to the 2050s is equivalent to an acceleration of the70-year population growth effect by 11 years for low growth, 7 years for medium growth, and 4 years for high growth. The effects are even more pronounced under the most dramatic climate scenario, which is scenario 5 (HadCM3-A22): an 18 percent increase in use from climate change from 2001 to the 2050s is equivalent to an acceleration of 18 years for low growth, 13 years for medium growth, and 7 years for high growth.

More case studies are needed in order to assess the interacting effects of population growth and climate change on residential water demand for various communities around the Okanagan. If climate change speeds up the population effect, this has implications for long range planning, especially when combined with projected increases in crop water demand (see Neilsen *et al.*, Chapter 8).

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chapter 10

Adaptation Experiences

Philippa Shepherd

10.1 Why Early Adopters?

The aim of this part of the study is to learn about the *process of adaptation*, specifically adaptation to multiple stressors on water resources in the Okanagan. In order to explore the adaptation process, the objective was to explore "*early adopters*" of alternative management practices. Early adopters being local authorities that can be characterised as first movers with respect to specific management strategies in the region.

Adaptation to evolving pressure on water resources in the Okanagan, including impacts of climatic change, will likely involve the application of conventional i.e. supply-side management, but more importantly novel methods of water management, as costs of expanding supply are rising, upland supplies and sites for new reservoir development are limited while license capacity is dwindling (Obedkoff 1994). The challenge will be preparing for the potential barriers to the initiation and implementation of untried approaches in the region, as well as identifying the necessary prerequisites or enabling factors that could aid shifts in water management practices. It is hoped that through studying the adaptation process experienced by local authorities that are, or have, implemented alternative methods of management, potential barriers and enabling factors can be identified, and inform future adaptations where relevant.

10.2 Adapting to Multiple Stresses

It might seem out of place to study adaptation to *current multiple stresses*, rather than current climate events, when this project is about climatic change. There are several reasons why studying adaptation to multiple stresses is useful. Although there might be some unique methods of adaptation specifically appropriate for climatic change impacts on water resources, options should make good water management sense on their own, as well as representing appropriate adjustments to anticipated climate changes (de Loë, Kreutswiser *et al.* 2001). This is crucial because of the inherent uncertainties in predicting climate change. More significantly, climatic change is not an isolated phenomenon; it is one (albeit more recently identified) pressure amongst those already present such as population growth, agricultural and forestry practises, and tourism. Finally, regardless of climate change, adaptive measures are needed because societal developments in themselves will increase vulnerability to environmental stress (Pielke 1998).

10.3 The Adaptation Process

In climatic change literature few have outlined what the adaptation steps might constitute. Smit, Burton *et al.* (2000) developed a *framework* for researching adaptation. They suggest that the important determining components are: signals (what), the adapting system (who), the applied strategy (how) and outcome (effectiveness). Non-climatic context is underemphasized. In a study of agricultural community adaptation to climate variability in Australia, Risbey, Kandlikar *et al.* (1999) emphasized scale, context and decision-making in their *descriptive* presentation of adaptation. Four stages represented key steps in the adaptation process: (1) signal detection; (2) evaluation; (3) decision and response; and (4) feedback . Risbey, Kandlikar *et al.* (1999) model emphasizes the continuous process-nature of adaptation, and the role of human agency and choice. For example, the characteristics of the signal or stimuli aren't the only determining factors shaping the type of response; more importantly the value-based decision-making process of signal detection and attribution influences response i.e. when is a signal a signal and not noise? Additionally, it was recognized that many decision processes simultaneously occur at different scales and with different agendas, each influencing the other through time.

Finally, Klein, Nicholls *et al.* (1999) presented iterative steps in a prescriptive model of *planned* adaptation in the context of coastal management. These steps involved four components: information and awareness, planning and design, implementation, and evaluation and monitoring. Climate and other impacts were presented as the drivers, while factors such as policy criteria and broad planning objectives constrained planning related specifically to climatic change.

Figure 10.1 represents the adaptation framework, inspired by the aforementioned structures, that is used to discuss adaptation process. Adaptive capacity represents those factors i.e. enabling conditions, which aid the process of adaptation. However, adaptive capacity is not a static entity; it is constantly changing as human systems develop and evolve. Therefore, there is adaptive capacity prior to the event that enables adaptation, but there is also the capacity that emerges from the adaptation process itself. In contrast to adaptive capacity, coping capacity is considered the capacity of a system to absorb shock, in other words its robustness, up until a perceived threshold.

10.4 Methodology

10.4.1 Selection of case studies

Cases selected represent alternative water management practises implemented by local authorities in the Okanagan Basin. Local authorities were the chosen institutional scale because they represent key decision-making bodies for water resource management. Although the role of regional and provincial agencies are, where relevant, included in the analysis. Cases were selected on the basis of four criteria (see Table 10.1). An overview of alternative management strategies being practised in the Okanagan was ascertained from informal conversations with municipal water managers as well as -perusal of the Water Efficiency Experiences Database[6], which contains 170 water conservation projects across Canada, and the Water Use Efficiency Catalogue of British Columbia[7]. Initially five different broad types of management strategies were identified: 1) metering domestic water use, 2) metering irrigation water use, 3) reclaimed wastewater, 4) water saving devices; 5) educational campaigns, and finally 6) institutional restructuring. Water saving devices and educational campaigns are often implemented in conjunction with other approaches. Four strategies within four different localities were selected:

- Case 1: Metering of agricultural irrigation in SEKID
- Case 2: Domestic metering with constant unit charge in Kelowna
- Case 3: Water reclamation in Vernon
- Case 4: Amalgamation of separate municipal utilities in Greater Vernon

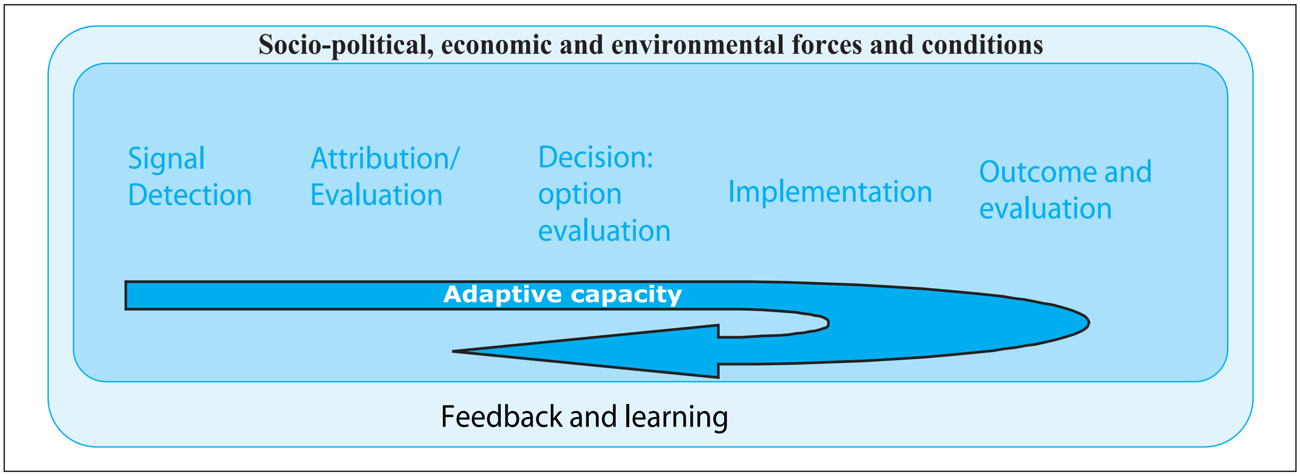

FIGURE 10.1

Adaptation Framework

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[6] *Accessible via the web at: http://www.cwwa.ca/water.htm*

[7] *Accessible via the web at: http://wlapwww.gov.bc.ca/wat/wamr/wat_use_catalogue/toc.html*

An attempt was made to select cases fulfilling the following criteria:

Criteria 1: "Early adopters" potentially representing adaptive and forward-thinking examples of management;

Criteria 2: Alternative or complimentary approaches to (traditionally) purely supply-side management e.g. demand-side management approaches;

Criteria 3: Approaches impacting the two major water consumers in the region, domestic and agriculture.

Criteria 4: Accessible data on process, outcomes and effectiveness.

10.4.2 Interview process and analysis

The interview process selected was a key informant approach. Key decision-makers in the relevant local authority, and/or important actors of participating stakeholder groups, were selected for each case study from primary participating committees and recommendation from key individuals (usually the water manager of the local authority). In general, interviewees were water managers, stewardship coordinators, municipal councilors/irrigation district board members and, in some cases, water users (e.g. farmers). Each interviewee was initially approached by letter and subsequently by phone. Interviews were semi-structured, providing ample leeway for

TABLE 10.1

Case studies

	VERNON	GWVU	KELOWNA	SEKID
Authority type	Municipality	Municipalities, Water Districts and a Regional District	Municipality	Water District
Location	North Okanagan RD	North Okanagan RD	Central Okanagan RD	Kelowna municipal boundaries
Strategy	Water reclamation	Utility amalgamation	Metering with CUC	Metering (and scheduling)
Criteria 1	Yes[1]	Yes[2]	No[3]	Yes[4]
Criteria 2	Yes	Yes[5]	Yes	Yes
Criteria 3	Agriculture (potentially domestic)[6]	Domestic/Agriculture	Domestic	Agriculture
Criteria 4[7]	Yes	Yes	Yes	Yes
Analysed time-line	1969 - 2003	1969 - 2003	1987 - 2003	1987 - 2003

[1] Although water reclamation is more widespread, Vernon was the first municipality in the region to implement water reclamation and commit to applying on land 100% of its effluent. It is also renowned for its environmental and forward-thinking approach to wastewater management.

[2] Greater Vernon Water Utility represents the only amalgamation of water administration in the Okanagan.

[3] Kelowna does not fulfil this criterion. Three other municipalities in the region have implemented metering prior to Kelowna: Coldstream, Penticton and Vernon. The first two were not chosen as implementation occurred many years ago and data on effectiveness was unavailable. Vernon was not selected as it is already featured as a case study. A fourth option was available which was not identified in my initial review of potential cases: Rutland Waterworks (a WaterDistrict). In retrospect this would have been a more favourable choice. Kelowna does represent an "early adopter" as regards to its activities resulting from the metering program i.e. reducing peak demand (or outside urban water use).

[4] SEKID represents the only Water District in the Okanagan and possibly in British Columbia that has implemented agricultural irrigation metering.

[5] Although GVWU represents an institutional approach, changes include both supply-side and demand-side management approaches.

[6] Water reclamation in Vernon represents an agricultural water management approach as it provides an alternative supply to freshwater for irrigation. However, it has the potential for being a domestic approach if used for urban irrigation.

[7] Although a lot of data was available for each case there were barriers to accessibility. There was a fee for accessing information beyond directly accessible Council Minutes in Vernon. Data on effectiveness was only gathered with limited success for Kelowna due to lack of co-operation.

interviewees to express their own opinions and thoughts about the particular project being studied.

39 individuals were approached, 28 were interviewed, 4 directly turned down the invitation, 2 individuals deferred me to others they considered better suited to answering my questions and for the remainder, interview times could not be organised during the three visits to the Okanagan. In other words 72% of individuals approached were interviewed (see Table 10.2). Of the 28 interviews all but three were face-to-face; the three were carried out by phone. All interviews were recorded and subsequently transcribed, and notes were taken during the interviews. Interview duration was between 45 minutes to 2 hours. 22 of the interviews were carried out during two trips to the Okanagan: 14-17 January and 4-8 February 2003. The remaining interviews were carried out intermittently during spring 2003.

Interview texts were inserted into the program ATLASTI for analysis. Texts were coded according to 15 primary codes of which the most important were: drivers, enabling factors, barriers, obstacles and conflict resolution (see results section for definitions).

TABLE 10.2

Interview process

CASE	INTERVIEWEES APPROACHED	INTERVIEWEES ACCEPTED
Vernon—water reclamation	7	**4 in total:** Water manager Former water manager Technician Former Mayor of Vernon
GVWU--establishing a region-wide authority	12	**7 in total:** Representative of the Technical Steering Committee 3 representatives from the Services Commission Representative of the Consultants working on the Master Water Plan Representative of the Master Water Plan Review Panel Representative of the Water Stewardship Committee
Kelowna—domestic water metering	7	**5 in total:** 3 representatives of the Board (including a former chair of the Okanagan Basin Water Board) Water manager Representative of the Kelowna Joint Water Commission
SEKID—metering agricultural irrigation	15	**12 in total:** Water manager (initial scoping interview) 5 representatives of the Board (former and current) 2 co-operating growers 2 representatives of MAFF 1 representative of Land and Water BC Fieldman (representative of BC Fruit Packers Association)
4 Cases	39 individuals approached	**28 interviews**

10.5 Results

Following are four diagrams summarising each case study. Each diagram presents:

- A time-line consisting of key happenings (i.e. decisions, events, studies, etc.).
- Breakdown of adaptation stages.
- Case analysis summary.

The adaptation stages consist of: 1) Signal detection; 2) Signal attribution; 3) Option evaluation and selection (decision); 4) Implementation; 5) Evaluation and feedback (Table 10.3).

TABLE 10.3

ADAPTATION STAGE	EXPLANATION	EXAMPLES
Signal detection:	An observed or perceived issue that initiated the first steps towards a decision. Detection can be thwarted by many factors including technical and resource limits, as well as perceptions of decision-makers.	In SEKID's case, the 1987 dry year triggered concern amongst SEKID management and Board that if another 3-year drought (like that in 1929-1931) ensued SEKID would not be able to cope; past events changed current perceptions. In GVWU's case, the initial signal was a future scenario of how Greater Vernon should manage water supply and demand under expected changes in consumption and availability. It seems that provincial push on water conservation was the main trigger in Kelowna's case.
Signal attribution:	This is the process through which decision-makers determine what is causing the signal.	Through the Okanagan Basin Study milfoil presence was attributed to increased nutrient i.e. phosphorus, levels in the lake mainly from municipal wastewater discharge. SEKID decided that water restrictions during the 1987 and 1992 dry years were not only caused by physical water shortages but inefficient (overuse) by growers i.e. it wasn't just considered a supply problem but also considered a demand problem.
Option evaluation and selection (decision):	Rationally decision-making involves an evaluation of available options and selection based on objective criteria. Different decision types exist such as risk aversion or satisficing. Entrenched values and political agendas of decision-makers but also other stakeholders can influence the decision process and outcome. Changing conditions (e.g. policies, environmental pressures, financial circumstances etc.) during the decision process can also shape final outcome.	Examples: Greater Vernon authorities differing needs and policies made for a long-winded decision process. Provincial incentives e.g. granting of water licenses to NOWA and not Vernon, regulatory changes i.e. new drinking water requirements, as well as environmental pressures e.g. closure of BMX creek, all influenced the decision process. In Kelowna's case, realisation of the cost to maintain infrastructure to meet rising water consumption confirmed and justified implementation of metering and a constant unit charge system.

TABLE 10.3 CONTINUED

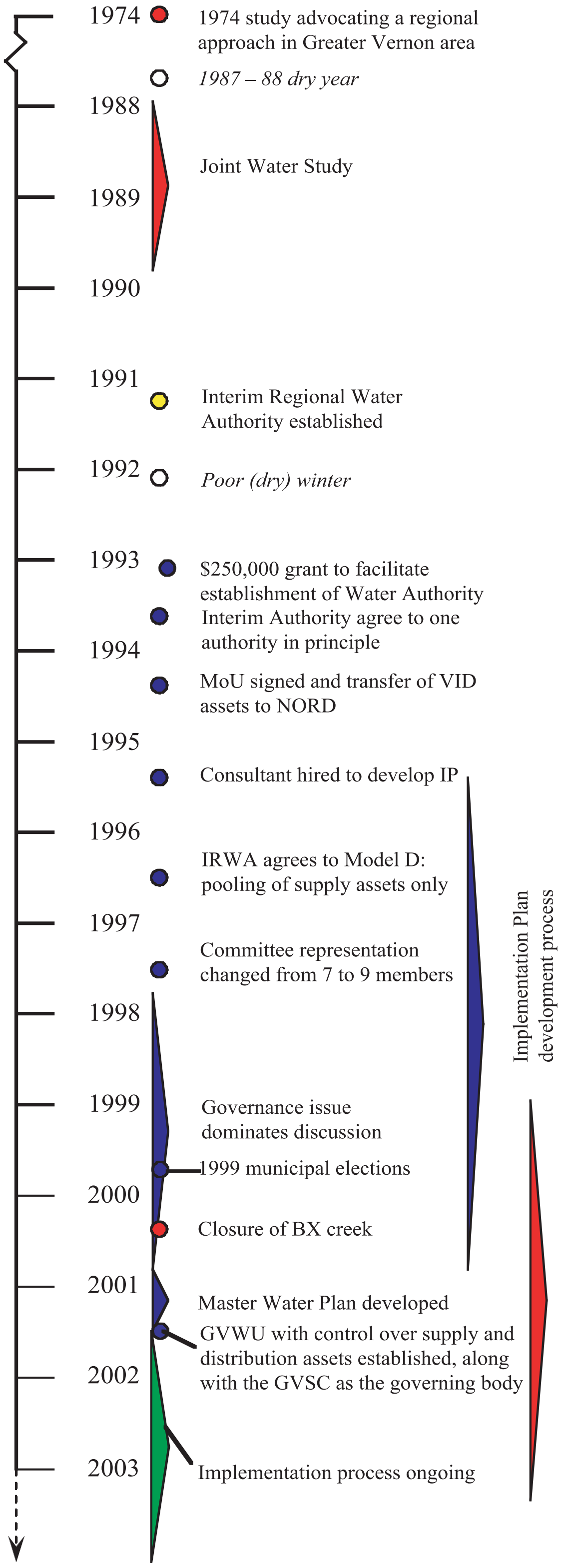
ADAPTATION STAGE	EXPLANATION	EXAMPLES
Implementation:	Putting into action the selected option. Unexpected hurdles, such as technical problems, resource limits, general public opposition can slow and the complicate implementation process. However, means can be used to reduce potential difficulties.	In order to reduce user concern that a metered rate would increase average water costs, a grace period was employed in which mock bills were sent to customers to prepare them for the change. Implementing wastewater reclamation in Vernon involved many difficulties including: farmer opposition to using reclaimed wastewater; public concern over health impacts, and sensitivity of wastewater reclamation to weather changes.
Evaluation and feedback:	In order to amongst other things determine the success of a given project, it needs to be evaluated post implementation. Is evaluation planned or ad hoc? What is evaluated? Finally, does the project and its evaluation result in further developments either in or outside of the system in question?	Evaluation of the universal metering program in Kelowna showed that a 20% reduction in consumption was achieved. However, it also allowed for the identification of high-end users, which in turn resulted in further targeted research by City of Kelowna to learn why they were high consumers and what methods could be applied to reduce their use. It was hoped by MAFF (Ministry of Agriculture, Foods and Fisheries) that the SEKID project would result in further implementation of agriculture metering in the Okanagan. Summerland is the only local authority as yet to show interest. No further diffusion of this idea in the area has resulted.

The figures also represent a summary of important aspects identified in each case study, specifically: Contextual Drivers, Enabling Factors, Barriers, Obstacles, Conflict Resolution and Lessons Learned (Table 10.4).

TABLE 10.4

CODES	EXPLANATION
Contextual drivers	Triggers and conditions along the adaptation process which either confirmed, challenged or re-directed the process.
Enabling factors	Conditions, resources, environments that have aided the adaptive process to achieve the initially defined objective.
Barriers	Factors that could have derailed the adaptation process.
Obstacles	Factors that caused difficulties at any point, but especially during implementation.
Conflict resolution	Methods that were implemented to resolve conflict, avoid potential problems and ease implementation.
Lessons learned (about procedure)	Lessons mentioned by interviewees specifically regarding how to improve procedure.
Lessons learned (overall reflections)	General lessons learned by interviewees from the experience or outcome of the adaptation process.

GVWU Time- line



Adaptation Process

Key signal	Provincial study identifying regionalisation as best approach to cope with balancing future demand and supply.
Attribution *(the identified problem/cause)*	Access to supply and finances (an institutional problem, not an environmental problem)
Contextual drivers *(factors influencing attribution, decision-process and evolution of the management option selected)*	Need to update infrastructure Concern over water quality Growing population Protecting the agricultural community Limited resources e.g. limited financial capacity Push from provincial government to become "model region" Financial support Impending drinking water regulations
Enabling factors *(conditional factors that aided adaptive behaviour)*	Political leadership Willingness to compromise Mutual benefits
Barriers *(factors that could have stopped each project from going ahead)*	Political concerns regarding control (over the water management)/ political commitment Disagreement about water quality issues Potentially public acceptance of the expense
Conflict resolution/avoidance *(methods that were implemented to avoid or resolve disagreement)*	Comfortable governance structure Expert information
Lessons learned *(reflections from interviewees on implementation)*	Public communication and education crucial Fair governance structure necessary but difficult to create Equal buy-in - benefits to all Evolutionary process - prepare for pitfalls Common goal required for partnership to work
Lessons learned *(general reflections from interviewees)*	Need for improved water quality for health Better appreciation for value of water Understanding of regional approach leading to universal gain

CASE STUDY 1

Water utility amalgamation in Greater Vernon

Actors

The co-operating partners in forming the Greater Vernon Water Utility (and accompanying governing body) included:

- City of Vernon
- District of Coldstream
- Parts of Electoral Areas B, C, and D (for which water services were initially provided by the Vernon Irrigation District (VID))
- Spallumcheen (more as an observer as would only be a receiver of bulk water supply under contract)

Other key actors influencing the regionalisation process included the North Okanagan Regional District (NORD) and various provincial ministries, especially the environmental and municipal ministries.

Representatives of the Councils of each local authority i.e. Vernon and Coldstream, along with Directors of Electoral Areas (representatives of the VID/NOWA) formed the initial decision-making body (the Interim Regional Water Authority - IRWA, supported by authority water management representatives which formed the Implementation Plan Technical Committee (which later became the Technical Steering Committee).

Time-line

It was during the 1970's that discussions about establishing a region-wide authority to manage water resources in the Greater Vernon area began. Provincial agendas were (and still are) pro greater regionalisation of water resource administration. Under the 1969-1974 Okanagan Basin Study, a report concluded that water resource management in the Greater Vernon area would be more effective under one administrative and governing body (Associated Engineering North Okanagan Regional District Joint Water Study 1989). Not until 1988 did the authorities in Greater Vernon respond to this advice. A consultancy firm was hired to write a report on each authority's water system i.e. Vernon, Coldstream and VID, and a report on a theoretical regional approach. The reports were reasonably conclusive: a regional approach to water management would offer advantages in terms of long-term economics, future water quality issues and optimization of existing supplies. At that time, based on discussions with the Water Management Branch, licenses beyond current capacity would not be available. Additionally, it was noted that improved treatment would be necessary in the future on most of the supply sources (Associated Engineering North Okanagan Regional District Joint Water Study 1989).

Subsequently, an Interim Regional Water Authority (IRWA) was established to continue the discussion of amalgamating into one water utility. It was agreed by the IRWA that once established "the role of the Regional Water Authority (or Regional Water Commission) would be to plan, treat, and supply water to the City of Vernon, and District of Coldstream for distribution within its boundaries, to distribute to the customers outside of the municipal boundaries, and to distribute water to the agricultural users within the two municipalities" (IRWA Minutes, July 9th 1991).

The Ministry of Municipal Affairs allocated $250,000 toward the development of a regional authority in June 1993. This was followed by an IRWA agreement in principle to "place all bulk water supply assets and licences under one authority" (IRWA Minutes, June 10th 1993). A special meeting was arranged in May 1994, attended by the Councils of the City of Vernon and District of Coldstream, V.I.D Trustees, Regional District Board Members, Minister of Municipal Affairs and staff to discuss the final composition of a Memorandum of Understanding for a regional authority. The Memorandum of Understanding for the North Okanagan Water Authority (NOWA - a temporary regional body) was subsequently signed on May 6, 1994, along with the dissolution of VID, its assets transferred to the North Okanagan Regional District. An Implementation Plan (IP) was required as part of the MoU. The MoU represented a commitment to the concept of regionalisation, while the objective of the IP was to identify, by consensus, a regional water supply management structure (KWLG&S Associated Preparation of the implementation plan for a Greater Vernon Area Regional Water Supply. Task 3 summary report for development of the plan. Draft. 1996).

By mid-1996, NOWA agreed that Model D i.e. pooling of all supply assets[8], be selected as the best

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[8] *Municipalities would enter into a Master Water Supply Agreement with NOWA. NOWA would become the single utility responsible for the management of bulk supply. NORD would assume ownership of all water licenses and supply facilities and provide full supply operations (through NOWA). The municipalities would continue to be responsible for distribution and NOWA would transfer its distribution assets, within municipal boundaries, to the respective municipalities. No 'exchange of funds' would occur (KWLG&S Associated Preparation of the implementation plan for a Greater Vernon Area Regional Water Supply. Task 3 summary report for development of the plan. Draft. 1996)*

management model for NOWA, and that the voting structure and representation on the NOWA Committee be re-evaluated (NOWA Minutes, July 3rd 1996)[9]. This new composition changed the distribution of power of different parties within NOWA (see Table 10.4). Governance became a controversial issue in December 1997, when it was realised that Vernon literally had veto power at the regional level over any financial implications[10]. The Vernon representative on the NOWA Commission stated that the "City Council's participation in the Regional Water Commission [NOWA] was, and is, contingent on Vernon Council's veto of Commission [NOWA] initiatives at the Participating Directors weighted vote level" (NOWA Minutes, January 15th 1998). As a consequence, the IP was essentially put on hold.

Municipalities would enter into a Master Water Supply Agreement with NOWA. NOWA would become the single utility responsible for the management of bulk supply. NORD would assume ownership of all water licenses and supply facilities and provide full supply operations (through NOWA). The municipalities would continue to be responsible for distribution and NOWA would transfer its distribution assets, within municipal boundaries, to the respective municipalities. No 'exchange of funds' would occur (KWLG&S Associated Preparation of the implementation plan for a Greater Vernon Area Regional Water Supply. Task 3 summary report for development of the plan. Draft. 1996)

The following year, NOWA agreed to an increased membership on the NOWA Commission: three members from Vernon, two from Coldstream, both Electoral Areas B and C Directors and two representatives of the agricultural community (NOWA Minutes, June 24th 1997).

Although NOWA would be able to influence budgetary decisions, the authority to make financial decisions remained with the North Okanagan Regional Board. Voting at the Board level is based on a 'participating directors' weighted vote. Vernon holds 12 out of 20 such votes thereby giving it veto power i.e. ability to veto initiatives and direction of NOWA.

An Ad Hoc committee was formed in 1999 to seriously look at governance issues related to the regional water utility model (pers. comm. Stamhuis, Cotsworth *et al.*). Renewed interest in the formation of a regional water supply at the political level, following 1999 elections,

TABLE 10.4

	IRWA (EARLY 1990S)	INTERIM (MOU)	NOWA (1997)	NOWA (2000)	GVSC (2001)	WEIGHTED VOTES AT NORD (UNCHANGED)
City of Vernon	1	3	3	1	3	12
District of Coldstream	1	2	2	1	2	4
EA B & C	1	2	2	2	2	4
Agricultural community	2	2	2	1	1	-
VID	2	2	-	-	-	-
Total	7	11	9	5*	8	20
Management structure	Agreed in principle to a single water utility		Model D i.e. pool supply assets but distribution assets separate		"Model E" i.e. supply and distribution assets pooled under a single authority	NA

*This model was proposed but never implemented

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[9] *The following year, NOWA agreed to an increased membership on the NOWA Commission: three members from Vernon, two from Coldstream, both Electoral Areas B and C Directors and two representatives of the agricultural community (NOWA Minutes, June 24th 1997).*

[10] *Although NOWA would be able to influence budgetary decisions, the authority to make financial decisions remained with the North Okanagan Regional Board. Voting at the Board level is based on a 'participating directors' weighted vote. Vernon holds 12 out of 20 such votes thereby giving it veto power i.e. ability to veto initiatives and direction of NOWA.*

kick-started the commencement of discussions in early 2000. BX Creek was also closed during this time due to high levels of cryptosporidium[11]. Finally, in September 2000 a modified implementation plan was signed off, and in November 2000 work on the Master Water Plan was initiated. The management Model D i.e. pooled supply assets but retain individual authority over distribution, was retained (Associated Engineering Implementation plan 2000).

Due to financial structural constraints[12], the governance and management structure was once again modified in mid-2001 resulting in the establishment of the Greater Vernon Water Utility, responsible for both supply and distribution of water to domestic and irrigation customers. The Greater Vernon Services[13] Commission became the final governing body.

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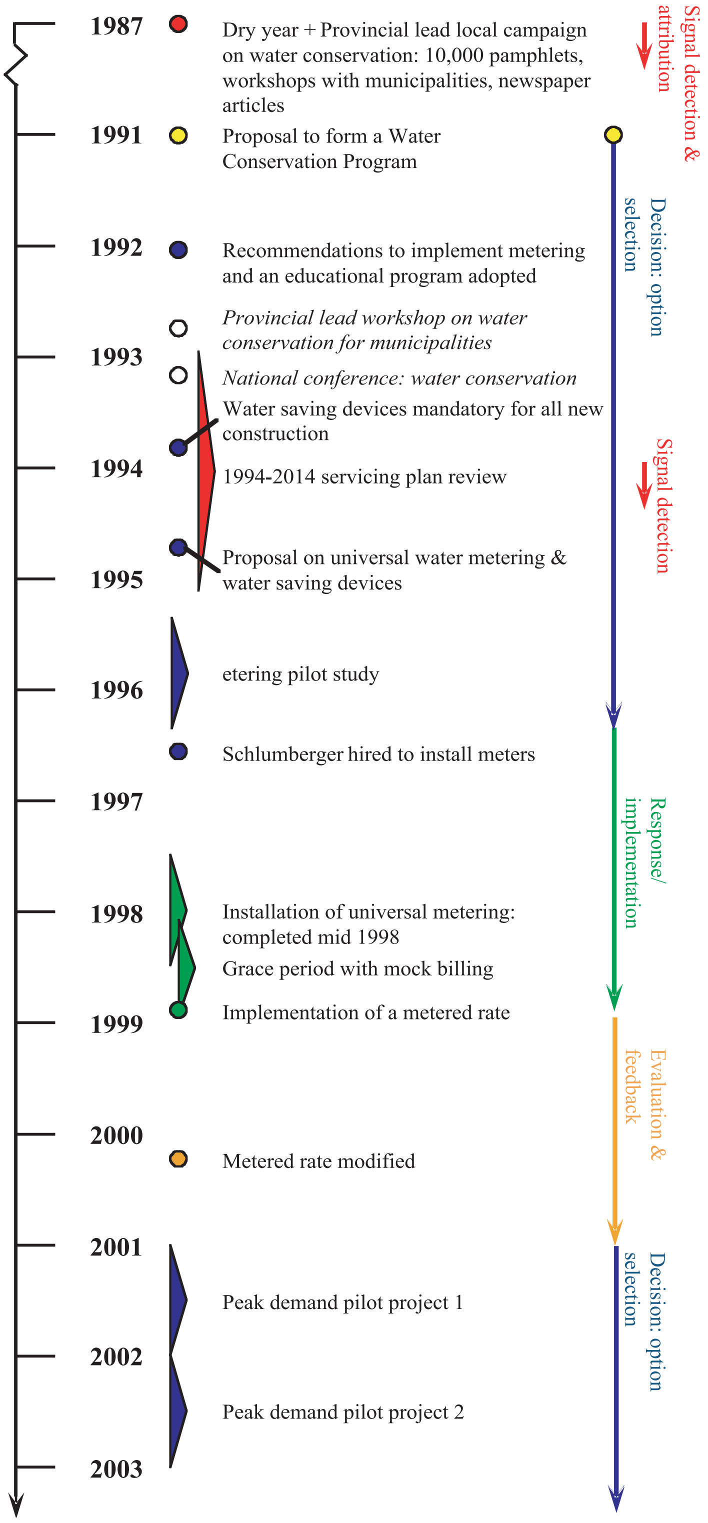
[11] *Represented 15% of Vernon's drinking water supply.*

[12] *Unable to reach consensus over the division of bulk water between distribution utilities (pers. comm. Stamhuis, Cotsworth et al.)*

[13] *Established in November 2000, the Commission mandate is to deal with matters pertaining to Parks & Recreation, the Greater Vernon Water Utility, the Multi-Use & Performing Arts Centre, Tourism & Economic Development and the Vernon and District Queens Committee.*

Kelowna Time-line

Adaptation Process



Key signal	Provincial water conservation campaign
Attribution *(the identified cause)*	Water demand
Contextual drivers *(factors influencing attribution, decision-process and evolution of the management option selected)*	Growing population Impending capital investment Comparative high per capita consumption Cryptosporidium outbreak Regional push for water conservation
Enabling factors *(conditional factors that aided adaptive behaviour)*	High level of awareness and interest of staff, Council and public Learning from neighbour experiences e.g. Vernon General "user pays" philosophy Political acceptability of the approach i.e. average user would not be significantly affected Municipal financial stability Borrowing approval from province
Obstacles *(problems that arose during the implementation process)*	Public attitudes i.e. water considered a plentiful resource Meters considered intrusive and controlling Internal communication between departments Some technical issues regarding installation
Conflict resolution/avoidance *(methods that were implemented to avoid or resolve disagreement)*	Awareness i.e. general and targeted education Testing i.e. pilot study Graduated implementation i.e. grace period for adjustment
Lessons learned *(reflections from interviewees on implementation)*	Build internal department relationships Education crucial Evaluation essential Business-case must be convincing
Lessons learned *(general reflections from interviewees)*	More accurate information enabled identification of key hotspots (high-end users)

CASE STUDY 2

Domestic metering in Kelowna

Key Actors

Five groups were involved in the process of establishing water metering in Kelowna City[14]: the City Council, management (Works and Utilities, Water Division – as well as other departments such as the Financial and Engineering departments, and Building and Inspection Services Department), external consultants, the provincial government (only in a funding capacity) and domestic water users in Kelowna.

Time-line

In 1987-88 the Okanagan Region experienced a significant dry year that left many water supplies in critical condition. In response, the provincial government initiated an awareness-raising campaign throughout the region encouraging conservation efforts. In August 1991, Kelowna Engineering Department was directed by City Council to develop recommendations on reducing water consumption in Kelowna and a plan to form a Water Conservation Program. Metering (with a constant unit charge) of single-family residential users[15] and a public education process (possibly including provision of water saving devices) were recommended for the Water Conservation Program and adopted by Council in April 1992 (Richardson 1992). In late September 1993 Kelowna's Plumbing Regulation By-Law was amended to prepare for a water-metering program, and install Ultra Low Flush toilets in new buildings in the City. Additionally Kelowna's Water Regulation By-Law was amended to make metering of all new users mandatory.

Then in late 1994, staff in the Water Division of the Works and Utilities department presented a proposal on universal water metering and installation of water saving devices to the Kelowna City Council. The final metering proposal was completed in January 1995. Early 1995, the 1994-2014 servicing plan review had indicated that in order to maintain current water demand for a growing population, infrastructure costs could exceed $40 million. The final program of implementation of universal metering is shown in Table 10.5.

TABLE 10.5

MONTH/YEAR	ACTIVITY
April 1995 to March 1996	Pilot project involving 102 residences that volunteered for meter installation[16] (Edmonton Water, 1996)
Early 1996	Report on the pilot scheme providing a detailed analysis of water consumption patterns of the 102 residences
Mid-1996	Contractor bid for installation and maintenance of universal metering. Schlumberger hired.
Early 1998	Based on the pilot project report, an acceptable rate structure was put together.
June 1998	Universal installation complete.[17]
January-November 1998	Grace period with mock billing.
November 1998	Implementation of the metered rate from a flat rate of $15.50 per connection to a base rate of $8 along with a CUC of $0.2076.
Spring 2000	Change in metered rate to a base rate of $7.60 with a CUC of $0.225.

The potential for reduction in water use was considered 20% from universal metering (mainly reduction in summer peak demand) and 10% from the installation of water saving devices (base demand) (Status report for City Council: implementation of universal metering 1994). Outdoor use was the primary target as it offered the greatest potential for demand reduction. Kelowna's overall objective of the metering-education program was stated as 20% reduction in single-family homes (Degen 1998). Prior to the implementation of rates, Council directed staff to inform customers of how a rate structure would change their bills i.e. a grace period. A customer education campaign was also implemented to inform customers on different methods to reduce consumption.

In all 11,500 homes were installed with meters. Rates were developed to achieve the aforementioned reduction targets, ensure sufficient revenue, be revenue

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[14] *Kelowna Municipality contains five water purveyors. This case concerns Kelowna Water Utility which services the main City area.*

[15] *Metering of commercial and industrial users was already in place.*

[16] *150 residences volunteered, however, only 102 had meters installed successfully.*

[17] *The bulk of meters were installed by the end of 1997 the remaining 'hold-outs' (problematic installation and customers refusing to have meters) were completed during 1998.*

neutral (for the City) and to be “politically acceptable”; in other words, annual bills for an average home would not significantly change from the former base rate. It was recognised at this point that a reduction in consumption may result in reduced municipal revenue and therefore rate increases in following years were recognised as a possibility (Degen 1998).

Following the metering program, Kelowna initiated two studies in 2001 and 2002 exploring methods to reduce peak water demand targeted at outside water use and high-end water consumers. Results of the studies identified education through social marketing i.e. based on personal contact with users, and a soil dressing, named “ogogrow” (high in nutrients with moderate moisture retention) to be the best approaches. With the help of Summerland Pacific Agri-Food Research Centre an alternative dressing was developed named “glengrow”**[18]** (pers. comm. Degen 2003). Kelowna is embarking on a City-wide program to implement these approaches for reducing peak demand.

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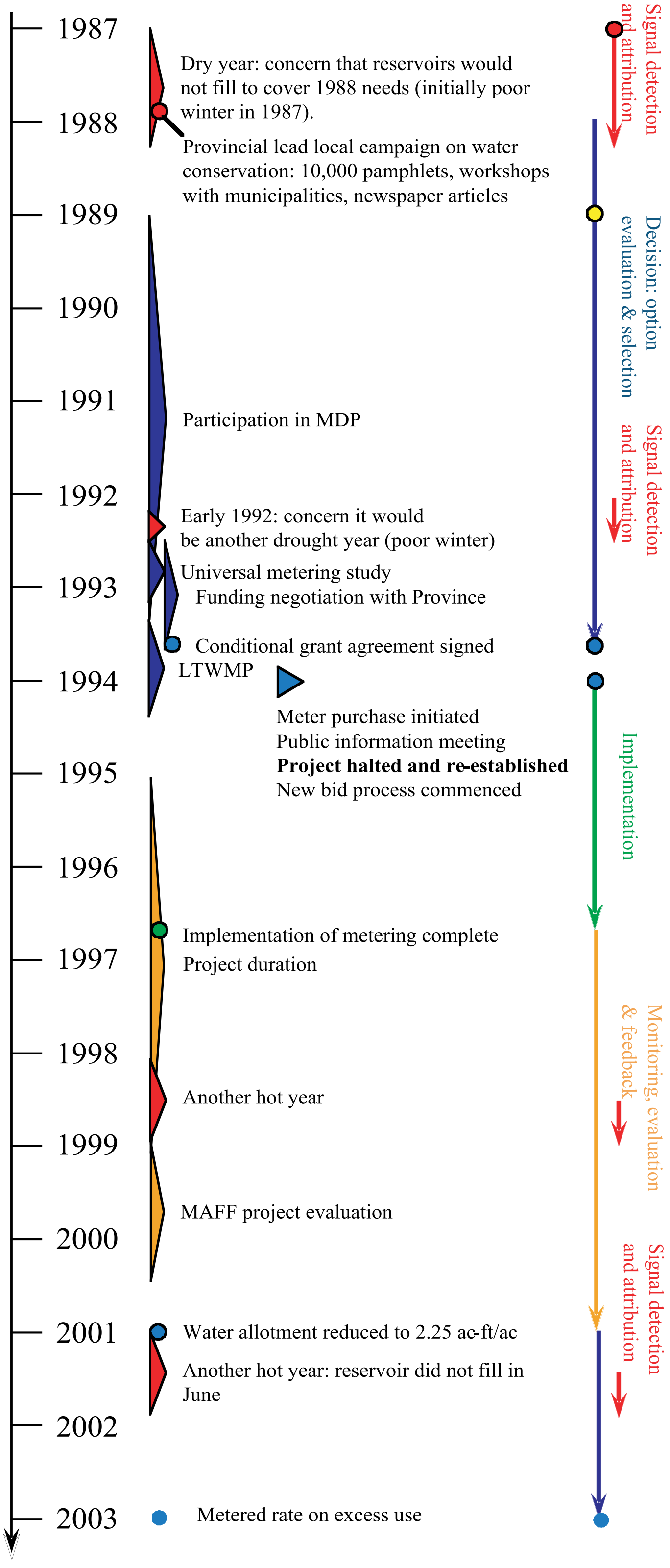
[18] *Glengrow consists of Kelowna's yard waste (prunings) ground up into fine compost.*

SEKID Time- line

Adaptation Process



Key signal	Extended hot growing season i.e. concern over meeting future demand with current capacity and conditions
Attribution *(the identified problem/cause)*	Overuse of water during dry spells and limited supply
Contextual drivers *(factors influencing attribution, decision-process and evolution of the management option selected)*	Increased residential development Large tracts of undesignated land Regional push for water conservation Conditional water license for further reservoir expansion Green Plan Funding
Enabling factors *(conditional factors that aided adaptive behaviour)*	Management pro-metering Board's open-mindedness toward metering Access to funding External expertise
Barriers *(factors that could have stopped each project from going ahead)*	Grower attitudes, discontent and distrust Potentially cost with lack of vehicles of finance
Conflict resolution/avoidance *(methods that were implemented to avoid or resolve disagreement)*	Communication and discussion: public information meeting and one-on-one meetings New management New bid on meters Information and education e.g. field days, water use
Lessons learned *(reflections from interviewees on implementation)*	Ensuring integrity, trust and transparency Effective communication Graduated program Time for preparation Education
Lessons learned *(general reflections from interviewees)*	Better drought management tool i.e policing Supply expansion is a regular planning function to anticipate and provide for growth. Once demand programs are maximized supply expansion is the obvious alternative.

CASE STUDY 3

Irrigation metering and scheduling in SEKID

Key Actors

Significant participants in the SEKID story include those internal to the district: the Board of Trustees, management staff and water users, and those external to the district: Federal and Provincial government, consultants and other organisations e.g. BC Fruit Growers Association (Table 10.6).

TABLE 10.6

Key participants in the SEKID story

ACTORS	COMPOSITION
Metering/Scheduling Project Committee Members (Established to oversee the implementation of the five-year demand management project).	SEKID Board of Trustees SEKID District Manager Representatives from BCMAFF Kelowna and BC Fruit Packers A SEKID farmer
Co-operating growers	Nine SEKID farmers
District staff	Internal and outside staff
General users	Farmers and residents
Advisory Board (Project supervision)	Representatives from: BC Ministry of Agriculture, Food and Fisheries (MAFF)
	Federal Agriculture and Agri-food Canada
	Irrigation Districts Association of BC
	Ministry of Environment, Land and Parks (MELP)
	BC Fruit Growers Association (BCFGA)
Consultants	Various

Time-line

Following, two very dry summers during 1987 and 1992 in the Okanagan, SEKID management and Board of Trustees began discussing how to improve demand-side management efficiencies in case of future droughts. In 1992, the district contracted Dayton and Knight to develop a report exploring costs of implementing metering in SEKID. This report concluded that:

- Total cost of implementing metering would be $1,193,000 ($441,000 for domestic and $692,000 for agricultural)
- If the District should implement a universal metering program it should be phased over a 5-year period beginning 1994
- The District should implement a bylaw requiring installation
- Explore other financing such as the Federal Green Plan
- There is a potential to reduce consumption by 38% (Dayton & Knight SEKID report on universal water metering 1993)

In 1990 the Ministry of Municipal Affairs released $20,000 to do a water study of Turtle Lake (a potential reservoir). At the same time, SEKID contacted MAFF to explore funding options for implementing metering. Dayton and Knight was hired to develop a Long Term Water Supply Plan in early 1993, which was completed in May 1994 (after metering went ahead). Regarding supply, the report concluded that under a drought sequence[19] there was over-committed Grade A water i.e. there would be a water shortage under these conditions (if all allocated water was consumed). The options suggested by the consultants to ratify the deficit included universal metering, scheduling and additional system storage at Turtle Lake (Dayton & Knight SEKID long term water supply plan 1994).

In late 1993, SEKID received verbal agreement from the provincial government that funding from the Canada-British Columbia Green Plan for Agriculture would be forthcoming. The Project Conditional Grant Agreement between SEKID and the province was subsequently signed on August 26th 1993. As stated in the agreement the project goal was three-fold: 1) Implementation of a demand management strategy through universal water metering; 2) Evaluation and demonstration of irrigation scheduling techniques; 3) Determination of a rate schedule that reflects an equitable allocation of water to agriculture users (MAFF Canada-British Columbia Green Plan for Agriculture, Project Conditional Grant Agreement 1993 p.15). Initially the project was committed to metering all users in the district i.e. all irrigation and new domestic connections were to be metered from 1994 onwards while existing domestic

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[19] *Ministry of Environment estimate of the critical Hydraulic Creek drought sequence is two consecutive 1 in 10 runoff years preceded and followed by two consecutive years of mean runoff (Dayton & Knight Ltd, 1994)*

connections were to be metered as changes were made to infrastructure. Reduced water use in SEKID was the main result expected, along with gathered information to assist development of future water policies in the Okanagan Valley and improve water use within the agriculture sector. Funding was finally secured in early 1994 once SEKID had selected a contractor for the purchase of meters.

In response to the metering project, some growers signed a petition opposing metering. Additionally, there was growing concern over the initial meter purchase process[20]. SEKID had not decided whether the universal metering project would go ahead, but they staged a public information meeting in January 1994 to discuss the project with water customers. Soon afterwards, the Board unanimously agreed to halt the metering project, probably due to the contentious nature of the project. Only after receiving a letter from the Ministry did they go ahead. The letter stated that subject applications would be 'held in abeyance' unless SEKID could prove that they were making beneficial use of their existing licenses, or they were undertaking to verify efficient use via means such as metering. In response, the Board rescinded their former decision and went ahead with the project, albeit only metering irrigation connections. Grower concern lead to the resignation of the manager at the time and some committed Board members were not re-elected. A new bid process was initiated and a different company was awarded the meter contract. SEKID received only a conditional water license to expand McCulloch reservoir in July 1994.

By late 1996, 421 irrigation service meters had been installed. Alongside metering, an irrigation-scheduling program was implemented as part of the public education process. Tensiometers were supplied to all growers while eight co-operating growers participated in an irrigation scheduling project involving the collection of data on water use, soil moisture and climate data. Growers were provided with weekly reports containing irrigation scheduling recommendations (Nyvall and Van der Gulik 2000). Three field days were held during the five years to demonstrate scheduling methods. In addition to water use, information on soil type in SEKID was determined using a LANDS system.

Analysis of water use during 1998 (one of the hottest years on record) indicated that the district's drought year demand was on average 2.25 ac-ft/ac – 10% lower than the original figure of 2.5 ac-ft/ac used to design the system in the late 60's (SEKID, 2003). This represented a "saving" of over 1,300 ac-ft considered at least partly attributable to the metering and scheduling project. Actual consumption was estimated to have decreased between 5-23% over the duration of the project (Nyvall and Van der Gulik 2000). As a result, allotments based on this figure were allocated in 2001, fines of $100 imposed on users exceeding the allotment in 2002 and finally in February 2003 a charge for excess use above the new base allotment of 2.25 ac-ft. Consideration of a metered rate began after a serious dry year in 2001 where in June the district's main reservoir did not fill (for the first time in 30 years) (SEKID, 2003).

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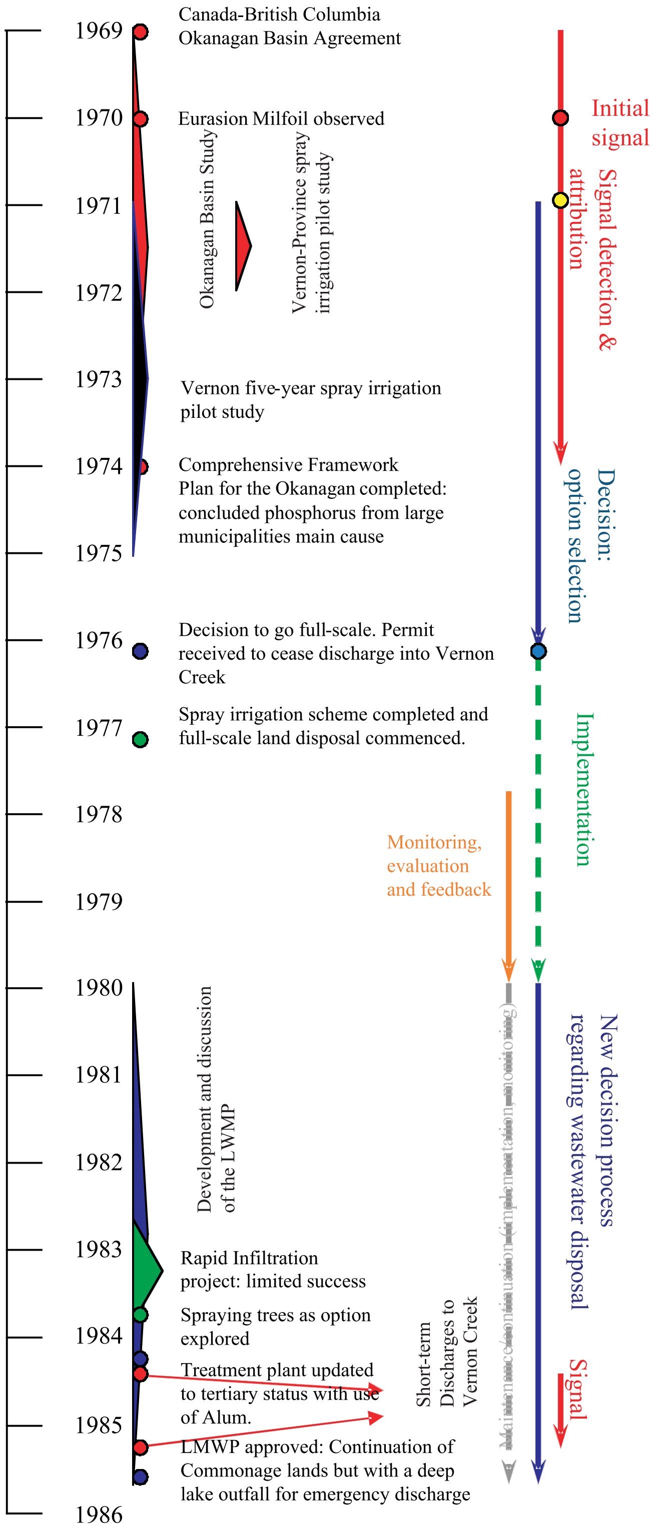
[20] *Rather than going through the appropriate bid process, SEKID, on recommendation by the then water manager, chose to give the bid directly to one consultancy.*

Vernon Time-line

Adaptation Process



Key signal	First ever observation of milfoil in British Columbia
Attribution *(the identified cause)*	Provincial study
Contextual drivers *(factors influencing attribution, decision-process and evolution of the management option selected)*	Staff interest in an environmental alternative to treatment Public & political perception Tourism Federal-Provincial attitudes toward water reclamation i.e. in favour but eventually conditional beneficial Provincial wastewater regulation
Enabling factors *(conditional factors that aided adaptive behaviour)*	Vernon's self-image Openness of the Council Success of the pilot study on the commonage area Farmer benefits from application of reclaimed water Citizen support for avoiding discharge into the lake
Barriers *(factors that could have stopped each project from going ahead)*	Political agendas Limited viable land for application Initial farmer attitudes against the use of reclaimed water (Spallumcheen) Mixed public perception Funding
Conflict resolution/ avoidance *(methods that were implemented to avoid or resolve disagreement)*	Compromise i.e. trying to factor in S.O.L demands into water reclamation policy Farmer incentives Buffer zones around residential areas Scientific evidence
Lessons learned *(reflections from interviewees on implementation)*	Ensure costs and benefits are equally shared by users and authority Mutually beneficial process Real value reflected in cost of reclaimed water Buy-in from citizens. Value the resource
Lessons learned *(general reflections from interviewees)*	Reclaimed water is a valuable resource Water reclamation not only a treatment method but an alternative supply approach.

CASE STUDY 4

Water reclamation in Vernon

Key Actors

A range of actors were involved in the evolution of water reclamation in the City of Vernon. Key organisations/groups involved in the decision-making process over the course of the time-line included:

- The City of Vernon
  - City of Vernon Council
  - Vernon Utility Management i.e. Engineering and Public Works department
  - Spray Irrigation Advisory Committee
- Environmental groups
  - Save Our Lakes environmental citizen group
- Okanagan Indian Bands
- Provincial government
  - Ministry of Environment, Waste Management Branch
  - Ministry of Forests
- Various consultants and research organisations e.g. UBC

Time-line

In 1970, the Eurasion Milfoil, an intrusive aquatic weed, was observed for the first time ever in B.C. in the Okanagan Lake around Vernon (Davies, Gow *et al.* 1996). According to a 1975 study, Eurasion Milfoil growth in the Vernon Arm of Okanagan Lake had been a source of public concern since the beginning of the 1970s. Beach areas along the shores of Vernon Arm were subject to increasing populations of Milfoil, occupying an area of about 100 acres (Wilson and Wan 1975).The Federal-Provincial Okanagan Basin Agreement Study concluded in 1974 that the main source of phosphorus was effluent discharge from major cities: Kelowna, Vernon and Penticton (along with other sources such as septic tanks), and assumed that phosphorus removal/reduction would limit Milfoil expansion (Haughton, Giles *et al.* 1974). Two obvious options were available to alleviate this problem: upgrading wastewater treatment facilities to tertiary status, or effluent spray irrigation.

After a successful pilot project, full-scale water reclamation was implemented in Vernon in 1977. Initially, production of wastewater exceeded application, so the City of Vernon embarked on the implementation of a Rapid Infiltration Program[21] in 1983 to dispose of "un-used" treated effluent. One year later (after 160 million gallons) the applied reclaimed water broke out below the basins. Subsequent charges and suits were laid against the City, and the then Ministry of Environment administered a stop order. As a result, the sewage treatment facility was upgraded to tertiary status, to include chemical removal of phosphorus[22] for use in the event of an emergency discharge to Vernon Creek. Due to high precipitation in 1983, minimal discharge into Vernon Creek occurred during 1984 and 1985[23]. (Jackson 1985; Jackson 1986). As part of the 1985 Liquid Waste Management Plan, a deep-lake outfall into Okanagan Lake was constructed to discharge excess effluent not used on the Commonage area (main spray irrigation area).

Following the election of Mayor Clark in December 1986, a citizen environmental lobby group, Save Our Lakes (S.O.L.), was formed in protest against the City Council's 1985 decision to construct a deep-lake outfall. Throughout early 1987, the group called for an immediate stop to the construction of a deep-lake outfall pipe; a greater focus on expansion of the spray irrigation program through forest land utilisation or construction of a new reservoir; and, a public referendum on the deep lake outfall option.

Growing pressure to improve the spray irrigation program also came from the Provincial Government, requesting that high rate application be avoided[24], and that suitable and beneficial uses for the effluent be prioritised. S.O.L initiated a court action against the City of Vernon, which resulted in a decree by the B.C. Supreme Court that the outfall could only be used as an emergency option for discharging effluent.

In fall 1990, a new Mayor was elected, Mr McGrath. Under the new mayor, an advisory committee on spray irrigation was established, and more significantly, a

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[21] *This entailed the establishment of 3 basins in an irrigation field area with sandy soils. The objective being to flood the basins and use the ground to remove phosphorus.*

[22] *With Alum - any of various double salts isomorphous with potassium aluminum sulfate.*

[23] *26.7% higher than the average yearly precipitation for the previous 60 years*

[24] *In an effort to avoid discharging effluent into Vernon Creek, the City had been operating the spray irrigation system at application rates that were at the upper end of acceptable agricultural rates.*

review of the 1985 Liquid Waste Management Plan commenced. Under the new Council, spray irrigation was prioritised and relations with S.O.L improved. Additionally, the Sewage Treatment Plant was renamed the Water Reclamation Plant. By 1997, the first stage of the LWMP was ready for public comment. A public meeting was held in June 1997 to discuss the location of the Water Reclamation Plant and the ultimate fate of effluent (land or water discharge). Following the meeting, Council accepted in principle an option that involved applying effluent to Predatory Ridge Golf Resort and Coldstream. At this point, treated effluent levels in the reservoir reached critical levels in late 1997 due to wet weather conditions. In August of that year it was advised by the Vernon engineer that a discharge into the Okanagan Lake was impending and prior to discharge tertiary treatment works would be activated to remove 90% phosphorus. The first ever discharge into the lake occurred in early 1998 and lasted over 88 days.

Coldstream opposed their inclusion in the LWMP advising Vernon that they would proceed with their own plan and would not provide Vernon with irrigable lands. A seventh alternative was developed based on a dual water system approach. Reclaimed water could be used for outside urban irrigation as well as for agricultural use, reducing demand for potable quality water. The new LWMP was approved in April 1999. However, after the election of a new Council and Mayor in 1999, the LWMP was again revised. The dual system was scratched in favour of an upgrade of the existing tertiary sewage system to a Biological Nutrient Removal (BNR) system. There was minimal opposition to the new LWMP within Council. Construction of the new plant was still underway in late 2003.

10.6 Adaptation to climatic change in the Okanagan: what can be applied from this study?

10.6.1 Autonomous versus planned adaptation

In climate change literature, this research would be identified as a study of autonomous adaptation. In other words, it looks at adaptations that have not specifically been implemented to cope with climatic change. Distinguishing between planned and autonomous adaptation is a simplistic dichotomy that only has utility for identifying the costs associated with adaptations directly responding to climate change. This study shows that although one trigger or signal can be identified, adaptation process in a given context will be driven and shaped by many factors, not just one motivating condition. Planned adaptation to climatic change will therefore be influenced significantly by initial conditions and the evolution of these conditions. Therefore, planning adaptation to climatic change will have to take into consideration the initial conditions that might constrain or encourage adaptation, as well as the many social uncertainties that will shape implementation and outcome. So, the first question to answer is what lessons can be learned from these studies that might be useful in planning for climatic change, both in terms of specific conditions and adaptive capacity.

The distinction between autonomous and planned adaptation also breaks down because the former could indirectly reduce vulnerability to climatic change, while adapting to climatic change will have many ancillary benefits. If autonomous adaptations are beneficial to climatic change they should be encouraged also for that reason. Multiple objectives, rather than a narrowly defined objective, should be the goal. So a second question is, do these so-called "autonomous" adaptations studied here have the potential for reducing vulnerability to climatic change (while being sensible measures for tackling current issues)?

10.6.2 Context and conditions in the Okanagan: challenges to adapting to climatic change

These cases reveal the complexities involved in any major decisions. Initial conditions set the scene for change, while many factors along the path of adaptation shape the journey and outcome. Specific conditions that could pose challenging to adapting to climatic change impacts (in concert with other stressors), and identified means to tackle such challenges, are outlined below.

10.6.2.1 Values and perceptions

The values of individual decision-makers and institutional values (i.e. agendas and policies) at different levels of government, as well as the values of users, significantly influence signal interpretation, option selection and the character of implementation.

Grower attitude toward the water resource is a significant issue for adapting to future climatic change. Firstly because irrigation still represents the dominant water use but more importantly, these attitudes are historically entrenched. Significant financial support for agricultural infrastructure has ensured access to cheap water, and water has been a plentiful resource with allotments based on peak demand needs. In order to maintain low water rates, capital will have to come from another source – so who will foot the bill? Residential spread onto agricultural dry lands and into the agricultural community is an increasing pressure on a resource that was once (and still is) the privilege of the farmer. Prior appropriation, which underpins water rights regulation in British Columbia, means that this privilege under drought conditions is maintained – at least without significant conflict between different user needs. Farmer attitudes are not the only perceptions that one needs to be cognisant. The sense of ownership extends to the local authorities as the GVWU case exemplifies. Advocating any form of regional approach (which is a key provincial agenda) requires buy-in from all involved, realisation of mutual benefits and ultimately comprise.

The character of decision-making procedures, specifically the need for transparency, direct communication, and stakeholder participation, is highlighted in these case studies as solid methods for achieving a just and possibly smooth transition. Trust between the decision-maker and the user (in a broad sense those affected by a specific decision), which can be aided through a transparent and participatory approach, is the underlying factor.

Education and communication (not only public education, but staff and Council education as well as interdepartmental communication) are also aspects of the adaptation process that were identified as means to reduce conflict. Success in raising awareness and educating the target audience of a changing circumstance is partially determined by the framing of information. How information is framed in these case studies seems crucial to fuelling or dissipating public dissent. Framing needs to be compatible with the target audience. Complex information was particularly challenging. Finally, preparation through proactive planning and action allows time for the social system at hand to "unlearn" and realign to a new way of thinking or doing.

10.6.2.2 Financial issues

Although access to financial support didn't manifest as a barrier in any of the cases (in other words, financial support was available - at the right time!), it cannot be assumed that financial sources will stay the same or at the same level in the future. Provincial funding and borrowing schemes come and go and are susceptible to governmental leanings .How provincial funding and lending for local water management infrastructure projects will evolve will partially determine whether the future burden of cost will fall more and more on the consumer. Additionally, as the resource becomes scarcer, price structures will be used to curb use. Rated metering in residential areas, such as in Kelowna, poses minimal conflict and there seems little reason not to apply this to all urban areas in the Okanagan. However, what is a politically acceptable water rate in one area might not be deemed so in another.

If increasing water rates for both residential and agricultural users is inevitable, there are implications. What about those that cannot afford increased water rates? What will the impact be on the agricultural community? How does cost relate to crop type and global food markets? Should the urban community subsidize the agricultural community? Unsurprisingly, access to provincial funds is key. It was intimated in the interviews that funding is currently used to forward provincial agendas e.g. GVWU and SEKID projects (agendas being regionalisation and water conservation respectively).

In summary, the key questions regarding financial support that would be useful when discussing adaptation to multiple stressors, including climatic change are:

- Who should bear the cost?
- What is acceptable cost? (Differing perceptions of political acceptability and equity)
- What will the cost be to the individual?
- Who should have access to provincial-federal funding and provincial lending? Under what conditions should they be disseminated?

10.6.2.3 Politics and policy

In each case, political will was cited as an important enabling factor; without political buy-in, a decision is hard to make. However, adaptation (especially over the long-run) is susceptible to changes in political agendas. As one interviewee put it, the action has to be politically resistant. Differences in perceived public (political) acceptability is another potential barrier. What might be considered acceptable in one region might not be in another. Regionalisation is most prone to political concerns because the challenge is getting 'buy-in' from multiple stakeholders. In terms of inter-governmental issues, transparency is needed to engender trust between the different levels of government, e.g. as in SEKID's case.

Regulatory change is an effective motivator for local change. The challenge is to ensure that the resources are there for effective implementation. For example, a Ministry representative noted that there is no longer adequate 'extension staff' to go out and talk to farmers in the field. In terms of water quality, more stringent standards will be costly for local government if funding is not available. The application of "beneficial use" is another example of regulatory pressure. Could this be applied more stringently as water resources become scarcer?

10.6.3 Adaptive capacity

While adaptation is the act of adapting (the decisions that are made, its evolution from initiation to implementation), adaptive capacity defines the conditions that allow (or prevent) adaptation to occur. According to Tomkins & Adger (2003), achieving social resilience to environmental pressures is the key aim of building adaptive capacity – or feature of an adaptive system. Three general characteristics are suggested as necessary features to enable social systems to be resilient: the ability to buffer disturbance, the capability to self-organise and the capacity for learning and adaptation. In other words, an adaptive system needs to be able to absorb shock but simultaneously be flexible enough to change when the coping threshold is reached[25].

There are many underlying aspects of a social system that determines its level of adaptive capacity. In the context of climate change, the IPCC (2001). defines adaptive capacity as: "ability of a system to adjust to climate change. General adaptive capacity for example, can be seen as a function of wealth; population characteristics, such as demographic structure, education and health; organisational arrangements and institutions; and access to technology, and equity, to name only the most salient variables. More specific adaptive capacity relates to the specialized training, research, and institutions that are required as inputs to climate adaptation measures and policy" (p.6). Yohe & Tol (2002) go further than providing a definition and develop an equation that estimates adaptive capacity based on 8 determinants: technology, resources, institutional set-up, human capital, social capital, risk sharing, information management and public risk perception.

Lorenzoni, Jordan *et al.* (2000) distinguishes between subjective and objective adaptive capacity qualities. Subjective qualities are considered as 'self-perception of stakeholders with regard to their ability to respond to challenges arising from environmental/climate impacts. Arguably the simple perception that *something needs to be done* in an organisation to respond to a particular threat is as, if not more, important than the presence of a particular threat' (p.150). Burton, Huq *et al.* (2002) echoes this sentiment: 'Adaptation depends upon the capacity of systems to adapt, and also on the will or intent to deploy adaptive capacity to reduce vulnerability. The mere existence of capacity is not itself a guarantee that it will be used' (p.150). Objective qualities on the other hand 'relate to its management (e.g. availability of information about change, the capacity to plan, its overall capital intensity), capabilities (financial, organisational, skills to manage change) and structure (flexible or rigid) – these will pre-determine adaptive capacity' (Lorenzoni, Jordan *et al.* p.150)

Based on these thoughts, there are three levels of adaptive capacity: general, objective and subjective. The goal of building adaptive capacity is to create a system that is resilient (in its broadest meaning).In other words one that has the capacity to cope until change is necessary, be able to change and learn from the adaptation.

As the study is at the level of the organisation, and not for example a nation, higher level components of adaptive capacity such as demographics have not been studied.[26] However, comments can be made regarding objective and subjective aspects of adaptive capacity. These comments summarise the details featured in the discussion of context and conditions in section 10.6.2 above, and in the tables in Appendix 10.

It is clear that many objective factors contributed to adaptation in these cases: financial capacity, expertise, technology, and institutional structures. For example, Green Plan provincial funding contributed to the go ahead of irrigation metering in SEKID, while access to provincial loans ensured lower domestic water rates in GVWU. Access to expertise is a requirement in any new development both in option evaluation and implementation. Technology that fits the specific physical challenges and user-maintenance needs

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[25] *Although there may be objective thresholds e.g. when water levels reach a certain level, defining what thresholds should be acted upon are susceptible to human perception.*

[26] *Although even at the level of a local authority, demographics or wealth can be a significant determinant of adaptive capacity or the system's vulnerability e.g. water use is strongly related to economic status.*

contributes to a successful outcome. Legislation and regulation can be effective barriers as some are institutionally entrenched such as the prior appropriation system of water rights. However, changes in regulatory regimes can be key motivators of change.

Subjective capacities also influence the adaptation process. For example, the desire to act in Kelowna's case, decision-maker values in Vernon's changing political landscape, or simply having a perception that it needs to be done e.g. SEKID. Trust is a pivotal element in enabling the adaptation process. In the case of SEKID, the manager being fired, contracting a new firm of consultants, and election of new members to the board are all elements that lead to greater trust in the purpose and fairness of the metering initiative. Creating the GVWU hinged on the establishment of a suitable governance structure, which was ultimately based on trust between the co-operating partners. Perceptions of each initiative were equally influential. Water reclamation was a controversial approach that never really embedded itself into the values of the politicians because of its very nature.

Effectiveness of objective determinants is dependent on many different factors. Timing, magnitude, relevance, application will all influence whether such factors will actually have an impact or not. Effectiveness of financial capacity is dependent on its magnitude and timing relative to perceived need. Direct experience-based knowledge (as opposed to scenarios and second-hand information) is much more effective for avoiding obstacles. In other words, early adoption is likely to be more challenging because little prior experience-based knowledge is available. Technology has to be adaptable to the specific conditions to which it is being applied. Comments on relative strength of each determinant aren't possible here but it is safe to say that many factors have to be in place simultaneously for change to occur. However, each determinant is not mutually exclusive from the others. How one impacts another; whether in combination they negate, compliment or enhance capacity is another question.

Finally, are there specific capacities that are more significant depending on the adaptation in question, will climatic change require unique capacities to reduce vulnerability? Arguably many of the aforementioned determinants will be required. However, capacities such as knowledge and perceptions will be key issues as climatic change is still a relatively new phenomenon and is not as yet explicitly considered in water management decisions at a local level. Whether regulatory regimes will have to change in order to cope more effectively with increased drought episodes in an ever increasing water short (i.e. imbalance between supply and demand) region could be another area where capacity needs some work.

Table 10.7 below presents the many factors aggregated from the four cases (not necessarily common to all four) that played a role in enabling action and ensuring follow-through.

10.7 Appropriate adaptations and effectiveness

There are many types of adaptation measures that can be implemented to cope with stress and change. Measures can be implemented at different scales by different institutions. Realistically, which option is the most appropriate depends entirely on context: available resources, type of stress, geographical location, as well

TABLE 10.7

Factors enabling action and ensuring follow through

"OBJECTIVE"	"SUBJECTIVE"
Financial capacity: ■ Initial authority financial stability ■ Access to financial support when needed	Values and perceptions of key actors: ■ Users ■ General public ■ Decision-makers ■ Experts
Knowledge and expertise: ■ External support and research ■ Internal management ■ Training opportunities	Organisational or institutional cohesiveness: ■ Internal i.e. Council-management ■ External i.e. provincial-local ■ Trust
Available technology ■ Specific to the adaptation ■ General	Political ■ Cycles (can be both a barrier and an enabling factor) ■ Political acceptability ■ Leadership
Institutional/regulatory system: ■ Current structure and content ■ Development of regulations	

as values and judgement. However, prescriptive criteria for selecting appropriate adaptations have been suggested.

Ivey *et al.* (2001) cited five characteristics of successful adaptation activities: 1) Anticipatory: proactive measures initiated prior to "an event"; 2) Flexible: effective under different water regimes; 3) "No regrets": justified under existing hydrological conditions; 4) Implementable: resources should exist; 5) Responsive: consistent with many of a community's other goals e.g. environmental. Loë, Kreutswiser *et al.* (2001) proposed eight factors that should be used to *screen* measures for *use in the near term*: "no regrets", reversibility, minimize environmental impacts, cost effectiveness, equity, reduce vulnerability, ease of implementation (feasibility) and effectiveness. Paavola and Adger (2002) point out that what strategy is selected can influence flexibility in strategy selection in the future. They distinguish between those adaptation strategies that are supplementary and those that are complimentary: if alternatives are supplementary, one alternative may compromise the ability to implement other alternatives; if complimentary, one alternative may increase opportunities for the implementation of other alternatives.

Do the adaptation options selected in this study fulfill any of the above characteristics if considering further implementation throughout the region? Answering this question fully is beyond this study. However, a cursory analysis according to these criteria is presented in Appendix 10. Additionally, these screening criteria should be applied to a much larger body of options, to ensure that all possible approaches have been considered before their application.

Applying these criteria identifies options that are: 1) paths of least resistance i.e. ease of implementation and available resources; 2) financially viable i.e. cost effective and equitable; 3) applicable under uncertainty i.e. no regrets, flexible and reversible; 4) sensitive to other goals i.e. minimise environmental impacts and consistency with community goals; 5) applicable under climatic change i.e. flexible and reduce vulnerability. Metering domestic and irrigation fulfill many of these criteria. Water reclamation is potentially difficult due to issues of physical and perceived barriers to implementation. Utility amalgamation requires significant financial outlays and institutional re-arrangement, and so doesn't represent a path of least resistance and isn't flexible or easily reversible. According to these screening criteria institutional rearrangement would be the last approach to take after acceptable technical and economic fixes were in place.

In conclusion, there is a time and place for each adaptation option; starting with those that represent paths of least resistance while endeavouring to pave the way for more substantial, yet problematical approaches.

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chapter 11

Costs of Adaptation Options

(from the 2003 Interim Report)

Roger McNeill

Because climate change is likely to change precipitation patterns, reduce snowpack storage and increase crop water demands, many water supply systems in the Okanagan may not be able to meet future demands based on their current supply capacity. A number of adaptation options are available that can help meet possible shortages due to climate change and other factors such as population growth. These options include both demand side measures and supply side measures. Demand side options include water conservation alternatives such as irrigation scheduling, public education, metering and adoption of efficient micro irrigation technologies. Supply side options include increasing upstream storage and switching to the mainstem lakes or rivers as a supply source, thereby relying on the large storage capacity of Okanagan lake.

The costs of both demand and supply side options will vary greatly depending on various features of the individual water supply systems and the type of demands served. It is difficult to advise or present site-specific adaptation options and their costs to individual water supply systems without detailed engineering assessments. However, the questions of managing water supply and demand are not new to the area. Continuing population growth and changing land use patterns have already placed stress on many local water supply systems and a great deal of engineering knowledge and experience exists in the study area relevant to adaptation options. Therefore the study team contracted the services of Earthtech Environmental Services in Kelowna, who have worked on development and management of numerous water supply systems in the Okanagan, to assess the range of adaptation costs and relevant system characteristics that would affect the choice of adaptation options (Hrasko, 2003).[27] The report by Earthtech forms the basis for the costs presented in this section.

11.1 Demand Side Management Options

These options have proven effective in several areas of the Okanagan and in other regions in North America. They can be used singly or more commonly as part of a package of water conservation initiatives. They include both technological options, such as changing to efficient micro irrigation systems, and social behaviour options where consumers are persuaded through public information or rational water pricing to reduce waste and conserve water.

11.1.1 Public Education

This option can achieve a 10% reduction in water use if a consistent effort is made to reach the public, stressing the importance of reducing consumption and showing how water can be used efficiently. The per unit cost of water saved will vary depending on the size of the system since there are definite economies of scale. For example a large system can afford to hire a full time coordinator in charge of public mail-outs and disseminating information to customers. For medium to large systems the costs of water saved by this option are estimated at $835 per acre-foot for a system with 10,000 connections and a full time coordinator.

11.1.2 Irrigation Scheduling

This involves metering of individual agricultural operations without per unit pricing. The objective is to provide each grower with an accurate figure of how much water he is using compared to how much is actually required based on soil and weather conditions. This option has proved to be very cost effective in the South East Kelowna Irrigation district which achieved a 10% water saving. For irrigation districts with large holdings, fewer meters are required on a per acre basis resulting in a low cost of $500 per acre-foot of water saved. For an irrigation district with smaller holdings the costs would go up to $835 per acre-foot.

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[27] *This report was jointly funded by the Municipality of Summerland and by the Okanagan Climate Change Project.*

11.1.3 Efficient Irrigation Systems

The Earthtech report analyzed both a microjet system and a trickle irrigation system. The figures discussed below are for trickle irrigation systems, which were slightly more cost effective in terms of per unit cost of water saved. Costs of installation are constant on a per acre basis meaning that there are no real economies of scale for larger conversions.

The trickle irrigation system should result in a savings of 30% of the water used by a conventional sprinkler system. In areas of high crop water demand the actual water saved will be higher on a per acre basis giving a lower cost per acre-foot of water conserved. As rough examples the analysis considers annual water demands of 2 feet, 3 feet and 4 feet with per acre-foot costs of water saved at $2500, $1667 and $1250 respectively.

11.1.4 Leak Detection

The amount of water that can be saved by leak detection and repair depends upon the age and maintenance of the system. Several older systems in the area could benefit by such a program with savings of 10% to 15% of current usage. The costs will depend on the nature of the leaks, as large leaks will have a lower cost per unit of water. An approximate range for the costs of water saved by leak detection is from $1300 to $1900 per acre-foot.

11.1.5 Domestic Water Metering

Larger communities in the Basin have already instituted domestic metering, but several smaller communities are unmetered and charge domestic users a flat rate. Based on the experience with larger communities, such as Kelowna, a reduction of 20 to 30% in domestic water use is reasonable with the implementation of meters and a usage based price. The cost of metering will be less for communities with over a 1000 connections because of bulk purchasing and installation. The cost range is from $275 per installed meter for the larger communities to $350 for the smaller systems. On a per acre foot basis the lowest cost would be $1882 assuming greater than 1000 connections and a 30% reduction. If a 20% reduction is assumed costs would be 50% greater ranging up to $2800 per acre-foot of water saved.

11.2 Supply Side Options

Historically most water supply systems have relied on water from tributary streams stored in upstream reservoirs. These types of systems, using gravity to distribute water, tended to be more economical than systems that required pumping from the mainstem lakes and rivers. Population growth and water quality concerns have resulted in some of the larger communities changing over to mainstem water supplies. The use of mainstem water also provides a measure of security against climate change because of the huge reservoir capacity represented by Okanagan Lake in comparison to small upstream reservoirs.

For a smaller system that may face shortages due to climate change, there are two basic supply side options:

- Supplement or replace tributary water supplies from other sources (usually mainstem water)
- Increase upstream storage capacity

Under the first option the principle source of supplementary water will be the mainstem lakes or river. This water would have to be pumped up to a balancing reservoir to feed the domestic and irrigation connections often located at a considerable altitude above the lake level. In some limited cases there may be groundwater supplies that could help supplement tributary water, although this option has not been analyzed in this report.

The second option involves increasing the height of current dams or building new dams and reservoirs on tributary water systems to increase the catchment during the freshet.

11.2.1 Switching to Mainstem Water Supply

For a single water supply system, the option of switching to mainstem water is worth considering because the potential exists to supply 100% of current and future water demands, a potential that does not usually exist with other supply or demand side options. On a larger scale there is enough storage in Okanagan Lake for every individual system to go to mainstem water as primary supply although the lake management regime would be affected. Currently the lake is managed for a combination of flood control and fishery concerns. A larger scale analysis would be required to determine an optimal rule curve to accommodate the potentially larger demands that would occur as well as the requirements for flood control, fisheries and transboundary lake level accords.

The economic cost of switching to mainstem water is very specific to the size and physical setting of the water supply system. Cost factors include the maximum daily demand, the elevation and distance from the mainstem water supply, the lake bottom characteristics near the intake, and how much of the current supply infrastructure could be incorporated. A major factor is whether the current balancing reservoir could be used in a lake pumping system or if a new one would have to be constructed. The report by Earthtech developed cost curves, which can be applied with site-specific cost factors to develop cost estimates of supplying mainstem water to individual systems. Given a reasonable range of assumptions about the current systems, the cost per acre foot of supplying lake water ranges from $648 per acre foot for a low elevation system with no new balancing reservoir to over $2,600 for a higher elevation system requiring construction of a new balancing reservoir.

11.2.2 Increasing Upstream Storage

Because upstream storage on tributaries has been the historically preferred way of supplying water since the early 1900's, most of the low cost sites have already been developed. A very limited amount of low cost storage enhancement may be available through raising the height of current dams or development of small sites. These low cost options would be in the order of $600 per acre-foot but are not available in most tributaries. Most systems, if any potential for increased storage exists, would be facing costs of at least $1500 per acre-foot. It is difficult at this stage to gauge the potential increase in water that could be supplied through storage without detailed engineering studies.

11.3 Summary of Adaptation Cost Information

In summary, there is no one least cost adaptation option for all water systems since costs will vary significantly from system to system. The lowest cost option in one area may turn out to be a higher cost option in other areas. Other factors, such a water quality and treatment options will also enter into the decision. Often a combination of options will be necessary in order to achieve full insurance against future water shortages and demand increases.

For future budgeting purposes, it appears that systems that are already near capacity would have to consider costs of least $1000 per acre-foot to conserve or develop supplies of water to adapt to climate change. If projections indicate that large amounts of water must be conserved or supplied then probably $2000 per acre-foot would be a reasonable figure to consider in future budgets. Site-specific engineering studies would have to follow to obtain more accurate figures.

As an initial reference, Table 11.1 below shows adaptation costs per acre-foot from lowest to highest. It must be noted that each figure in Table 11.1 applies to specific circumstances; managers of a particular water system would have to consider the physical characteristics and customer base of their system before determining where they fall on the spectrum of water adaptation costs.

11.4 References

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TABLE 11.1

Range of Adaptation Costs

OPTION	COST PER ACRE FOOT	POTENTIAL WATER SAVED OR SUPPLIED
Irrigation scheduling - large holdings	$500	10%
Lowest cost storage	600	limited
Lowest cost lake pumping	648	0-100%
Public education -large and medium communities	835	10%
Irrigation Scheduling - small holdings	835	10%
Medium cost storage	1000	limited
Low cost lake pumping (no balancing reservoir)	1160	0-100%
Trickle irrigation in high demand areas	1500	30%
Average leak detection	1567	10-15%
Trickle irrigation in medium demand areas	1666	30%
Lowest cost domestic water metering	1882	30%
Medium cost lake pumping	2200	0-100%
Domestic water metering, small communities	2300	30%
Higher cost lake pumping	2700	0-100%
Higher cost metering	2700	20%

chapter 12

Exploring anticipatory adaptation in the Okanagan, BC

James Tansey and Stacy Langsdale

12.1 Introduction

This chapter describes the results of a study focusing on water management in the Okanagan Valley in southwestern British Columbia. The study extends earlier work on the likely impacts of climate change in the region (Cohen and Kulkarni 2001) primarily by shifting the emphasis away from future impacts of climate change and towards actions and interventions in the short to medium term that may reduce the vulnerability of the region to climate variability and climate change. In the earlier study, stakeholders were invited to attend a one-day event to explore possible future adaptations to the region wide impacts predicted using three downscaled Global Circulation Models, in combination with a hydrological model that was tested and calibrated for the region. While the findings were useful, three broader lessons were derived from the study. First, it became apparent that few, if any of the key governance decisions were being made at the regional scale. Instead, it became clear that the key decisions affecting water supply and demand are made at the local scale of regional districts, irrigation districts and municipalities. Secondly, even in the absence of future climate change impacts, decision makers in the region were already highly sensitised to the vulnerability of the hydrological system to annual variability and to current and future pressures from agricultural intensification and population growth. Thirdly, a range of demand and supply side interventions ranging from increased capture and storage of water from the spring freshet to agricultural metering have been tried in the region. While climate change was not a driving factor in these decisions, a number of these interventions amounted to ‘no regrets’ adaptations.

The objectives of the study described below were:

1. To identify and evaluate anticipatory supply and demand side adaptations in both the agricultural and residential sectors;
2. To evaluate the viability of these adaptation options in consultation with governmental, non-governmental and private sector stakeholders associated with specific municipalities within the study region. This evaluation, described below, explored the policies and regulations that support and hinder specific proposed adaptations, new policies that could aid implementation and governance arrangement including issues of scale, cost bearing and political acceptability.

12.2 Case Studies

It became clear from the early stages of this study that, for better or worse, few decisions within the Okanagan Valley were being made on a regional or bioregional scale. The institutions involved in the governance of water in the region have been described in detail elsewhere (see Chapter 3), but a brief summary is included here. Responsibility for governance of water in the Okanagan, is divided between four scales: Federal, Provincial, Regional and Local. There is a delicate balance of power between Federal and Provincial government, enshrined in the 1867 Constitution Act. Most notably, the Province has jurisdiction over surface water and groundwater resources, while the Federal government has jurisdiction over water resources within First Nations reserves within the Okanagan Valley. While the Provincial government has jurisdiction over most of the critical aquatic and terrestrial environments in the region, the Federal government does assume responsibility for all fish bearing watercourses under the Fisheries Act. On paper, at least, this Act allows the Federal government, through the Department of Fisheries and Oceans, significant scope to intervene in practices within Provincial territory that affect watercourses that bear migratory fish such as salmon. In practice this mandate is used cautiously (Harrison 1996). The only regional organisation is the Okanagan Basin Water Board (OBWB), which was established in 1974 but has rather limited mandate focused on two key regional issues: milfoil invasion and the treatment of liquid waste.

Local governments within the Province are key players in the management of water resources. The Local Government Act RSBC 1996, administered by the BC Ministry of Community, Aboriginal and Women's Services, sets out the framework for the local government system in British Columbia. It defines the creation, structure and operation of the three types of local government: regional districts, municipalities and improvement districts, as well as their powers and responsibilities, which differ between the three. The Okanagan is split into three regional districts, 11 municipalities and 40 improvement districts. Regional districts are the latest form of local governance, being established in the Okanagan in the mid-1960s to provide basic services, such as water, to residents of unincorporated areas. Municipalities generally provide multiple services to an urban customer base, while improvement districts were established to deliver one or more public services to a community, such as water, fire protection, street lighting, dyking, drainage, garbage collection and parks. The smallest bodies providing water are Water User Communities – public corporate bodies incorporated under the Water Act RSBC 1996. Six or more different licensees, each of whom hold their own license(s), can form a Water User Community.

The Province is responsible for allocating water licences within the region and over time, these have been granted on a 'first come, first served' basis known as prior appropriation in legal terms. The other legal clause relevant to the allocation of water rights in the region is that of beneficial use. If the Province determines that a licence holder is not making beneficial use of water then it is possible for all or part of that licence to be rescinded. In practice, beneficial use interventions have been extremely rare in BC and historical allocations structure the status quo in the Okanagan region. The result is that around two-thirds of the water available in the region is allocated to agricultural use, while around one third is allocated to residential use. In practice, while the Ministry of Sustainable Resource Management (MSRM) is responsible for allocating water licences based on ongoing monitoring of water supply, very little effort is invested in monitoring actual water use within the region. Moreover, as population has expanded and agriculture has intensified, most streams in the Okanagan Valley are fully recorded, which means that they are unable to support additional licences.

In face of significant population growth pressures, significant annual climatic variability and the relative scarcity of new sources of water supply in the Okanagan, stakeholders in the region have understandably been concerned about water security issues. In recent years various levels of government within the region have taken a greater interest in water demand interventions and a number of municipalities and irrigation districts have undertaken metering, irrigation scheduling and public education initiatives. A parallel study examined some of the key driving and enabling factors behind four case studies where water demand interventions had successfully been implemented (Shepherd, McNeill *et al.* 2003; Shepherd, J. Tansey *et al.* 2004). In this study we chose to focus on two case study sites in the central and southern Okanagan Valley. In order to advance the research agenda beyond the status quo, the two case studies took a broad scenario based approach to the analysis of the viability of a range of water supply and demand interventions.

12.3 Methodology

Long term planning within government and businesses typically occurs under conditions of great uncertainty that typically exceed the capacity of traditional predictive scientific methods. In the case of climate change impacts, the IPCC recognised that rather than try to predict future greenhouse gas emissions in the face of great uncertainty, it would be more appropriate to formulate a range of scenarios showing the differential impact of distinct development pathways. Scenario methods have also been used for many years by businesses to deal with the inherent uncertainties involve in business operations (Ringland 1998). Researchers at Shell International began to develop their well-known approach to scenario analysis (Wack 1985; Wack 1985), later used by the World Business Council on Sustainable Development to explore sustainable futures (Shell, 1999). Over roughly the same period, a large academic futures study literature began to develop[28]. Ringland suggests that the methods have become increasing popular due to recognition of the uncertainties under which businesses operate. Similar approaches have been pursued in research on soft energy pathways over the last two decades and were also used in the famous 'Limits to Growth' study. Most recently, the Georgia Basin Futures Project developed a regional Participatory Integrated Assessment (PIA) model to support regional dialogue in

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[28] *Key journals reporting on this literature are Futures and Technological Forecasting and Social Change.*

the Georgia Basin bioregion in Western Canada (Tansey, Carmichael *et al.* 2002). The product--Georgia Basin QUEST--operationalises an approach to scenario planning known as backcasting and allows a wide range of users to explore the trade-offs involved in a range development choices within the region over the coming forty years.

Such scenario-based approaches have sought, to varying degrees, to represent some of the biogeophysical limitations on human activity while recognising that there is scope for human choices to have a direct impact on these limits. The model used in GB-QUEST represents a possibility space within which users can navigate between a range of 'not implausible' futures (Yohe, Jacobsen *et al.* 1999).

This study was inspired by the flexibility that scenario-based approaches bring to the analysis of climate change impacts. To date, the Okanagan study as a whole has utilised regional expertise, Global Circulation Models and other tools to generate assessments of the likely impacts of climate change on the availability of water and the rates of evapotranspiration in the region. These early assessments have formed the basis of a number of stakeholder dialogue meetings within the region (Cohen and Kulkarni 2001; Neilsen D., C.A. S. Smith *et al.* 2001; Cohen and Neale 2003).

The team chose to utilise a scenario-based approach that recognises that while interventions may be both technically and economically feasible, there may be legal and institutional reasons why one option is favoured while another is disregarded. In pursuing this approach, the team recognised that it remains extremely difficult to predict, with any degree of certainty, what the impacts of climate change will be. Nonetheless, there is strong evidence that we can reduce vulnerability to future climate change impacts by planning for and managing our resources more sustainably in the present. It was beyond the scope of this study to develop a full integrated assessment model for each community so instead the team developed a qualitative evaluation framework for the workshops. The study framework asked experts from government, NGO's and business to evaluate a range of adaptation options focused on increasing water supply or reducing demand. In broad terms, participants were asked to evaluate the viability of these adaptation options by considering both legal enabling and constraining factors, political support, public support and questions related to scale.

12.3.1 Local Workshops: Oliver and Trepanier

12.3.1.1 Identification of communities

The Okanagan is defined as a single region but contains heterogeneous communities ranging from relatively large and fast growing urban centres such as Kelowna through to small but stable rural settlements. Two contrasting communities were selected for this study in order to reveal any potentially significant differences that might result from the local political context. The first community selected was Oliver, towards the south of the Okanagan Valley. Oliver itself is a small but growing community located between Penticton and Osoyoos. The town itself has 4400 residents and the surrounding rural area, which falls within the jurisdiction of the municipality, contains an additional 4500 residents. The town was originally established around a mine and more recently has sought to brand itself as the winemaking capital of Canada; there are fourteen vineyards in the surrounding area. Oliver is located within the Regional District of Okanagan-Similkameen. The second case study focused on the Trepanier Landscape Unit in the centre of the Valley. The meeting was held in Westbank, which lies outside Kelowna and is subject to significant population pressure from the major urban centre. TLU is also subject to a major planning and management review at the moment and has a distinctly different governance structure.

12.3.1.2 Recruitment

Participants were recruited via the network of contacts that was established in the earlier project. The central goal of the recruitment strategy was to achieve reasonable diversity with respect to the levels of government and non-governmental stakeholders present. The composition of the participants is summarised in Table 12.1

TABLE 12.1

Workshop participants

STAKEHOLDER	OLIVER	TLU
Federal	2	2
Regional District	4	3
First Nations	2	1
Provincial	4	7
Regional	0	2
NGO	3	3
Consultants	0	2
Local	5	0
Total	20	21

The recruitment process did not achieve balanced representation across the two workshops but did manage to achieve reasonable levels of diversity. It should be pointed out that the goal was not to conduct a traditional multi-stakeholder analysis, where full representation would have been more important. Instead the goal was to engage key actors who would be able to draw on their own knowledge and experience to identify the factors influencing the implementation of the various adaptation options that would be discussed. In this sense, the goal was not for the representatives to bring their various interests to the table; rather it was to evaluate what would have to happen for an adaptation option to be successful.

12.3.1.3 Selection of adaptation options

In preparation for this study, an economic review was completed of the range of adaptation options in the region, which evaluated both the range of costs of implementing a given strategy and the range of savings that could be expected or additional supply made available. Options were selected on the basis of an earlier consultant's report and so were deemed to be appropriate technologies for the region. This initial study, described in detail by Shepherd, McNeill and Neale (2003) was used as the starting point for the workshops within the two target communities. The adaptation options are described in greater detail in Table 11.1 (in previous chapter).

The costs per acre-foot and supply/savings columns are estimates and would vary significantly depending on the geographic location and on the existing infrastructure. For instance, the vertical and horizontal distance over which the water must be pumped largely determines costs of lake pumping. While Table 11.1 (in previous chapter) presents a menu of adaptation options, one of the initial tasks in each workshop was to narrow the list (Table 12.2) and to refine exactly what was meant by each option. For instance, Oliver is not adjacent to the lake, so the only pumping option was to withdraw from the mainstem.

TABLE 12.2

Adaptation Options discussed at each workshop

OLIVER	TLU
Increase upstream storage	Increase upstream storage
Pump from mainstem.	Pump from lake
Increase groundwater pumping	Increase groundwater pumping
Irrigation scheduling & Trickle irrigation	Irrigation scheduling & Trickle irrigation
Metering	Ag. Metering/Water pricing
Public education	Public education
Water recycling/ reclamation	Leak detection
Block pricing	Water reuse – for agriculture
Legislation for domestic conservation	Land use changes, xeriscaping

The specific details of the adaptation options chosen by participants in each case study are described in the tables below.

12.3.1.4 Discussion questions

The participants were asked to consider eight key questions related to the viability of the adaptation options identified above. In each case, the goal was not to evaluate which options would be best for the case study area but rather to consider the enabling and constraining factors relevant to each. To take an example from earlier meetings with stakeholders, it is clear that while irrigation metering and scheduling is cost-effective and is likely to reduce water use significantly, it faces deep resistance from the agricultural community. Since this was well known, the participants were asked to consider what institutional arrangements would be necessary to ensure that this option could be successfully implemented. The results of this discussion are presented below.

The eight discussion questions are organised into three themes addressing social acceptability, the legal framework within the region and political realism/acceptability. The questions are presented in Table 12.3 along with explanatory notes.

TABLE 12.3

Workshop discussion questions

THEME	QUESTION	NOTES
Social acceptability	Who will benefit from it? Why?	What interests or stakeholders (including those present in the workshop) may benefit and why
	Who may oppose the option? Why?	What interests or stakeholders (including those present in the workshop) may oppose and why
Legal framework	Are there any laws, regulations or policies that would ease or support implementation?	What current laws or policies mandate or support this adaptation option at the Federal, Provincial or Municipal scale.
	Are there any laws, regulations or policies that would prevent implementation?	What current laws or policies mandate or support this adaptation option federal, provincial or municipal scale.
	What new laws or regulations could ease or support implementation?	Consider what new laws or policies at any scale would significant enhance the implementation of this option
Political realism and acceptability	Do the politicians and the electorate support the measure?	Focused primarily on municipal representatives and local provincial representatives
	What level of governance has jurisdiction over the proposed action?	Is this primarily a municipal, provincial or federal matter?
	Who would take responsibility for implementing this measure / Who will pay?	How would the adaptation option be implemented over time, who would cover capital costs and who will monitor and regulate.

It was recognised that the questions might not be mutually exclusive. For instance, there is likely to be at least some overlap between political and social acceptability. In this case we were keen to identify options that may face popular dissent or support as distinct from political dissent or support.

12.3.1.5 Workshop agenda

The workshops were held within the case study communities in order to maximise the number of participants likely to attend. The agenda covered one full day and was organised into the stages described in Figure 12.1. Following introductions the participants were given a series of short presentations on the research that has been completed to date by the wider research team. This research describes future possible impacts of climate change on precipitation patterns, snow accumulation and melting, stream hydrographs and crop water demand. In addition, the presentation described assumptions about the rates of population growth likely in the region and described some of the other ongoing research about the likely impacts of that population growth under different housing and development scenarios. These presentations provided important context for the remainder of the workshop.

The participants were shown the list of adaptation options and were given an opportunity to review them

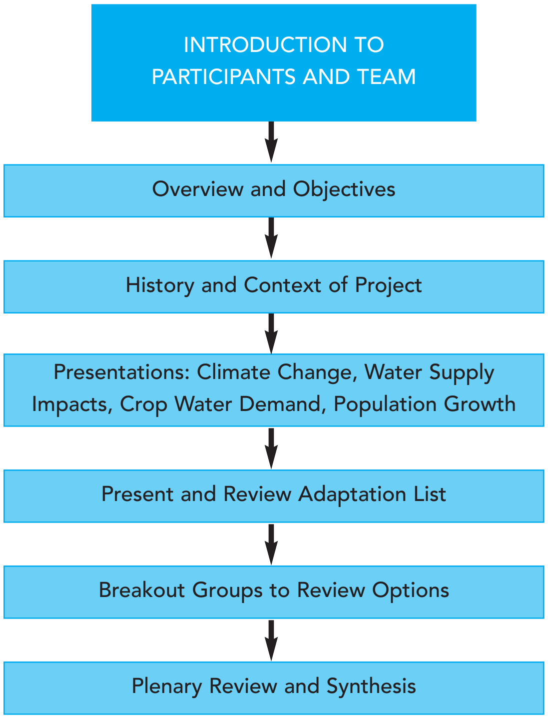

FIGURE 12.1

Local workshop overview

and to add other options to the list. The full list of adaptation options was divided among the breakout groups; each group was assigned three distinct options. The participants had been allocated to breakout groups in advance of the meeting in order to ensure each group was heterogeneous but the participants were given an opportunity to change groups if they had a strong desire to discuss a specific adaptation option. For the most part, participants remained with the breakout group to which they had been assigned. The groups had around fifty minutes to discuss each adaptation option. A facilitator led discussions guided by the eight discussion questions in Table 12.3 and comments were recorded both on a flip chart and in note-form. The first step in each discussion was to briefly clarify what the members of the breakout group understood by the adaptation they were to discuss. For instance, there are a number of approaches to agricultural metering within the region, depending on the crops and local conditions. The breakout groups were first asked which approach would be suitable to their local area. This process of clarification narrowed the range of options discussed. Once the group had settled on a particular option they worked their way through each of the key questions described in the table above. The facilitator and reporter took notes and attempted to keep the discussion as focused as possible on the key questions.

12.3.2 Basin-Wide Workshop: Kelowna

12.3.2.1 . Introduction

On the 17th of February 2004, a third adaptation workshop was held in Kelowna to discuss climate change and water management in the Okanagan Basin. This workshop did not target one particular community; instead, this event focused on aspects of adaptation that would be important when considering basin-wide implementation. There was a larger group in attendance, so the dynamics of group discussion were not as "controlled" as in the local workshops. Due to this situation, no academic analysis was conducted on participant responses. Group responses are presented in Appendix Chapter 12C.

The scale of discussion was broader in geographic area, so the adaptation measures discussed were also broader. General approaches were discussed rather than specific adaptation strategies. There was also an implicit change in focus from 'what is appropriate for our community' to 'how could this be applied on the larger scale.' Thus, there was a greater emphasis on governance structures; how to implement and orchestrate change on this scale. This change of focus brought a different community of participants into the room than at the previous events, although some participants had also been to one of the local workshops.

12.3.2.2 Recruitment

Participants that attended the previous two local workshops were invited to participate in this larger event. Additionally, we recruited through the network of contacts established in the earlier project, including participants outside of Oliver and TLU. Invitations were also sent to officials of all the local Okanagan communities. Forty-four participants attended the workshop, not counting any of the research team members. This is twice the number that participated in the local workshops (see Table 12.1). The breakdown of representation is shown in Table 12.4. The majority of participants represented the public sector, primarily from the Provincial, Regional, and Local governments, but this was an appropriate reflection of the regional context of the workshop. These groups of government officials represented a wide range of communities, and provincial ministries, so there was a diverse representation of organisations within the room. This was a reasonable level of diversity for the purposes of the exercise, as the goal was simply evaluation, and not making decisions or reaching consensus.

TABLE 12.4

Basin-Wide workshop participants.

STAKEHOLDER	PARTICIPANTS
Federal	3
Regional District	6
First Nations	1
Provincial	10
NGO	3
Consultants	3
Local	15
Academic	2
Total	44

12.3.2.3 Selection of adaptation topics

Given the time constraints for this workshop and the expected number of participants, we led five groups to discuss one approach for a 90-minute period. We gave the participants a choice between discussing specific adaptation strategies (as was done in the two local workshops) or general approaches. A quick, informal

TABLE 12.5

Discussion Questions at the Basin-wide Workshop

THEME	QUESTION	NOTES
Basin-wide implementation	What makes this option suited for basin-wide management? What benefits are gained from basin-wide coordination of this measure?	This question encouraged group members to think basin-scale context, not just local implementation
Environmental Aspects	Would this option affect water quality in the ecosystem? How?	Would this approach have any positive or negative impacts to water quality
	Does this measure create potential conflicts with instream flow requirements for fish or other wildlife?	Would this approach create conflicts with other uses, particularly instream fish flow requirements
Social viability	Is this option socially acceptable?	Is this opposition to this idea among the region's community of stakeholders
	Would this option increase or create conditions of conflict?	What conflicts would arise with implementation of this approach
Institutional viability	What institutional structure/framework is needed to manage this option on a basin-wide scale?	What Federal, Provincial, Regional or Local governance structure is necessary for implementing and leading this approach
	Is there currently an institution that could implement this measure?	Who might take responsibility for implementing or managing this approach
Legal viability	Do the current laws support this measure?	Identify laws or policies at any scale that ease and support, or may prevent
	If not, are there additional laws that could allow implementation of this measure?	What new laws would significantly enhance implementation of this measure
Financial viability	Do the potential benefits justify the costs of implementing this approach?	Are the hydrologic benefits worth the financial cost of implementation
	How could this approach be financed?	Who would cover capital costs, and who would monitor and regulate

vote resulted in selection of the latter. This discussion of general approaches was more relevant to the larger geographic scale. The approaches discussed were:

- Measures that increase access to water supply to the basin's water users.
- Measures that decrease residential water demand in the basin.
- Measures that decrease agricultural water demand in the basin.
- Measures that support water planning and management, or assist indirectly in increasing supply or decreasing demand (governance issues)

Two groups discussed the fourth item, as the interest from participants warranted this. Participants self-organized into the five groups, given guidance only to try to distribute numbers fairly evenly.

12.3.2.4 Discussion questions

A list of questions helped facilitate a focused discussion. As with the local workshops, there were questions on evaluating the feasibility of the option, identifying obstacles, barriers and enabling factor, plus new questions on institutional viability and environmental feasibility. The full list of questions is provided in Table 12.5.

12.3.2.5 Workshop agenda

A complete outline of the day's agenda is shown in Figure 12.2.

The major tasks completed at the workshop, described here in more detail are:

- Research Presentations
- Breakout Group Discussion
- Plenary Session for Review and Synthesis

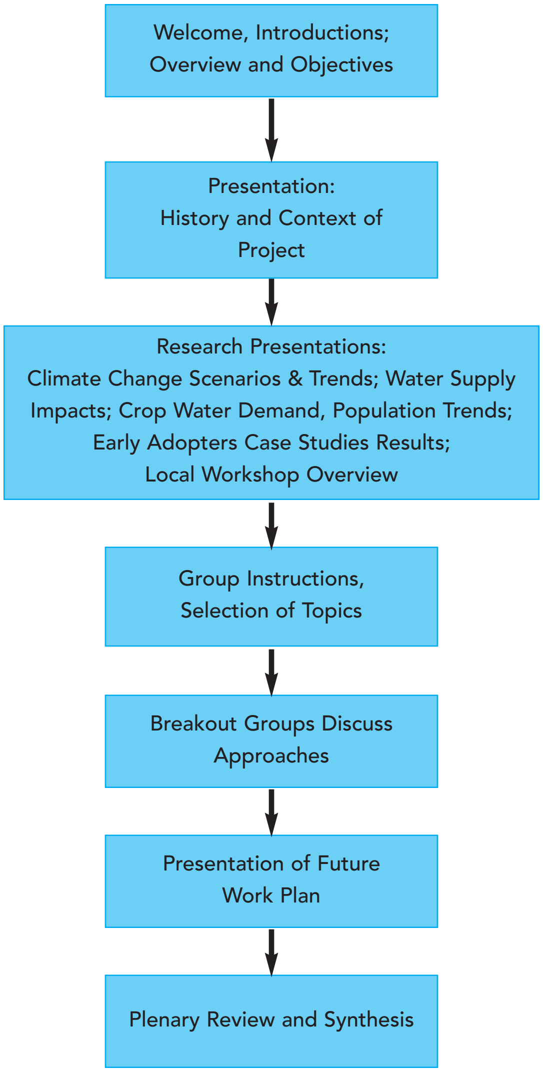

FIGURE 12.2

Basin-wide workshop Agenda

Research presentations were more extensive than those given at the previous workshops, including additional topics and additional recent results. Topics covered were: climate change scenarios and trend analyses, hydrologic impacts under climate scenarios, crop water demand under climate change scenarios, water balance case studies/demographics, early adopters case studies, and results from the local workshops. These topics are addressed in other sections of this report. An additional presentation addressed our future research plans, providing the opportunity for feedback from the participants on the relevance of our plans to their needs.

12.4 Results

12.4.1 Local Workshops

The findings of the workshop are reported in Appendix, Chapter 12, A, B. The two communities had quite distinct reactions to the adaptation options due to their current use profile, location and projected population increase, so are described separately.

It was recognised early in the workshop that Oliver has fewer immediate concerns about water availability than other parts of the Okanagan Valley and is generally thought to have a secure residential and agricultural supply. The drought of the preceding summer had a lower impact on Oliver. Participants from Oliver felt that increased storage would not be viable in the short-term because other options are currently cheaper, although they recognised that in the long-term, storage may be an important option. Participants felt that pumping additional surface water from the mainstem was a viable option although it would meet with opposition from environmental groups and from residents on the shore. Nonetheless it was recognized that given the current sensitivity to water quality concerns among politicians that it might not be possible to use mainstem water as a potable source. In contrast, groundwater was seen as a cleaner source of water and more politically acceptable as a result.

On the demand side, irrigation scheduling and trickle irrigation were seen as effective interventions. Evidence from the recent drought suggested that irrigation demand could be reduced by as much as 60% with better control over water use. This was recognised as a crisis response and long-term shifts to metering and trickle irrigation would be likely to meet with opposition for two reasons. First, farmers prefer to maintain access to the water resources allocated through existing licences. Second, some farmers are concerned about the rate at which population growth has proceeded in the region and therefore oppose interventions that would free up more water for residential uses. To quote one farmer 'We'll open the taps and use up all the water if we think it will limit population growth'. Public education was seen as an important demand side intervention. Participants recognised that education of both children and of existing users could be very important for reducing long-term demand. It was also acknowledged that a number of Federal programmes require education as part of any new policy.

Water recycling already occurs within the region and in one case was implemented as a way of reducing phosphate enrichment of Okanagan Lake. While it was recognised to be technically feasible in the region, there would likely be opposition on the basis of perceived health concerns related to the use of grey water in food production.

Legislated domestic conservation could benefit most users and is currently supported by local by-laws as well as provincial policies. There is more support for conservation in higher density areas and in the period immediately following a drought-related crisis.

Trepanier Landscape Unit (TLU) is on the western side of the Okanagan Valley, close to Kelowna. It is an area that has seen much greater population growth in recent years and responses to adaptation options were somewhat different. On the supply side, increased lake pumping was seen as a viable option and already occurs within the region. Pumping would be supported depending on the cost, which in turn depends on the horizontal and vertical distance that the water is pumped. Participants suggested that the electorate has limited knowledge of water supply issues and generally perceive lake water to be dirtier, suggesting that 'mountain water' is cleaner. Participants also suggested that it would be useful to fully separate agricultural and residential water supply in order to avoid the need to chlorinate the full supply. The viability of groundwater pumping also depended on the physical characteristics of the well. It was recognised that groundwater use is not directly regulated within BC. Indirect regulations that do exist focus on water quality at the time of installation rather than the total quantity of water withdrawn. If extraction started on a large scale then there may be significant environmental effects.

Concerns over irrigation metering were similar to the concerns expressed in Oliver. Participants stated that it might require a really serious crisis before there is sufficient will to intervene. Domestic metering is considered effective although it depends on where it is proposed. Clearly large users would be opposed, but there may be concerns that water pricing through metering would be regressive. Public education, described in broad terms was considered an important point of intervention for reducing water demand but it was suggested that more research is needed to identify the best forms of communication and education.

Improved leak detection, particularly in pipes was considered an important adaptation option that is largely supported by existing legislation. Water reuse or recycling has also been considered although there are some concerns about health impacts and on the suitability of recycled water for food production.

The tables summarising the findings from the two case studies provide much more detail regarding each of the options discussed. A number of conclusions stand out from the two case studies. First, there are few, if any adaptation options that would be both effective and politically viable across entire Okanagan. Clearly it is important to choose adaptation options that have a robust impact on the volume of water supplied to or used by the region. Of the examples examined elsewhere, much of the success in demand management interventions has been achieved in the residential sector and the agricultural sector is more resistant to change. On the one hand, this reflects a strong interest among agricultural users on maintaining control over water resources. On the other hand, it is also part of a more subtle strategy of opposition to population growth within the region. Since population forecasts predict significant increases over the coming years, per capita reductions in water use may be offset by increases in total population. Participants from Oliver suggested that the municipality was keen to stay relatively small but other areas have been strongly encouraging population growth. The collective impacts of this population growth are difficult to regulate and may be very significant in the long run.

Secondly, historical context has a significant impact on the political acceptability of adaptation options. Participants from Oliver spoke of the resentment on the part of farmers of jurisdictional changes in water management in the region that 'stole water from farmers'. It is clearly important to understand this kind of local political context as part of any adaptation strategy.

Thirdly, of all the adaptation options, participants appeared to be most sensitised to the benefits and impacts of increasing groundwater supply. This may be partly a result of wider provincial and federal interest in matters related to groundwater. At this stage, groundwater withdrawals are largely unregulated. This suggests that if water becomes scarce due to continued drought conditions then groundwater wells could become more popular among irrigators, where conditions are appropriate. The impacts of large-scale groundwater withdrawals on the environment are currently poorly understood and deserve greater attention.

12.4.2 Basin wide workshop

Participant responses during the group sessions are summarised in Table (Appendix, Chapter 12, C). Several recurring themes arose in these dialogue sessions.

There was support for integration, expressed in a variety of ways. There was support to integrate land use planning with water resource planning, water purveyors with municipalities, surface water with groundwater management, supply side with demand side options, and science and hydrology with implementation options. These reflect a new paradigm of integrated assessment and management. The last type – integration of the science, hydrology and management options will be addressed in the next project (see Chapter 13).

In all three workshops, there was discussion around the lack of knowledge about, and regulation of groundwater resources in the basin. Basin-wide mapping and data collection is needed to be able to manage the resource. Licensing and regulation is also needed for management. Participants felt that governance could come from the Province (MWLAP) or, if the Province was not able to, possibly the Regional Districts could take a leading role.

There exists a lack of public awareness of regional water resource problems. This ignorance is an obstacle to implementing most of the adaptation strategies in both direct and indirect ways. Public education of water issues, which most participants supported, would be most effective on a basin-wide scale.

Those who expressed support for basin-wide governance recommended expanding the roles of the Okanagan Basin Water Board (OBWB) and Okanagan Mainline Municipal Association (OMMA). One participant observed that the OBWB worked on past crisis issues, so they would be able to handle future crisis issues. However, another participant noted that the OBWB requires unanimity to implement any changes. Some participants commented that external (Federal/Provincial) incentives may actually discourage local initiatives, as they discourage self-governance. Support for grassroots involvement would encourage local responsibility and, therefore, would be more beneficial over the long term.

Most of the groups reported that the existing laws neither supported nor prevented implementation of adaptation strategies. One exception was the agricultural demand management group, who were concerned that existing flow control regulation would not work for metering or pricing structures. New laws would assist in implementing both groundwater expansion and residential demand management.

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chapter 13

Towards Decision—A Look Ahead

Stewart Cohen, James Tansey, Stacy Langsdale,
Denise Nielsen, Bill Taylor, Scott Smith

During the 2002-2004 period during which this study has been carried out, the goal of this collaborative research team and its partners has been to develop integrated climate change and water resource scenarios in order to stimulate a multi-stakeholder discussion on the implications of climate change for water management in the region. The study team's two main objectives are: a) providing a set of research products that will be of relevance to regional interests in the Okanagan, and b) establishing a methodology for participatory integrated assessment of regional climate change impacts and adaptation that could be applied to climate-related concerns in Canada and other countries.

In this concluding chapter, we reflect on what we have learned from this exercise (Section 13.1), and look ahead to a new phase which will focus more on the challenges of creating a dialogue on adaptation policy in the Okanagan (Section 13.2), including the development of a decision support tool that could help to provide insights on how climate change concerns could be accounted for in the overall planning process for the region's water resources (Section 13.3). This new phase will be supported during 2004-2006 by the Climate Change Impactsand Adaptation Program (Natural Resources Canada).

We also outline a new direction for research on effects of climate change on crop production in the Okanagan. This proposed study (Section 13.4) will be a separate effort, though it is anticipated that there will continue to be ongoing information exchange between the two studies.

Some final thoughts are offered in Section 13.5 to close this report.

13.1 Linking Global Climate Science to Regional Decision Making

Human induced climate change or 'global warming' represents a global-scale stress with characteristics that manifest themselves in various ways at different scales. Emissions of greenhouse gases have the same effect on the globe's temperature regardless of the origin of these emissions. However, impacts of changing global temperature and precipitation patterns will lead to biophysical impacts that are regionally unique, depending on the initial state of each region's ecosystems and natural resources. At the same time, societies have been developing in different ways from place to place, and their relationships with their biophysical environments have been influenced by social, political and economic forces that are also regionally unique.

Atmospheric scientists have been actively debating the concept of 'downscaling' global scale climate models so as to better capture the influences of landscapes and location on regional climate patterns. This notion of downscaling is also relevant in studies of ecosystems and economies for which there are general principles, articulated at aggregate levels of continents and nations, which also require some kind of modification in order for these to be applied to specific places.

Accompanying this change of scale is the recognition that there are interconnections between regional biophysical environments, regional socioeconomic forces, and external influences of various kinds that help to shape the planning and development context within regions. This suggests that in addition to downscaling, there needs to be a process of 'integration' of various dimensions of knowledge about how regional resource systems operate, how they're affected by biophysical and socioeconomic forces, and how they might be affected by future changes of various kinds.

In this particular exercise, we have focussed on the development of an integrated framework for assessing the implications of climate change for water management in the Okanagan region of British Columbia. This framework is one of team building in which researchers and stakeholders are asked to provide insights and analyses for the Okanagan using a common set of climate change scenarios and shared learning of both scenario impacts and the regional context upon which these impacts would be felt.

13.1.1 What we learned

The overall picture of human induced climate change in the Okanagan region is one of warmer wetter winters and warmer drier summers during the 21st century. Local topography would continue to influence micro-scale climate patterns, and consequently, land use decisions. Okanagan water supplies would experience shifts towards earlier timing of seasonal availability, as well as reductions in annual volume. These hydrologic changes would likely force a re-examination of operating rules for reservoirs in order to meet flood protection requirements as well as the needs of communities, irrigators, and aquatic ecosystems.

Demand for irrigation would increase due to longer warmer growing seasons. This would occur for all crops at all locations to varying degrees. Population growth would create additional pressures on water supplies. Considering the needs of aquatic ecosystems, as well as those of irrigators and domestic users, this suggests that there will be more years with supply shortages for various communities and perhaps at the basin scale as well. The Okanagan is already recognized as having the lowest per capita availability of freshwater in Canada (Statistics Canada, 2003), and the climate change scenario described in this report is very likely to exacerbate this problem. In the absence of well coordinated drought management, conflicts similar to those observed during the 2003 drought could occur more often.

Expanded application of water saving technologies is one example of an adaptive measure that could offset the additional climate-related pressures on regional water supplies. There are other demand side and supply side options as well. Communities and water purveyors have considerable experience in addressing adaptation challenges, although these have not been specifically about climate change. Several local examples of early adoption of demand reduction measures (e.g. Southeast Kelowna Irrigation District) illustrate the importance of local leadership, the need for incentives from higher levels of government, and the challenge of overcoming entrenched interests and various perceptions of the state of the resource. This experience has generally been positive in the long run, but the region still finds itself faced with the challenge of trying to plan for a watershed without a coordinated framework or basin-wide authority for doing so. Dialogue with regional stakeholders suggests that there are a range of options for supply side and demand side management that could become part of an adaptation portfolio, but there are financial and social issues associated with these, with implications for water-related governance.

13.1.2 Research gaps

The broad picture of climate change implications described above, and in greater detail throughout this report, is based on a series of model-based studies, using data obtained from local stations, field sites, and archives. Perspectives on past adaptation experiences and future prospects are drawn from interviews and dialogue exercises with regional water professionals, user groups, elected representatives, regional planners, and other water interests.

This collaborative team-based approach provides important opportunities for interdisciplinary learning. There are, however, uncertainties due to data gaps and model representation of biophysical processes. Examples include a lack of high elevation climate stations, uncertainty in mapping regional precipitation patterns, exclusion of precipitation and CO_2 enrichment from the crop water demand model, and lack of knowledge about groundwater processes. Some of these uncertainties could be reduced by increased investment in field monitoring programs, especially at higher elevations, but this would have to be sustained over the long term.

The social components of this study are also subject to uncertainties regarding process and data. Examples include concerns about water consumption data, missing voices from the groups being interviewed or participating in workshops, and the lack of quantitative information about the effectiveness of adaptation measures within the scenarios of climate change.

Global warming is by definition a very uncertain field of study. We do not know the full range of future climate possibilities. There are also many possible development paths that could evolve in the Okanagan, and this would affect the region's vulnerability to climate-related pressures, and its capacity to adapt. Research can address some of these uncertainties, and increase our understanding of the connections between global-scale climate change and its local implications. It is unlikely that research will completely eliminate these uncertainties. However, the climate change problem is a potentially serious one for the Okanagan. What then is the best way to move forward from our current knowledge base so that we can provide information that could be useful for developing a proactive adaptation strategy?

13.2 Creating a Dialogue on Adaptation Policy

As this exercise moves from establishing researcher-stakeholder relationships to scenario building, we now reach a new phase in the dialogue. Having provided some preliminary analyses of adaptation options, in terms of their feasibility and costs, we can begin to discuss how these various options could become part of an adaptation portfolio. The portfolio idea suggests a range of measures that facilitates risk sharing and risk reduction for the region as a whole, as well as for individual communities and water purveyors. However, this portfolio would have to fit into the regional context of future planning and development, including consideration of various long-term goals and objectives of such plans.

In the Okanagan, regional planning responsibilities are shared between different levels of government, including regional districts, municipalities, First Nations, as well as the Province of British Columbia. Specific concerns related to water would engage both government and non-government interests in water. Although the Okanagan Basin Water Board exists as a regional water management body, it does not have (at this time) the mandate to produce a comprehensive water management plan for the region.

So far, the study team has identified existing development pressures on water supplies, characterized future potential climate change impacts and formulated a list of adaptation options in conjunction with stakeholders. Dialogue is resulting in prioritising these adaptation options and identifying critical barriers to their implementation. The third logical step in this process is to develop materials and workshops that support local actors in implementing viable water demand and supply interventions in the region.

As part of the 2004-2006 study, the team will work in conjunction with Smart Growth BC to execute these tasks. Smart Growth BC is a non-governmental organisation and registered charity based in Vancouver that has worked extensively in the Okanagan region. In March 2003 Smart Growth BC organized and conducted a conference that was attended by over 400 delegates from the Okanagan Valley, to discuss issues impacting future development in the region. Together, the team and Smart Growth BC will develop training and information workshops aimed at supporting the implementation of interventions that reduce residential water demand, as a complement to options to increase supply. These interventions will help reduce the vulnerability of the region to climate change induced water supply fluxes.

In the first year of the project, the team will develop an interactive decision support tool in conjunction with regional stakeholders. Details are provided in Section 13.3, below. The rich findings of this process will be analysed to identify broader policy implications. The dialogue team will also develop an evaluation framework that will assess the utility of decision support tools to the stakeholders involved.

The agricultural sector remains the largest water user in the region and, from research to date, appears to exhibit mixed responses to the prospect of having to consider adaptive measures that focus on demand side management. It is well established that existing technologies can significantly reduce water demand in the agricultural sector in the semi-arid conditions that prevail in the Okanagan Valley. The SEKID example (see Shepherd, Ch. 10) illustrates how implementation of metering has led to a reduction in water use for irrigation. On the other hand, comments from both the SEKID case and the Oliver dialogue workshop (see Tansey & Langsdale, Ch 12) revealed concerns about how such savings could be diverted to domestic users to support population expansion.

As a follow-up to local case studies reported here, we will examine various possible causes of resistance to demand side management during the first year of the project, and will identify analogous case studies in other regions in North America where demand reduction interventions have been successful. In the second year of the project, the team will engage in a focused scenario or charette design process with representatives from the agricultural sector from a community in the southern Okanagan. These stakeholders will identify the conditions necessary to support demand side interventions in the agricultural sector. The results of this process will be developed into a report that describes key policy recommendations for implementing water demand management in the agricultural sector.

13.3 Role for System Dynamics?

For several decades, researchers have been looking for ways to bridge the gap between technical research and local management (often end-users of research results).

Engaging stakeholders in a modeling process is one method that creates consistency between the research conducted and what managers need to know. This activity itself creates a learning space for developing shared understanding of system behaviour and providing insight about how changes perturb the system. In a case where a model was used to help manage water supply in Las Vegas, Nevada, USA, Stave (2003) found that the focus of the discussion changed "from who was to blame for the water problem...and how to solve it...to how the system works and why it responds to policy changes at is does" (pg 311). Involvement of stakeholders in the model building process has aided in negotiation and consensus-building processes (e.g. van den Belt *et al.*, 1998). Having a shared understanding of how the system behaves and what impacts management options would have on the system are prerequisites to reaching a consensus or decision. Thus, participatory modeling can play a significant role in assisting a community with making management decisions.

For the 2004-2006 study, steps in the model-building process will follow those described in Costanza and Ruth (1998). A core team of stakeholders, the "advisory team," will be recruited and involved in each stage:

1. Development of a low resolution conceptual model,
2. Development of a second model with increased quantitative detail
3. Incorporation and testing of scenarios and management options

Based on Costanza (1996), models can be classified according to a three-point spectrum as shown in Figure 13.1. Most of the models described in this report sit in the lower left-hand corner, having high quantitative precision. The modeling process in the next project will take on a very different character. The conceptual model created in Step 1 will be high in qualitative realism, but also contain significant breadth, to the extent deemed appropriate by the advisory team. The model will be In Step 2, the model will move toward quantitative realism by incorporating the results of research described in this report, as well as relevant research by our study partners. The result of this will be a model that has an appropriate balance between realism, generality and precision; a balance that will enable it to provide understanding about system behaviour. Future management options will be incorporated in Step 3. This will result in a tool useful for exploring a wide range of management scenarios. Although management options will not be the primary focus until Step 3, discussion of the key options in the earlier stages will ensure that appropriate time and spatial scales are selected to be able to incorporate these options later.

Management of water in the Okanagan requires dealing with a complex system that includes hydrologic, climatic, socio-economic and political components. Complex systems are characterized by strong (often non-linear) interactions, complex feedback loops, and significant time and/or space lags (Costanza, 1996). System dynamics is well- suited to complex problems, particularly when the problem is not well-defined, and occurs over an extended time horizon (Vennix, 1996, in Stave, 2003). System dynamics modeling uses

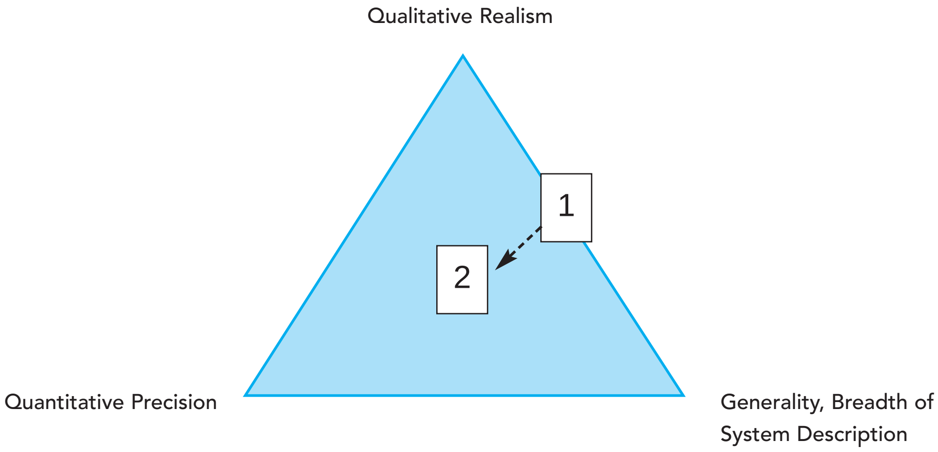

FIGURE 13.1

Model classification framework and location of models created in Steps 1 and 2. Concept based on Costanza (1996).

simulation and focuses on capturing the qualitative aspects of system behaviour. Models are created with graphical stock and flow diagrams that are somewhat intuitive and easy to understand with minimal training. Most System Dynamics software also contains an interface level, ideal for stakeholder interaction with the model. These characteristics allow stakeholders to be involved in all the stages of model construction, from the initial concepts through to testing of alternatives.

There is a natural fit between participatory modeling and system dynamics, and over the last fifteen years, examples of this technique have become increasingly common in a variety of applications (Andersen and Richardson, 1997). Benefits include increased understanding of system behaviour on the part of both stakeholders and researchers, and many of these processes have created consensus among participants. Water interests in the Okanagan have been primed through the previous stakeholder workshops and are ready and supportive of this next phase of work.

13.4 Threats and opportunities for agriculture which may affect adaptation to climate change

Tree fruit and grape production in S. British Columbia is an intensively managed, high value industry, with high capital costs both for land and infrastructure. Unlike other agricultural production systems, for horticultural crops, quality is often of greater importance to economic returns than yield. The S. Interior of British Columbia has climatic advantages such as high temperatures, low rainfall, low relative humidity and high light intensity which promote very high quality tree fruit and grape production. However, low rainfall also means that crop production is entirely dependent on irrigation for water supply and increasingly there is competition for the resource from population growth and requirements for fish and wildlife habitat. Some aspects of future water supply and demand were assessed and discussed in this report. However, there are other aspects of agricultural production which may be affected by climate change and may affect adaptation response. Future work will examine some of the potential biophysical effects of climate change on horticultural production in the Okanagan valley.

13.4.1 Relationships between annual historic crop production and weather events and climate-related thresholds for crop production in S. British Columbia

The extremes and not the mean changes in weather are of interest in predicting the effects climate change on crop production and these may limit crop distribution. For example, the geographical range of the main tree fruits grown in Canada are limited by winter injury (Quamme, 1976; Quamme *et al.*1982). Analysis carried out by Caprio and Quamme (1999) on apple production in the Okanagan Valley, indicated that low temperatures occurring from the beginning of November to the beginning of January and from the beginning of February to mid-March are by far the greatest impact of all weather associations. This winter injury in British Columbia is caused by outbreaks of cold Arctic which flow down valley troughs. In the Okanagan Valley outbreaks of Arctic air cold enough to cause damage to apple trees occurred 11 times from 1920 to 1991 (72 years).

Daily weather occurrences associated with annual variations in historical production can be determined using an iterative c2 method. This method generates indices of association that can be used to establish the days during the year and the degree that temperature and precipitation are associated with poor and good production. A critical value can be determined for each association. An iterative c2 method has been applied to determine the associations between daily weather measurements for apple (Caprio and Quamme 1999) and grape production (Caprio and Quamme 2002) in the Okanagan Valley of British Columbia and winterkill of wheat in Montana (Kalma *et al.*1992) with good results. The analysis is consistent with what is known about the weather impacts on production of these crops and has identified impacts that were previously unknown. This study will further extend the observations to other fruit crops and to forage and vegetable crops grown in the Okanagan Valley. Critical values generated by this study can be used to project the change in site suitability with climatic change.

In addition, these techniques may be used, in conjunction with synoptic typing to relate large scale weather patterns to constraints on crop production. Synoptic typing is a method of classifying large-scale weather patterns which exercise distinct controls over surface weather. A synoptic classification scheme for the Okanagan Basin has just been completed which links synoptic fields from the NCEP Reanalysis data, to surface observations using a Classification and Regression Tree (CART) decision tool (Cannon, unpublished). This will allow us to explore more fully the potential changes in large scale weather patterns affecting southwestern BC. The analysis has been extended to synoptic fields from selected GCM scenarios which will allow determination of the frequency of synoptic patterns over the next century. Hall and Quamme (1994) demonstrated a relationship between the Pacific North American Teleconnection and El Nino and winter freeze events detrimental to apple production in S. British Columbia. Thus, Arctic outbreaks are not simply random events but appear to have a pattern of occurrence. The identification of this and other weather patterns, which are significant for crop production, will be determined for the historical record and under climate change scenarios.

13.4.2 Risk Assessment for crop production

Crop suitability for a given region is greatly influenced by climatic thresholds, e.g. potential plant damage due to extreme minimum and extreme maximum temperatures, spring freeze risk and length of growing season. The frequency of exceeding climatic thresholds for individual species is obtained from the climate record and from historic fruit production records. Viewed from a risk perspective, an increase or decrease in vulnerability to climate change is assessed by determining the change in the frequency of threshold exceedance under future climate conditions. For example, warming trends imply a decrease in risk of plant damage associated with extreme winter minimum temperatures, whereas, an increase in the frequency of extreme summertime maximums would leave apples more susceptible to sunscald. A method for assessing risk is described by New et al (2002) whereby the uncertainties associated with climatic sensitivity and greenhouse gas scenarios are exploited to define the cumulative probability distribution of projected changes in temperature and precipitation. A Monte Carlo simulation technique is used to repeatedly randomly sample the temperature response associated with various greenhouse gas scenarios and climate sensitivities for a large number of GCMs. The probability of exceeding a climatic threshold can be read directly from the cumulative probability distribution plots. By tracking changes in probability over successive future time slices (2020s, 2050s and 2080s) the rate of change in risk may also be assessed.

13.4.3 Changes in land use capability

Currently, the Okanagan is at the northern limit of viable economic production for a number of crops e.g. peach, cherry, apricot, wine grapes. Using locally developed temperature and heat unit thresholds for tree fruits (OVTFA 1995), and grapes (Grape Atlas ref.) combined with soil and topographic data, and risk assessment of extreme climate events future spatial distribution of land suitable for tender horticultural crops will be developed in response to climate change and variability scenarios.

13.4.4 Risks associated with fruit quality

Historical records of fruit quality including grades (Extra fancy, Fancy, Cee grade, etc) which incorporate measures of fruit colour and size production figures and occurrence of fruit disorders and other related information will be used to determine historical relationships between fruit quality and key meteorological data. The initial primary source of weather data will be three long term weather stations spaced throughout the production region from south (Osoyoos) to mid (Summerland) to north (Coldstream-Vernon). Subsequently it may be possible to extend this data set spatially and incorporate additional, shorter duration data sets by use of climate models. Use of multiple regression models (Johnson and Ridout, 1998), factor analysis and chi-square indices of association (Caprio and Quamme, 1999) will be used to determine levels of daily weather occurrences 'critical' for development of optimum fruit quality using best available models of future climate, it will be possible to project the likelihood of occurrence of 'quality' problems, their spatial distribution and possible economic impact. The use of apple as a test case is seen as a necessary first step to subsequent examination of other major crops. By this process it will be possible to identify adaptive strategies including possibilities of altering the kinds of crops produced in the region.

13.4.5 Potential changes in spatial distribution and pressures from major insect pests of tree fruits and grapes in the Okanagan Basin

Temperature and therefore climate, acts on invertebrates directly as a driving variable for physiological development, feeding rates, mating, egg laying, mortality, and seasonality, and acts indirectly through its impact on plant distribution, plant quality and seasonal availability.

A very large body of data describing the effects of temperature on a wide range of invertebrate pests of a diverse group of crops, including Canadian tree fruits is available (Bergh and Judd 1993; Judd *et al.* 1993, 1994; Judd and McBrien 1994; McBrien *et al.* 1998). Climate change, in particular global warming, has the potential to greatly impact the diversity of insects which are classified as pests within a region, through geographic expansion from southern to more northern regions, and to increase the severity of current pests by extending the insect's season leading to more within season generations of pests, or increasing feeding rates etc. Predicting which pests will broaden their range, or increase in severity is difficult because: the impact of temperature is nonlinear; it interacts strongly with daily photo period; variation within populations of certain species may allow for rapid selection of successful genotypes; seasonality may be obligatory rather than facultative and often insect emergence in spring is linked to phenological events in plants.

Some insight into the potential impact of climate change on invertebrate pests can be gained by coupling temperature outputs from a series of GCM scenarios, spatially interpolated using PRISM (Daly *et al.*, 1994) with insect development models. Unlike plants which may show a more linear response to temperature, invertebrate development is often linear over part of its range and nonlinear at the extremes (Schoolfield *et al.* 1981) it is these extremes which are most interesting and most useful for predicting future change. Both linear degree-day models and nonlinear development models where available will use output from GCM scenarios to simulate development of several species of interest to tree-fruit and grape producers. Availability of development models, particularly nonlinear models will dictate what species are chosen for examination. These developmental predictions will have a stochastic element by incorporating variation in insect development times (Wagner *et al.* 1984) using a cumulative Weibull function. The species-specific Weibull distribution functions and nonlinear developmental rate functions will be incorporated into an insect phenology simulation model (Wagner *et al.* 1985) that uses a rate summation approach to predict emergence of insects under field conditions. Briefly, the model uses the nonlinear developmental rate function to determine the rate of insect development at a given temperature, accumulates the daily developmental rates, and inputs them as an independent variable in the Weibull distribution function to predict the cumulative proportion of the insect population that emerges through time. These predictions will be generated with various data sets output by the GCMs to examine how current pests may become more severe and how more southern pests may fare locally under future climate conditions.

13.5 Final Thoughts....

This collaborative study has outlined a scenario of climate change and its implications for water management in the Okanagan Basin during the 21st century. This study has depended on field research, computer-based models, and dialogue exercises to generate an assessment of future implications, and to learn about regional views on the prospects for adaptation. Along the way, it has benefited from strong partnerships with local water practitioners and user groups. After several years of building relationships with researchers, practitioners, decision makers and community interests, perhaps the time is right to try this experiment of participatory model building and policy dialogue.

The idea all along has been that good stakeholder relationships is the foundation of a strong partnership between researchers and regional interests. This is what will enable a participatory integrated assessment to move beyond conversations that are perhaps at a general level, to a richer level of detail where specific ideas can be debated. Moving from qualitative dialogue to model-assisted conversations is part of a process of exploration, in which quantitative information and information technology are used in a more direct way to create pictures of the future that might not have otherwise been foreseen. Although this process cannot guarantee that future impacts and performance of adaptation measures will be accurately predicted, we hope that joint ownership in the futures process will make it easier to bring global scale climate change into the regional development context, in a manner acceptable to those who will be responsible for making these difficult choices for their constituents.

Finally, it is appropriate to recognize and celebrate the conclusion of this collaborative. Before 2002, participants in this collaborative had been engaged in separate studies of water and agriculture. During 2002-2004, the collection of expertise on water and agriculture provided a synergy that led to the creation of a richer dialogue that would not have otherwise occurred. The proposed agricultural study described Section 13.4, separate from the policy and model development efforts in Sections 13.2 and 13.3, marks a return to smaller individual initiatives in climate-related agriculture and water resources research in the Okanagan Basin by the members of the collaborative. We anticipate that there will continue to be connections between the two efforts, as part of the overall building of regional capacity to address the challenge of understanding and adapting to climate change.

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APPENDICES

Expanding the Dialogue on Climate Change & Water Management in the Okanagan Basin, British Columbia

appendix
chapter 3

Institutions

A-1: Inventory of Institutions

Institutions: Definition – public agencies that have legal authority over water management in the Okanagan basin.

ORGANIZATION NAME	DESCRIPTION/MANDATE WITH RESPECT TO WATER RESOURCES	OTHER NOTES
INTERNATIONAL ORGANIZATIONS		
International Joint Commission	The *International Joint Commission* is an independent bi-national organization established by the Boundary Waters Treaty of 1909. Its purpose is to help prevent and resolve disputes relating to the use and quality of boundary waters and to advise Canada and the United States on related questions.	Boundary Waters Treaty of 1909 • established the IJC with three members from Canada and three from the US • gives IJC jurisdiction over all cases involving the use, obstruction or diversion of boundary waters • approval of the IJC is required for obstructions and diversions or other activities that affect the natural flow or alters the levels of boundary waters • each country has the right to develop and use water on their own side of the border as they wish • any party injured as a result of activities on the other side of the Canada/US border is entitled to the same compensation as an injured party in the originating country • boundary waters must remain free for navigation • boundary waters shall not be polluted so as to cause harm on the other side of the border • order of precedence for uses: 1. domestic/sanitary, 2. navigation, 3. power and irrigation
Osoyoos Lake Board of Control	Established in 1946 by the IJC to oversee operations of the Zosel Dam (located 2.7km below Osoyoos Lake), which controls the level of Osoyoos Lake. In 1980 the State of Washington sought the Commission's approval to construct works replacing the deteriorating Zosel dam. The application to replace Zosel dam was approved by the Commission in 1982 followed by a Supplementary Order in 1985 to address certain specific matters including the relocation of the new structure. Construction of the new control structure was completed in 1987 with funding provided by the Province of British Columbia and the State of Washington,. Actual operation of the dam is conducted by the Oroville and Tonasket Irrigation District under contract to the project owner, the State of Washington Department of Ecology (WDOE). A new International Osoyoos Lake Board of Control was established to supervise the operation of the new structure in compliance with the Commission's Order of Approval. The	One of the Board's responsibilities is to issue drought declarations, and their removal when such criteria, contained in the Orders, are satisfied. Such declarations allow Washington to raise the Lake level above that for non-drought conditions. During normal years the lake elevation is held between a maximum elevation of 911.5 feet and a minimum elevation of 909.0 feet. However, during a drought year water may be stored to lake elevation as high as 913.0 feet. Zosel Dam effectively controls the elevation of Osoyoos Lake except during periods of very high snowmelt runoff when natural conditions force the lake above elevation 913.0 feet.

ORGANIZATION NAME	DESCRIPTION/MANDATE WITH RESPECT TO WATER RESOURCES	OTHER NOTES
	six-member Board holds an annual meeting and reports to the Commission each April. Monthly of daily lake levels and flows are kept to assure compliance with the Orders.	
BC/Washington Environmental Cooperation Council	Established by the Environmental Cooperation Agreement entered into by the Governor of Washington State and Premier of British Columbia on May 7, 1992. Its purpose is to ensure coordinated action and information sharing on environmental matters of mutual concern. Task Forces have been established to address several critical cross-border environmental issues that require joint attention by Washington State and BC. The Task Forces facilitate information sharing, coordination and cooperation on issues of mutual interest.	
FEDERAL AGENCIES		
Fisheries and Oceans Canada	"responsible for policies and programs in support of Canada's economic, ecological and scientific interests in oceans and inland waters; for the conservation and sustainable utilization of Canada's fisheries resources in marine and inland waters; for leading and facilitating federal policies and program on oceans; and for safe effective and environmentally sound marine services responsive to the needs of Canadians in a global economy." In the Okanagan, DFO is responsible for the Okanagan River Sockeye run.	Division of responsibilities for water is complex and often shared. Under the *Constitution Act*, provinces own water resources, which includes both surface and groundwater and are responsible for: • flow regulation; • authorization of water use development; and • authority to legislate areas of water supply, pollution control, thermal and hydroelectric power development. • Federal responsibilities are in areas that have the potential for significant national economic impact: • navigation; and • fisheries. Water on federal lands (e.g., National Parks), in the territories and on the reserves of Canada's aboriginal peoples falls under federal jurisdiction. The federal government also has responsibility for boundary and transboundary waters. Shared federal-provincial responsibilities: • interprovincial water issues; • agriculture; • significant national water issues; and • health (from http://www.ec.gc.ca/water/index.htm)
Transport Canada	Responsible for the *Navigable Waters Protection Act*	
Environment Canada	Administers the federal *Water Act. Federal Water Policy* goals include protection and enhancement of the water resource and promotion of efficient use of water.	
Agriculture and Agri-Food Canada	Research branch conducts scientific research, produces reports and works to establish and promote standards and best practices with respect to water management. There are plans to develop a National Land and Water Information Service that would provide farmers and municipalities with up-to-date web-based water resource information at a scale relevant to environmental farm planning.	Okanagan Valley Tree Fruit Authority mandate was extended, through to March 31, 2006, supported by a $25 million government funding commitment, mainly financing replant programs. The purpose of the corporation is to: • assist in the rehabilitation and improvement of orchard land and orchards, • develop and operate programs to improve productivity of the tree fruit industry and the marketability of tree fruit, • commission applied research into production and marketing, • provide for the training of growers and farm workers, and • subject to the regulations, assist growers, packinghouses, processors and marketing enterprises by providing advice and assistance.
PROVINCIAL AGENCIES		
Ministry of Sustainable Resource Management	Responsible for land use planning and coordination of land and water policies. Mission: To provide provincial leadership for sustainable economic development of the province's land, water and resources.	See goals, objectives and strategies from the Management Services Plan for a more detailed list of activities.

ORGANIZATION NAME	DESCRIPTION/MANDATE WITH RESPECT TO WATER RESOURCES	OTHER NOTES
	NOTE: The ministry has strategic policy responsibility for land and water management. LWBC has responsibility for operational delivery of land and water management. The budget for land management is allocated to LWBC, and the budget for water management is allocated to the ministry, which sub-contracts delivery to LWBC.	
Land and Water BC Inc.	Provincial crown corporation responsible for operational aspects of water allocation (water licensing), dam safety, water use planning and water utilities. Under the "umbrella" of MSRM. Mandate: Allocating Crown land and water resources for the benefit of all British Columbians.	Applications for water licenses made to existing MSRM regional or district offices. The LWBC website has not been completely updated since water was added to its mandate. Check back for further updates.
Ministry of Water, Land and Air Protection	Mission: The ministry helps British Columbians limit the adverse effects of their individual and collective activities on the environment. The ministry works to protect human health and safety by ensuring clean and safe water, land and air; to maintain and restore the natural diversity of ecosystems, and fish and wildlife species and their habitat; and to provide park and wildlife recreation services and opportunities to British Columbians and visitors. Responsible for environmental protection functions (eg. water quality).	Water, Air and Climate Change Branch Environmental Protection Branch See goals, objectives and strategies from the Management Services Plan for a more detailed list of activities.
Ministry of Health Services	Public Health Protection Branch responsible for food and environmental health protection programs including inspection and monitoring of public drinking water supplies and sewage disposal facilities. Administered by regional medical and environmental health officers.	Enforces the Health Act (includes Safe Drinking Water Regulation and Sewage Disposal Regulation) and Drinking Water Protection Act (not in force).
Ministry of Forests	Administers BC's Forest Practices Code. The FPC includes considerations of water quality and resource integrity in logging operations. Developed watershed assessment procedure under the FPC for assessment of logging impacts on watersheds.	The BC Government is currently undertaking a consultation process on restructuring of the Forest Practices Code to a more "results based" code. See http://www.resultsbasedcode.ca/ for info.
Ministry of Agriculture, Food and Fisheries	Administers the *Farm Practices Protection (Right to Farm) Act* Publishes environmental guidelines under this act for agricultural sectors (eg. fruit growers) that include water management and other practices which impact water (eg. irrigation, drainage and nutrient management). Fisheries focus is on aquaculture.	
REGIONAL AGENCIES		
Regional District of North Okanagan	Responsible for parks and recreation programs and facilities; fire protection, noxious weeds and insects control, solid waste disposal, recycling, tourism/economic development, water supply and distribution, planning and development services.	North Okanagan Water Authority (formerly Vernon Irrigation District) Water Stewardship Committee Silver Star Water Utility Whitevale Water Utility Grinrod Water Utility

ORGANIZATION NAME	DESCRIPTION/MANDATE WITH RESPECT TO WATER RESOURCES	OTHER NOTES
Regional District of Okanagan Similkameen	Responsible for waste management, some water and sewer systems, land use planning.	The Public Works Division manages, operates, and maintains the Naramata, Olalla, Faulder, and Apex water systems, and the Okanagan Falls sewer system.
Regional District of Central Okanagan	Responsible for land use planning, parks and recreation, waste management, water and sewer services. Administers six water systems servicing from 8 to 645 properties. Collects user fees and maintenance fees.	Regional District of Central Okanagan Water Utility Drainage Systems Westside Regional Sewer System
Okanagan Basin Water Board	The OBWB was established as a coordinating agency for implementing the recommendations of the Okanagan Basin Study conducted from 1969 to 1974 and is responsible for water management functions identified in the study that pertain to the basin as a whole. Current board activities focus on control of Eurasian water milfoil and funding of liquid waste treatment projects in partnership with the provincial government. A broader mandate can be established with the agreement of the three Okanagan regional districts. The board consists of three representatives from each of the Okanagan Basin's three regional districts.	
LOCAL AGENCIES		
Improvement Districts	Incorporated under the Local Government Act to provide services (eg. water distribution and fire protection) in a specified geographic area.	Most improvement districts are outside of municipal boundaries within regional districts. Local Government Act Improvement District Governance Most improvement districts provide only one service. The most popular service is water. Most improvement districts that provide water services provide both irrigation and domestic uses. Rutland Waterworks District South East Kelowna Irrigation District Black Mountain Irrigation District Lakeview Irrigation District Winfield Okanagan Centre Irrigation District Westbank Irrigation District Meadow Valley ID West Bench ID Lower Nipit ID Kaleden ID OK Falls ID Sun Valley ID Skaha Estates ID Rolling Hills WWD Parkdale ID Poplar Grove ID Vaseaux Lake ID Fairview Heights ID Boundary Line ID Keremeos ID Cawston ID Hedley ID Similkameen ID Allison Lake ID Osprey Lake WWD
Development / Irrigation Districts	See Improvement Districts	
Municipalities	Incorporated under the Local Government Act	Okanagan Similkameen Regional District municipal water systems: http://www.rdos.bc.ca/business_directory/rp_d_infrastructure.htma

ORGANIZATION NAME	DESCRIPTION/MANDATE WITH RESPECT TO WATER RESOURCES	OTHER NOTES
Water User Communities	A Water Users' Community is a public corporate body incorporated under Section 51 of the Water Act. WUCs are formed when six or more licensees would benefit from joint use of a water storage or delivery system. WUC Manager is responsible for assessing and collecting fees under the supervision of the comptroller.	for information http://srmwww.gov.bc.ca/wat/wrs/wuc/wucinfo.htm
FIRST NATIONS		
Okanagan Nation Alliance and Okanagan Nation Fisheries Commission	ONA is the Tribal Council which represents the people of the Okanagan Nation. The ONA's mandate includes: *"Protection, enhancement and preservation of the peoples, lands and resources of the Member Bands of the Okanagan Nation.* *Protection, enhancement and preservation of the environment, fish and wildlife resources located within the traditional territories of the Okanagan Nation."* "The Okanagan Nation Fisheries Commission (ONFC) was formally established in 1995. The seven bands of the Okanagan participate in the ONFC. The goal and mandate of the ONFC is the conservation, protection, restoration, and enhancement of indigenous fisheries (anadromous and resident) and aquatic resources within Okanagan Nation territory. The ONFC provides technical assistance to the member Bands and also acts as a liaison with federal and provincial agencies."	"The Okanagan people have not signed a treaty with the Federal Government nor do they recognize the Provincial Government as having jurisdiction within their homeland. These issues are being dealt with at the present time. The Okanagan Nation is comprised of the following Indian Band Reserves located within the Nation's traditional homeland boundaries: Upper Nicola, Nicola Okanagan, S-Ooknahchinx Westbank, Tsinstikeptum Penticton, Sn Pint'Kin Osoyoos, Inkameep Upper Similkameen, Simikameugh Lower Similkameen, Simikameugh"

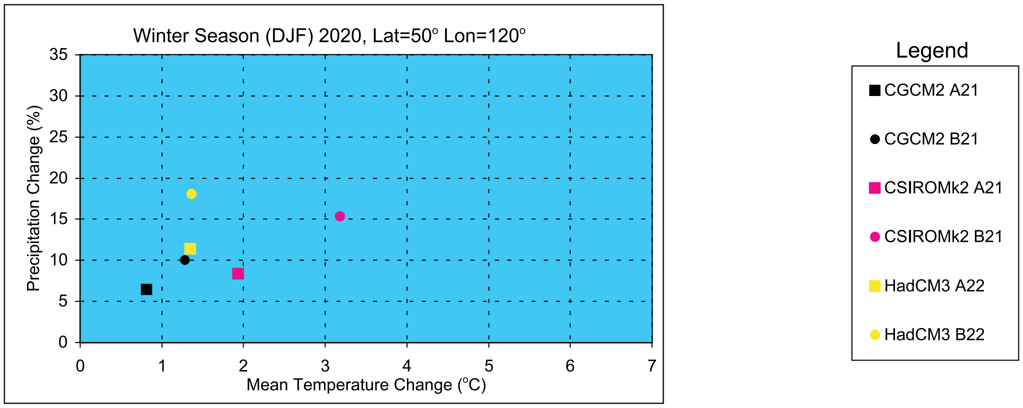
A-2: Other Stakeholder Organizations

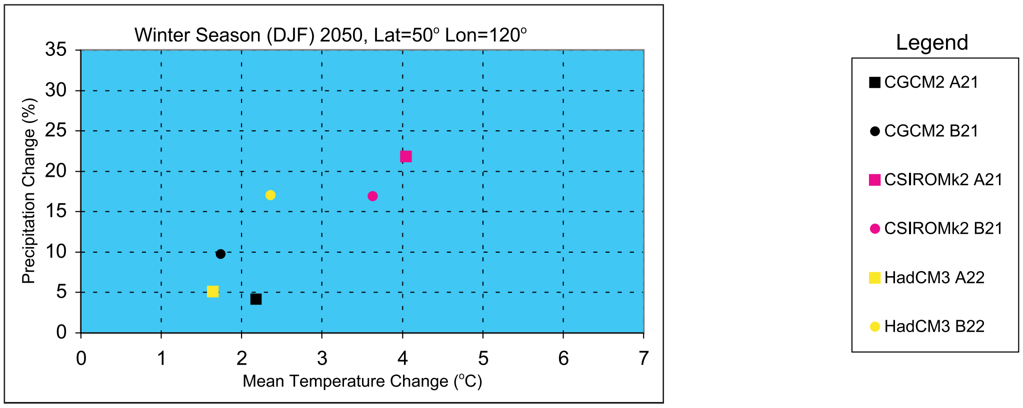
BC Watershed Stewardship Association	Stewardship advocacy organization. Province wide with strong membership in Okanagan
Water Supply Association of BC	Representing the interests of British Columbia's public domestic and irrigation water suppliers and their customers.
Okanagan Basin Technical Working Group	Tripartite group comprised of representatives from DFO, MWLAP, and ONFC. Initiated as a result of efforts in Douglas County, Washington, to respond to declining Okanagan River Sockeye runs. Funded by Douglas County. General objectives for this group are to identify and 'steer' initiatives designed to rebuild fish stocks, including salmon, in the Okanagan River basin in Canada.
Okanagan Similkameen Boundary Fisheries Partnership	Supports locally driven community planning around watershed issues and will be providing regional context / connection between roundtables, as well as future liaison support to fisheries agencies for local roundtables.
Friends of Brandt's Creek	The Friends of Brandt's Creek is an environmental organization established in 1994 to protect Brandt's Creek from further deterioration and to try and restore it to a healthy environment.
BC Lake Stewardship Society	The purpose of the BCLSS is to promote stewardship, understanding and comprehensive management of lakes and reservoirs and their watersheds
South Okanagan-Similkameen Conservation Program	Created by the Ministry of Environment, Lands and Parks and Environment Canada in 2000 to coordinate and harmonize conservation and habitat restoration efforts between governments, NGOs and community groups.
Community Watershed Round Tables	The community watershed round tables were initiated by Michelle Boshard in an effort to enhance community dialogue on watershed management in the region. There are five round tables: Trout Creek, Coldstream, Okanagan Indian Band, Lake Country, Mission Creek, Penticton(?). Administrative support is provided by the Okanagan Similkameen Boundary Fisheries Partnership.
BC Water and Waste Association	Non-profit association dedicated to the safeguarding of public health and the environment through the sharing of skills, knowledge and experience in the water and wastewater industries.
BC Fruit Growers' Association	The BCFGA is an industry association representing fruit growers interests. The BCFGA activities include lobbying government for positive change to risk management programs, such as crop insurance and the Net Income Stabilization Program, and providing services and products to growers. Services and products are provided at a discount to members.

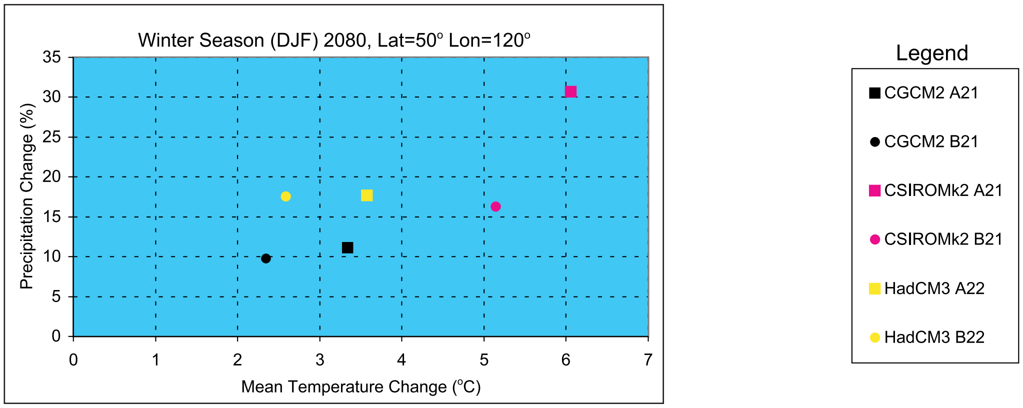
appendix chapter 5

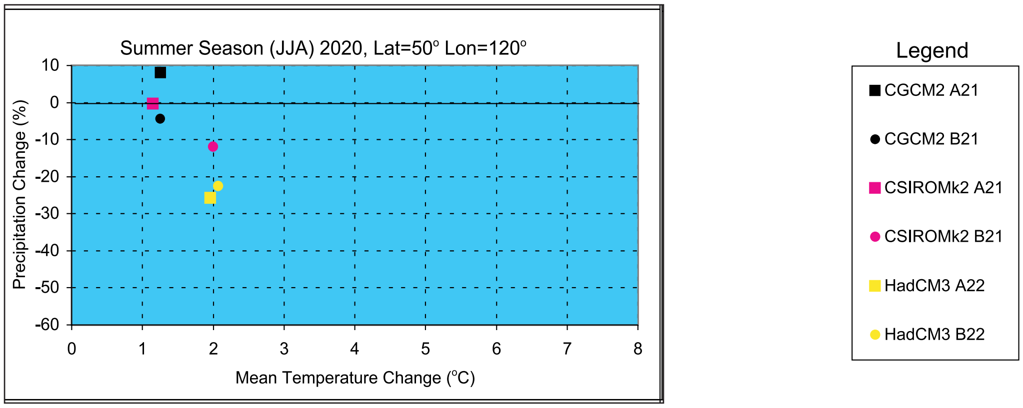
Climate Change Scenarios

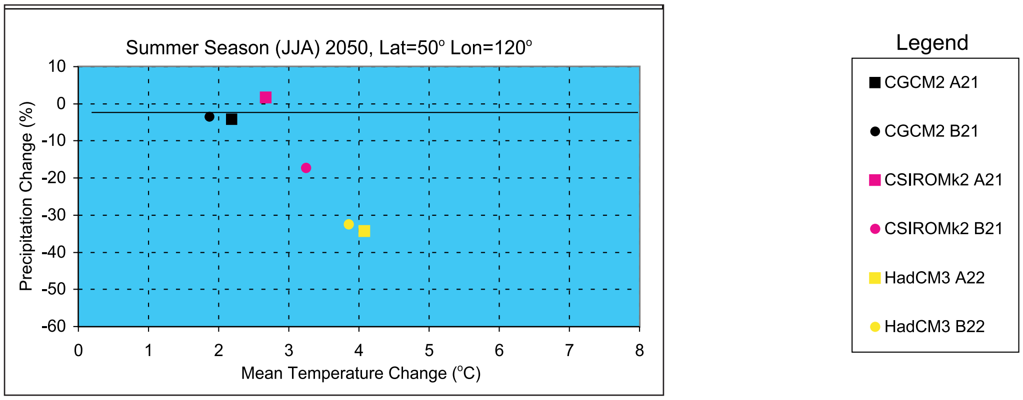
The following figures show scatter plots of projected changes in average daily temperature (degrees C) and precipitation (percent) for the 2020s, 2050s and 2080s relative to 1961-1990 for winter, summer and annual periods for three GCMs and two SRES scenarios.

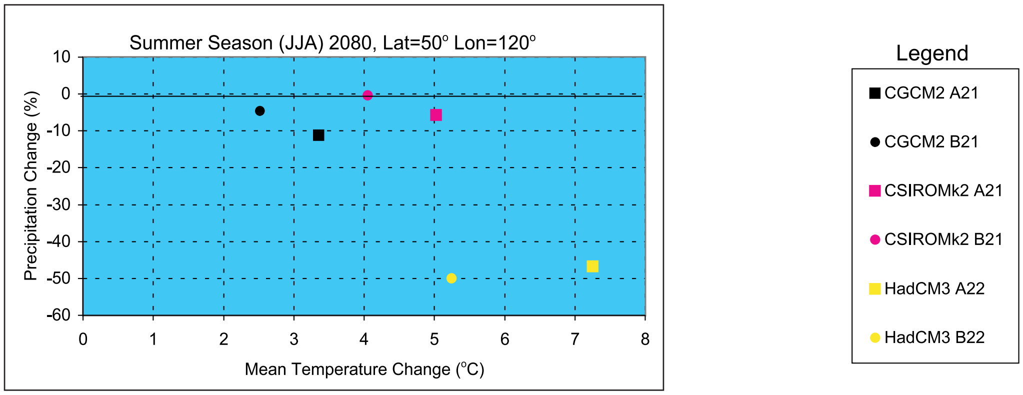


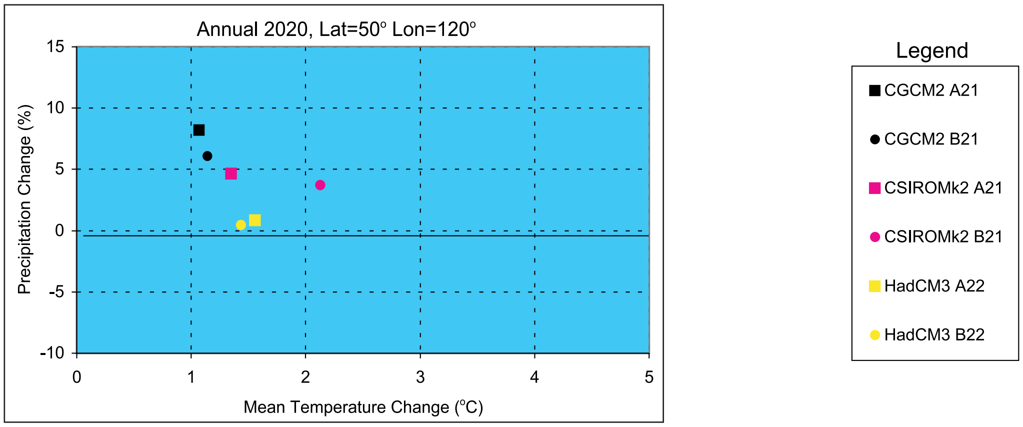


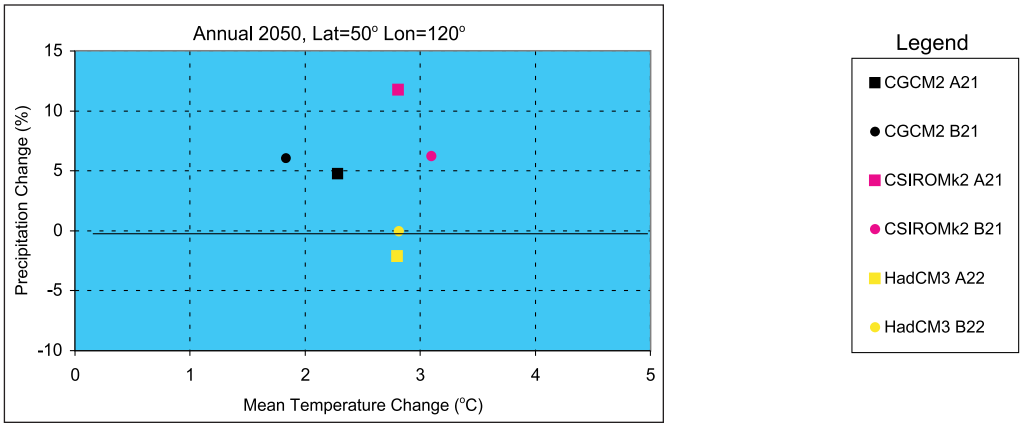


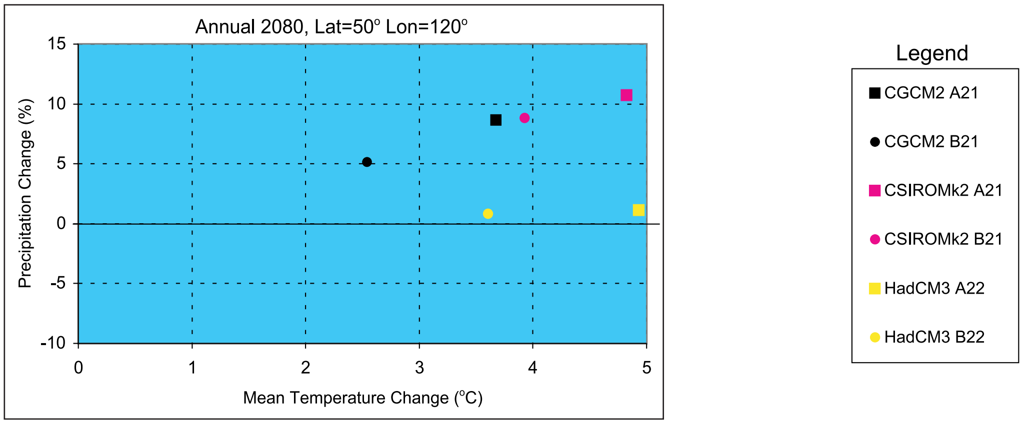

Summer Season (JJA) 2020, Lat=50° Lon=120°
Precipitation Change (%)
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
Mean Temperature Change (°C)
Legend
■ CGCM2 A21
● CGCM2 B21
■ CSIROMk2 A21
● CSIROMk2 B21
■ HadCM3 A22
● HadCM3 B22


Summer Season (JJA) 2050, Lat=50° Lon=120°
Precipitation Change (%)
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
Mean Temperature Change (°C)
Legend
■ CGCM2 A21
● CGCM2 B21
■ CSIROMk2 A21
● CSIROMk2 B21
■ HadCM3 A22
● HadCM3 B22

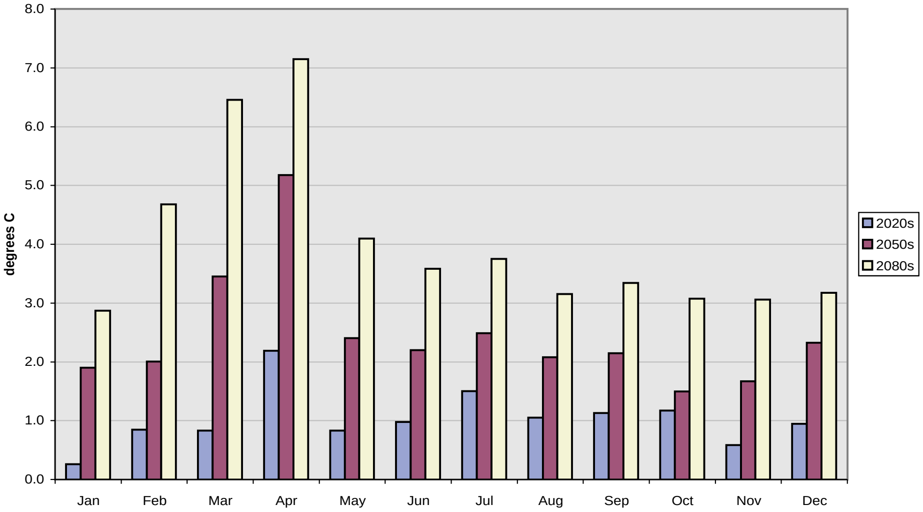

Summer Season (JJA) 2080, Lat=50° Lon=120°
Precipitation Change (%)
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
Mean Temperature Change (°C)
Legend
■ CGCM2 A21
● CGCM2 B21
■ CSIROMk2 A21
● CSIROMk2 B21
■ HadCM3 A22
● HadCM3 B22


Annual 2020, Lat=50° Lon=120°
Precipitation Change (%)
15
10
5
0
-5
-10
0
1
2
3
4
5
Mean Temperature Change (°C)
Legend
■ CGCM2 A21
● CGCM2 B21
■ CSIROMk2 A21
● CSIROMk2 B21
■ HadCM3 A22
● HadCM3 B22

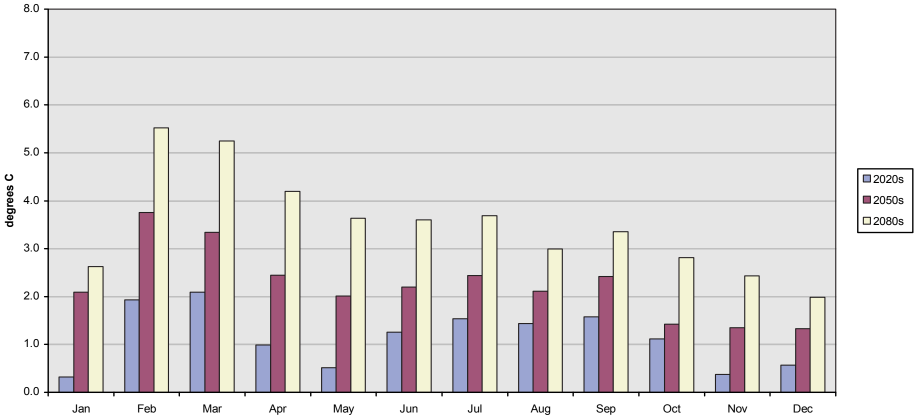

Annual 2050, Lat=50° Lon=120°
Precipitation Change (%)
15
10
5
0
-5
-10
0
1
2
3
4
5
Mean Temperature Change (°C)
Legend
■ CGCM2 A21
● CGCM2 B21
■ CSIROMk2 A21
● CSIROMk2 B21
■ HadCM3 A22
● HadCM3 B22


Annual 2080, Lat=50° Lon=120°
Precipitation Change (%)
15
10
5
0
-5
-10
0
1
2
3
4
5
Mean Temperature Change (°C)
Legend
■ CGCM2 A21
● CGCM2 B21
■ CSIROMk2 A21
● CSIROMk2 B21
■ HadCM3 A22
● HadCM3 B22

CGCM2 Tmax changes SRES A2



CGCM2 Tmin changes SRES A2 - 1



CGCM2 Precip changes SRES A2 - 1

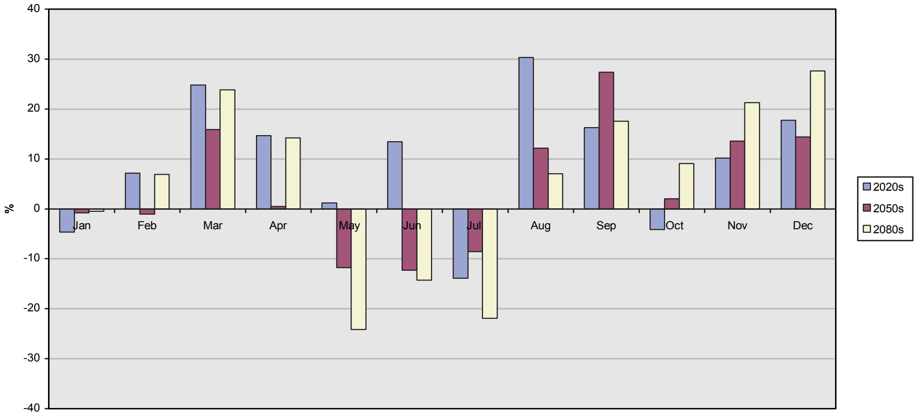
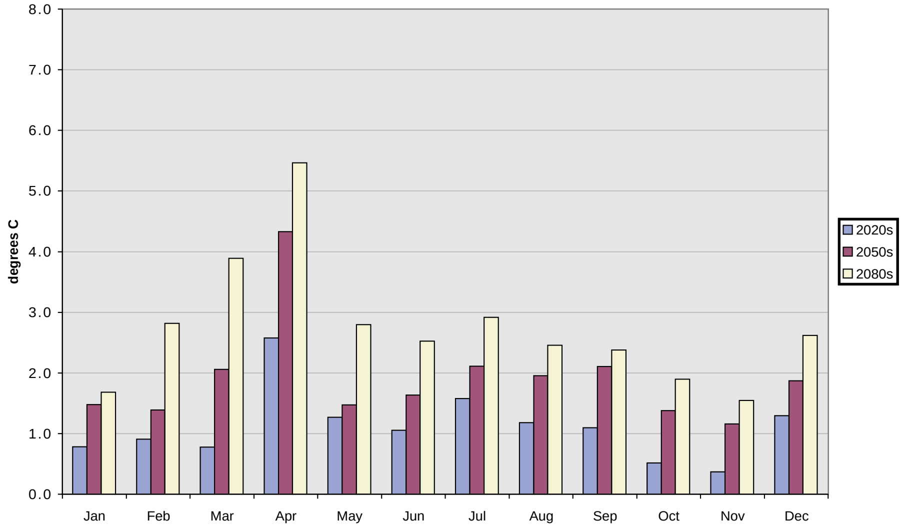


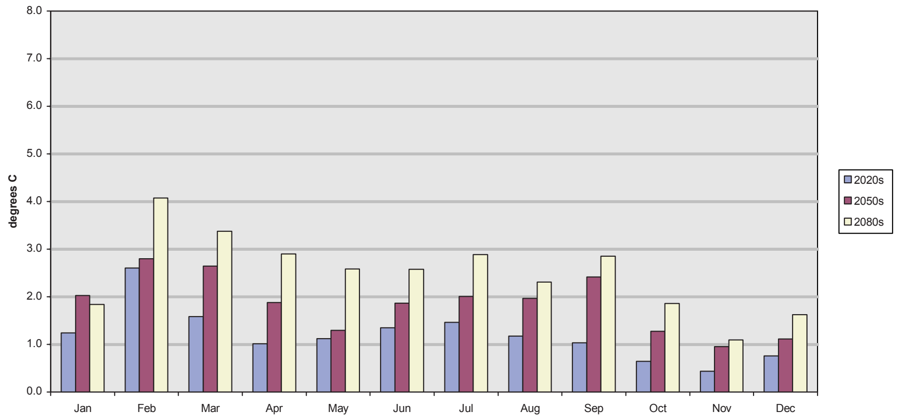
FIGURE A-1

Canadian model CGCM2. SRES emissions scenario A2.

CGCM2 Tmax changes SRES B2



CGCM2 Tmin changes SRES B2 - 1



CGCM2 Precip changes SRES B2 - 1

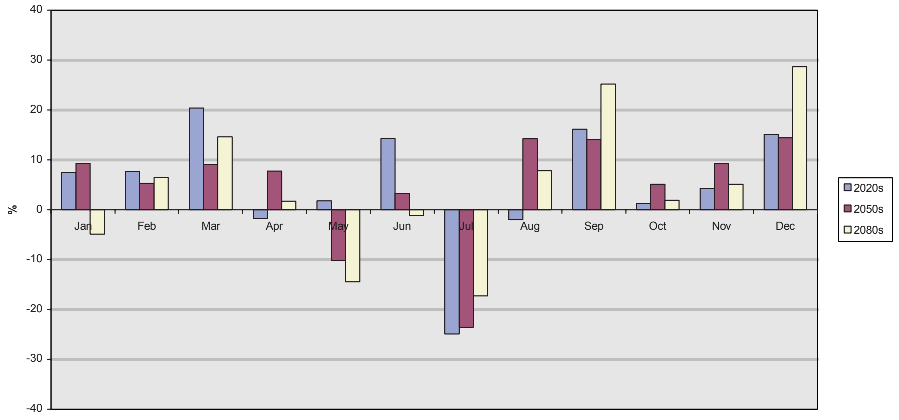
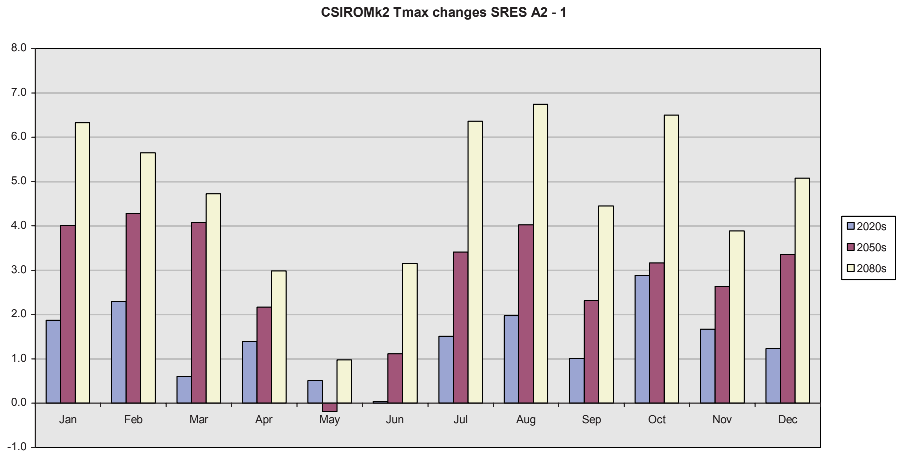
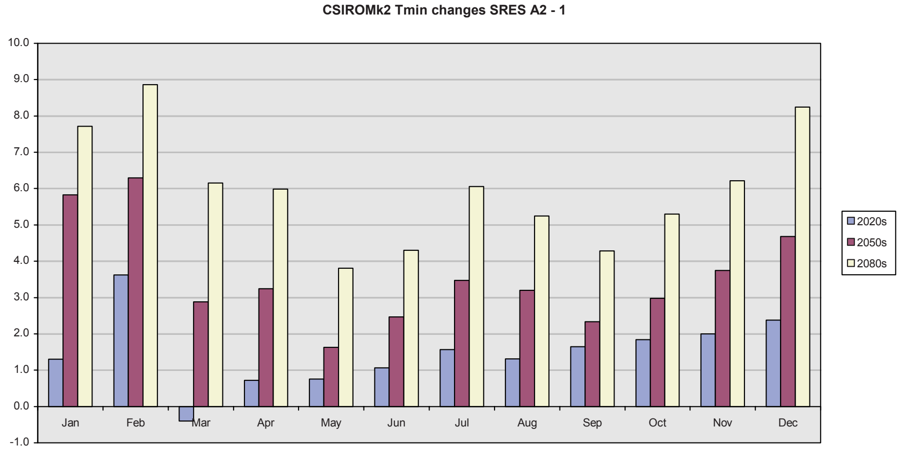


FIGURE A-2

Canadian model CGCM2. SRES emissions scenario B2.


CSIROMk2 Tmax changes SRES A2 - 1


CSIROMk2 Tmin changes SRES A2 - 1

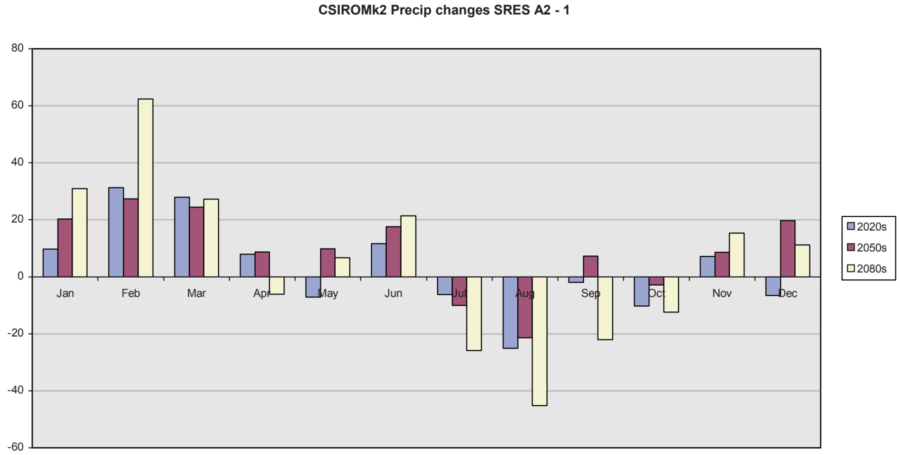
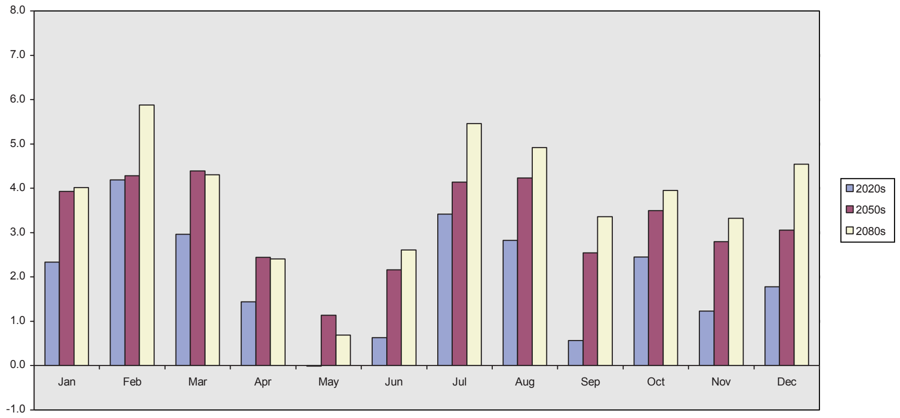

CSIROMk2 Precip changes SRES A2 - 1

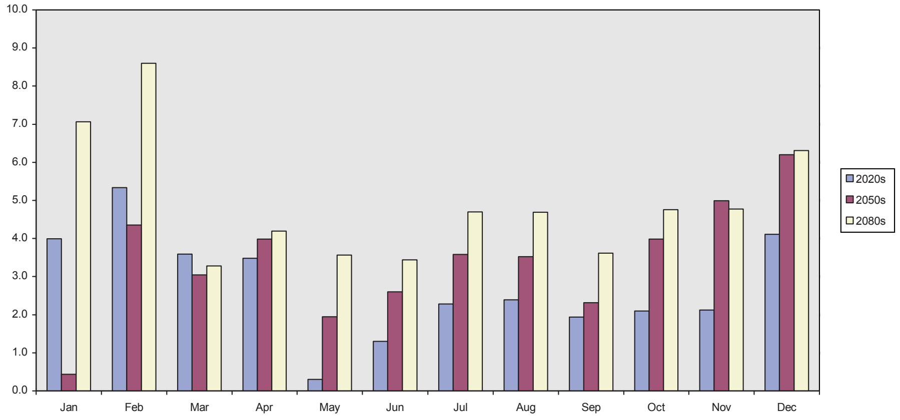
FIGURE A-3

Australian model CSIROMk2. SRES emissions scenario A2.

CSIROMk2 TMax changes SRES B2 - 1



CSIROMk2 Tmin changes SRES B2 - 1



CSIROMk2 Precip changes SRES B2 - 1

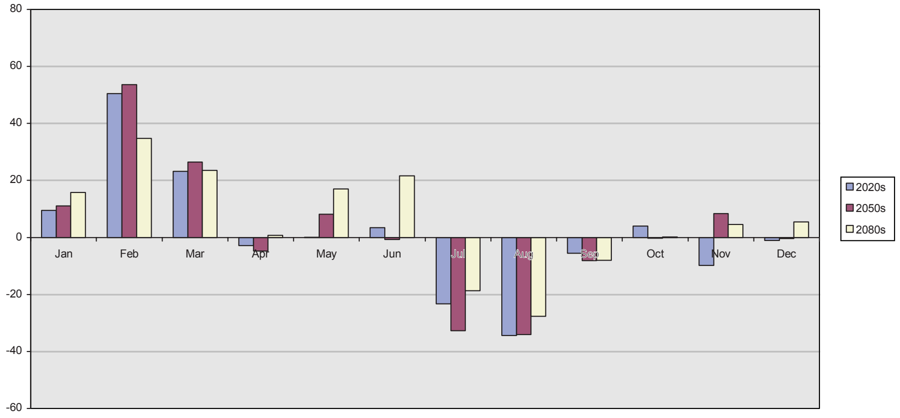


FIGURE A-4

Australian model CSIROMk2. SRES emissions scenario B2.

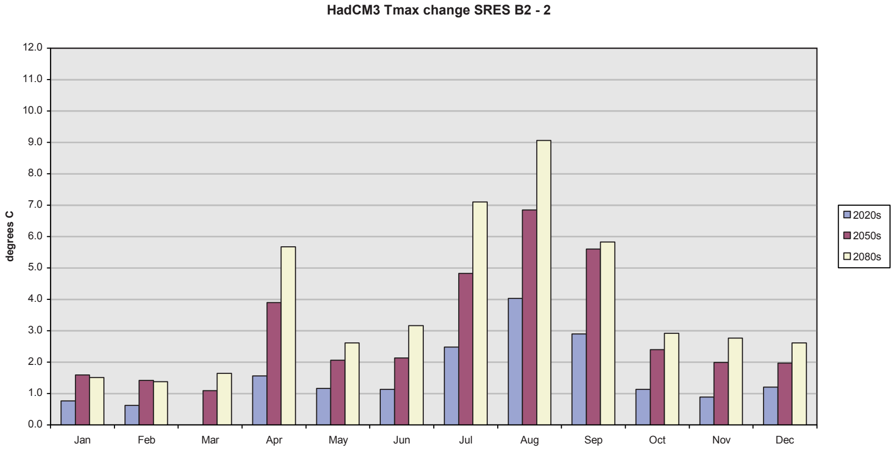

HadCM3 Tmax change SRES A2 - 2

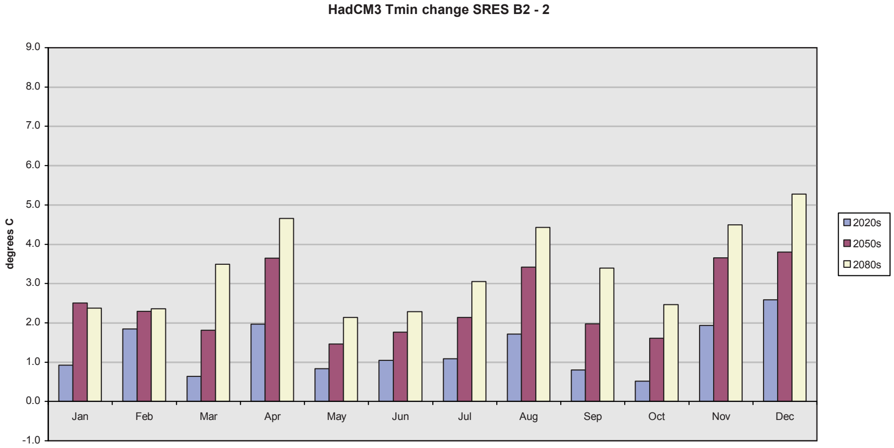
HadCM3 Tmin change SRES A2 - 2

HadCM3 Precip change SRES A2 - 2

FIGURE A-5

British model HadCM3. SRES emissions scenario A2.





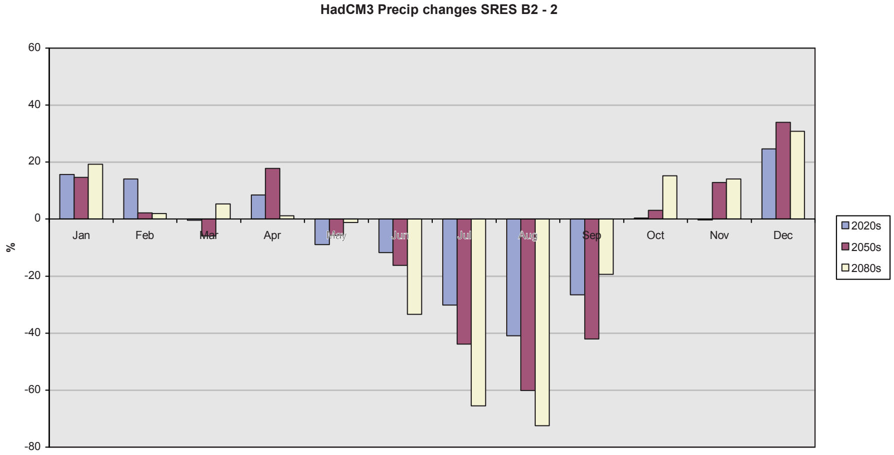


FIGURE A-6

British model HadCM3. SRES emissions scenario B2.

appendix
chapter
8

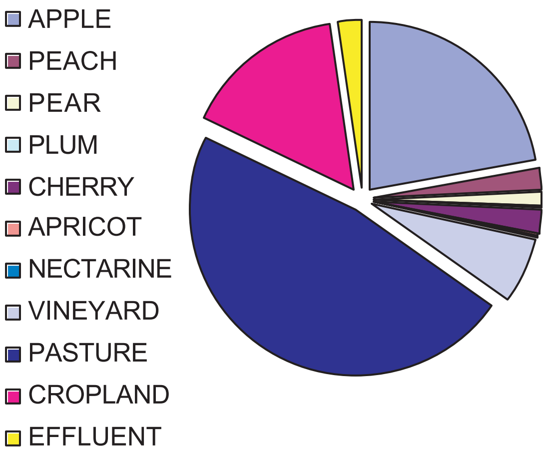
Water Purveyors

NO.	WATER PURVEYOR NAME
1	Not Covered by a Water Purveyor
2	Black Mountain Irrigation District
3	Bobtail Ranch
4	Boundary Line Irrigation District
5	Burrowing Owl Vineyards
6	Bylaw 369 - Falcon Ridge
7	Bylaw 434 - Killiney Beach
8	Bylaw 597 - West Kelowna Estates
9	Bylaw 687 - Green Bay
10	Bylaw 793 - Pritchard/Shanboolard
11	CORD
12	Casaloma
13	City of Kelowna
14	City of Penticton
15	Corp. of the District of Summerland
16	Covert Farms
17	Fintry
18	Former Naramata Irrigation District
19	Glenmore Ellison Improvement District
20	Greater Vernon Water Utility
21	Greystoke
22	Jennens
23	Kaleden Irrigation District
24	Lakeview Irrigation District
25	McIntyre Bluff Ranch
26	Meadow Valley Irrigation District

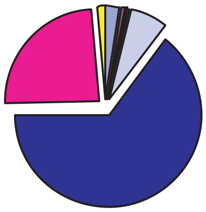
NO.	WATER PURVEYOR NAME
27	Municipality of Lake Country
28	Municipality of Peachland
29	Okanagan Falls Irrigation District
30	Okanagan Indian Band Reserve 1
31	Osoyoos Indian Band
32	Osoyoos Irrigation District
33	Penticton Indian Band Reserve 1
34	Rolling Hills Water Works District
35	Rutland Water Works
36	Shuttleworth Creek Irrigation District
37	Skaha Estates Improvement District
38	South East Kelowna Irrigation District
39	South Okanagan Mission Improvement District
40	Sun Valley Improvement District
41	Sunnyside
42	Town of Oliver
43	Town of Oliver Water Works
44	Town of Osoyoos
45	Town of Osoyoos Water Works
46	Traders Cove
47	Vincor International (Bear Cub)
48	Vincor International (Bull Pine)
49	West Bench Irrigation District
50	Westbank Irrigation District
51	Wilsons Landing
52	excluded

Source: PARC GIS “aguse” export file, 10 Dec 2003.

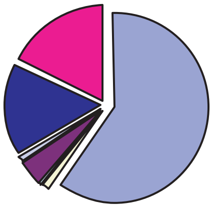
Okanagan Basin



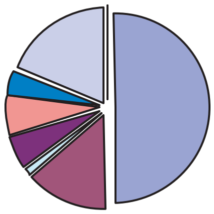
Not Covered by a Water Purveyor



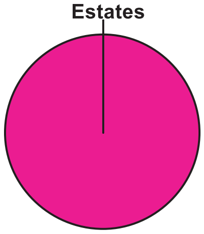
Black Mountain Irrigation District



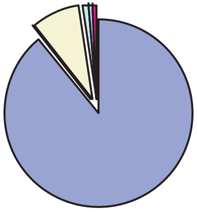
Boundary Line Irrigation District



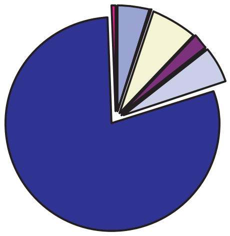
Bylaw 597 - West Kelowna Estates



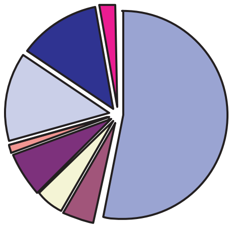
Bylaw 793 - Pritchard/Shanboolard



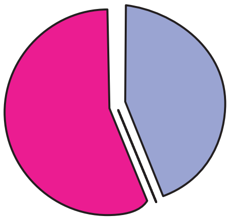
City of Kelowna



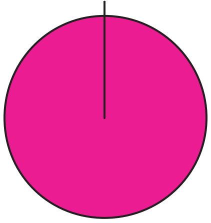
City of Penticton



Covert Farms

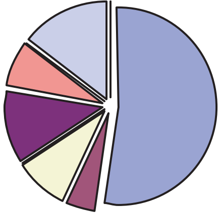


Fintry

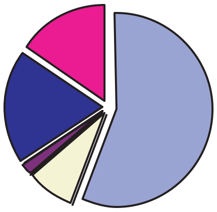


■ APPLE
■ PEACH
■ PEAR
■ PLUM
■ CHERRY
■ APRICOT
■ NECTARINE
■ VINEYARD
■ PASTURE
■ CROPLAND
■ EFFLUENT

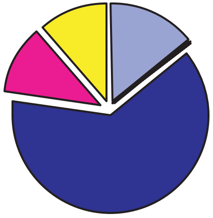
Former Naramata Irrigation District



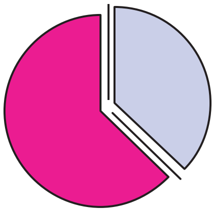
Glenmore Ellison Improvement District



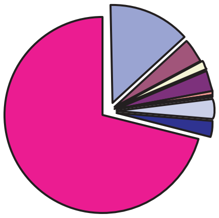
Greater Vernon Water Utility



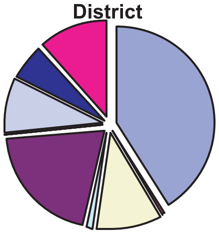
Rolling Hills Water Works District



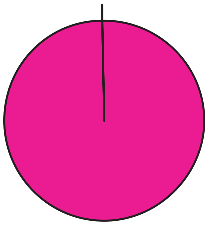
Kaleden Irrigation District



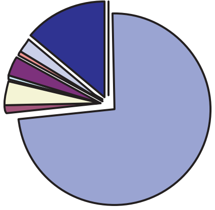
Lakeview Irrigation District



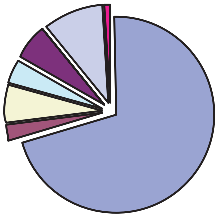
McIntyre Bluff Ranch



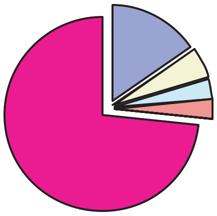
Municipality of Lake Country



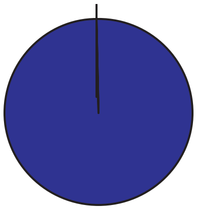
Municipality of Peachland



Okanagan Falls Irrigation District



Okanagan Indian Band Reserve 1



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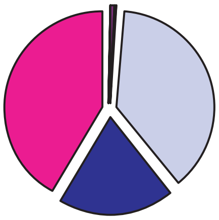
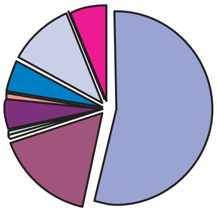
- ■ APRICOT
- ■ NECTARINE
- ■ VINEYARD
- ■ PASTURE
- ■ CROPLAND
- ■ EFFLUENT

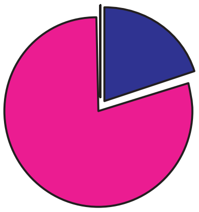
Osoyoos Indian Band



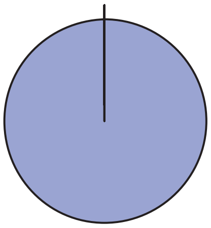
Osoyoos Irrigation District



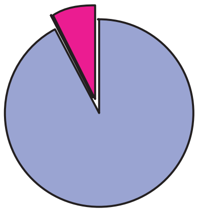
Penticton Indian Band Reserve 1



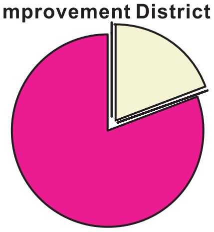
Rutland Water Works



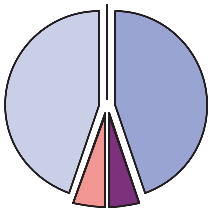
Shuttleworth Creek Irrigation District



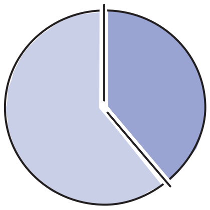
Skaha Estates Improvement District



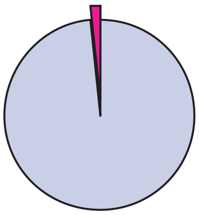
South Okanagan Mission Improvement District



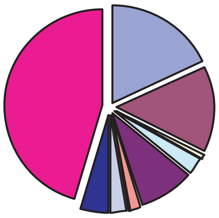
Sunnyside



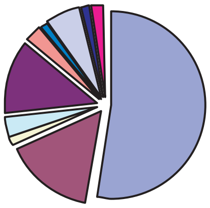
Sun Valley Improvement District

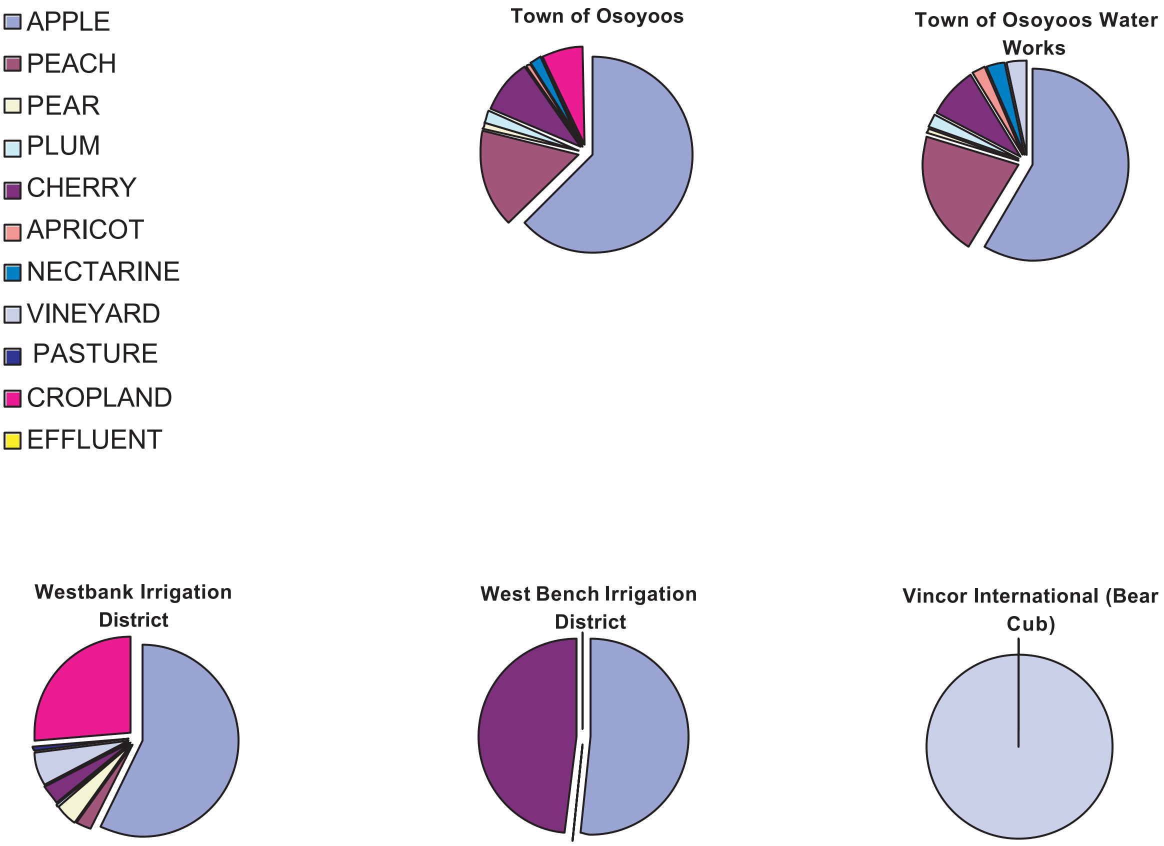


Town of Oliver



Town of Oliver Water Works




APPLE
PEACH
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PLUM
CHERRY
APRICOT
NECTARINE
VINEYARD
PASTURE
CROPLAND
EFFLUENT
Town of Osoyoos
Town of Osoyoos Water Works
Westbank Irrigation District
West Bench Irrigation District
Vincor International (Bear Cub)

appendix chapter 9

Residential Water Demand Scenarios, Penticton

Scenarios are produced using 3 population growth scenarios and 6 climate change scenarios for Penticton. These are described in Chapter 9. Figures A9.1-A9.3 summarize the 6 climate change scenarios for each of the population growth scenarios. Figures A9.4-A9.9 do the reverse.

CC1 = CGCM2-A21, CC2=CGCM2-B21,

CC3=CSIROMk2-A21, CC4=CSIROMk2-B21,

CC5=HadCM3-A22, CC6=HadCM3-B22.

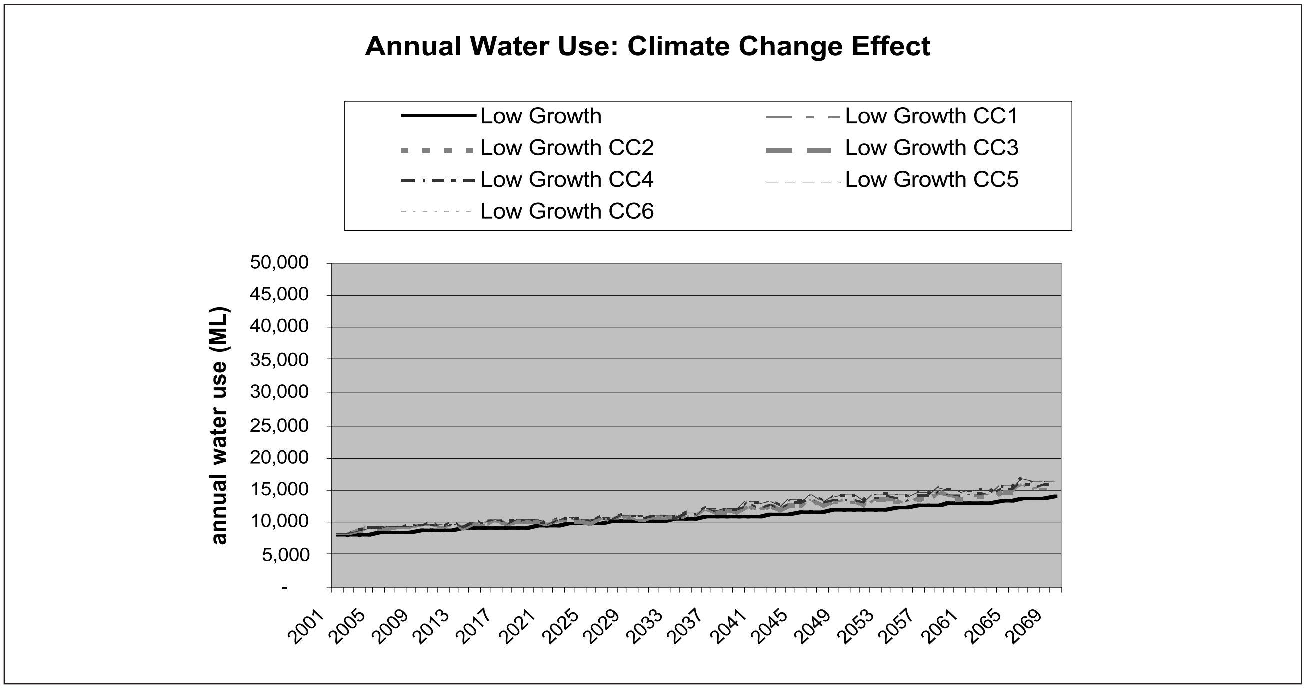

FIGURE A9.1

Low population growth scenario.

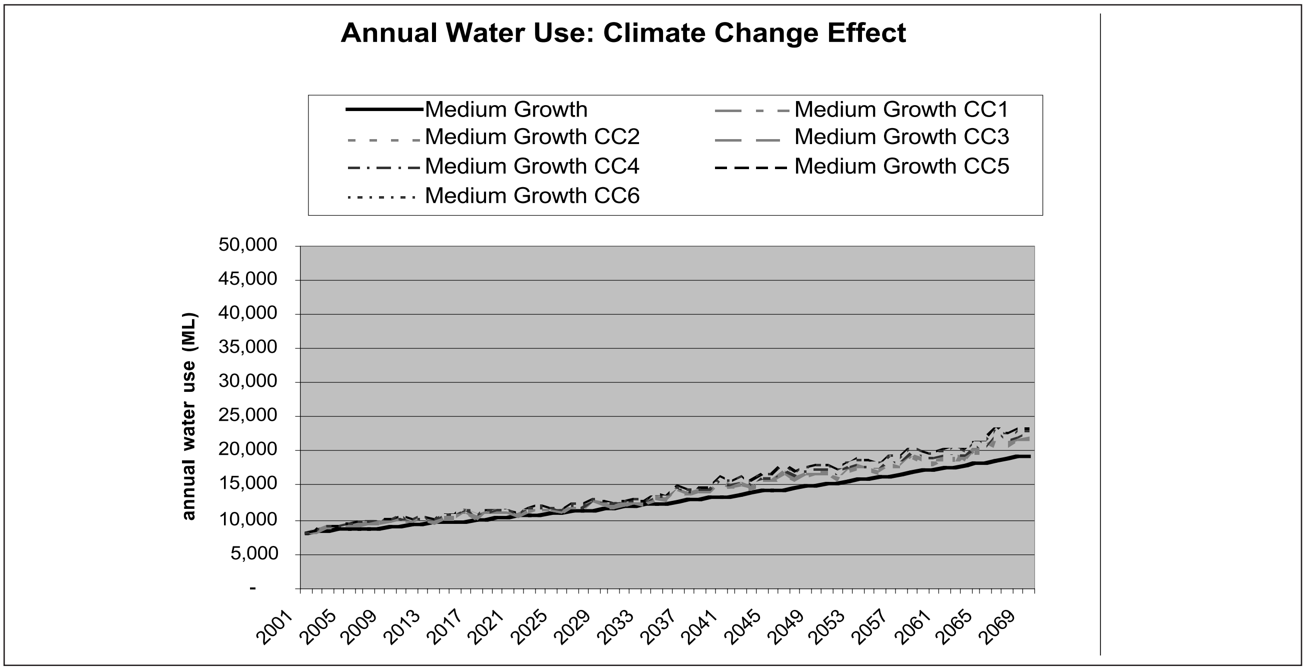

FIGURE A9.2

Medium population growth scenario.

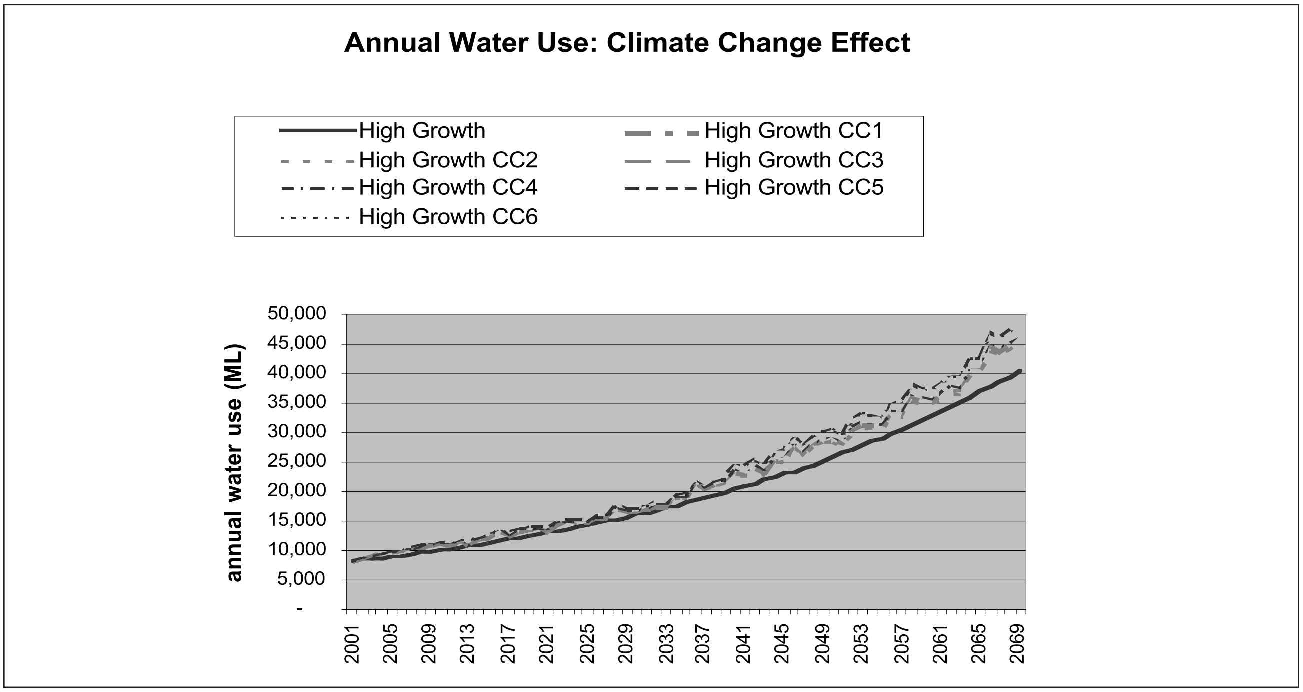

FIGURE A9.3

High population growth scenario.

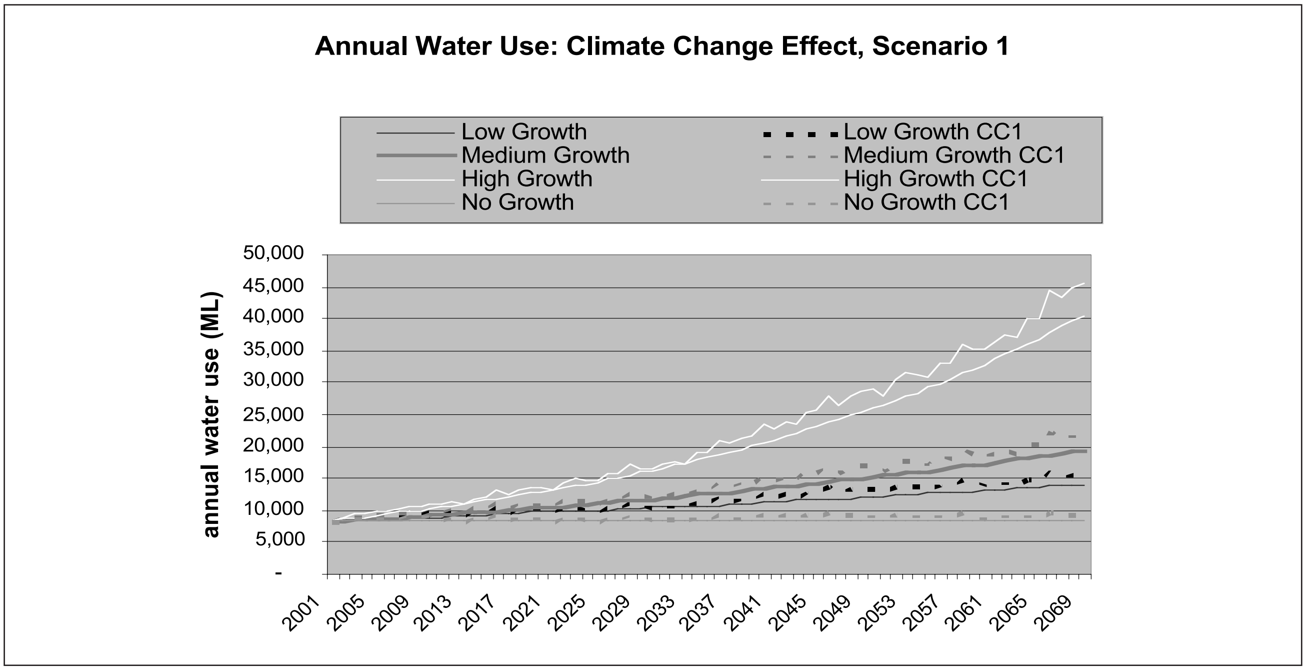

FIGURE A9.4

CGCM1-A21 climate change scenario.

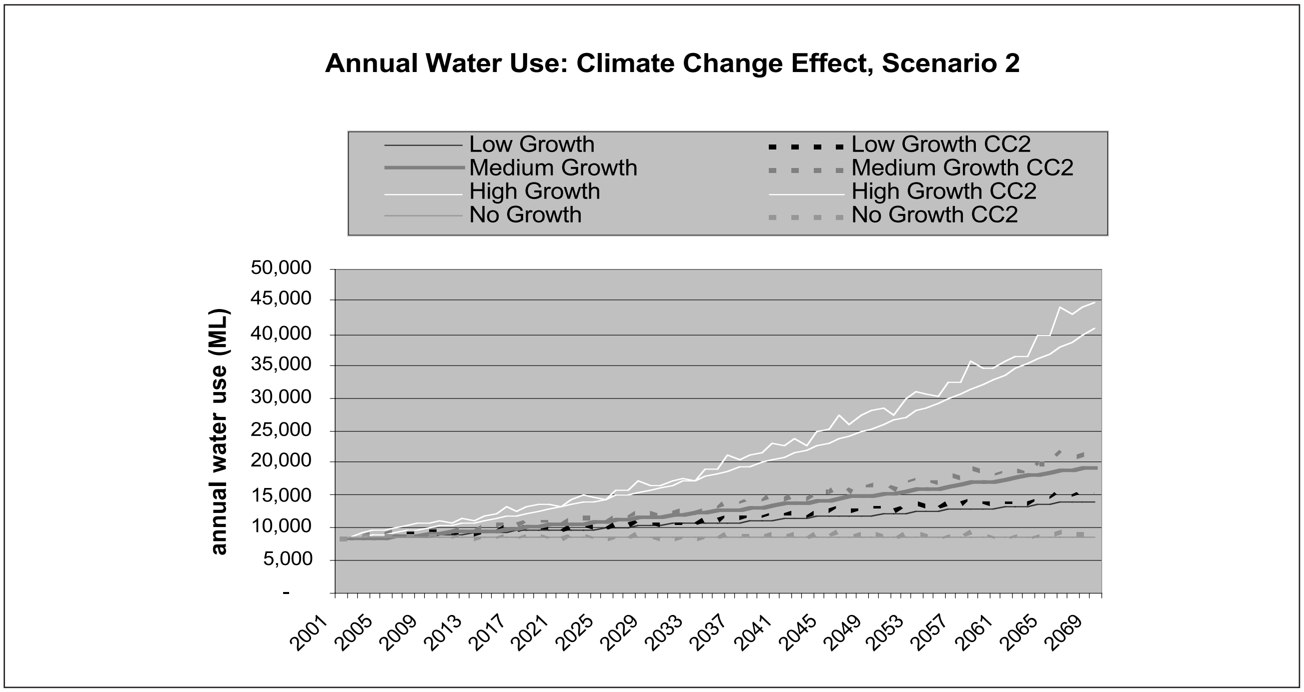

FIGURE A9.5

CGCM1-B21 climate change scenario.

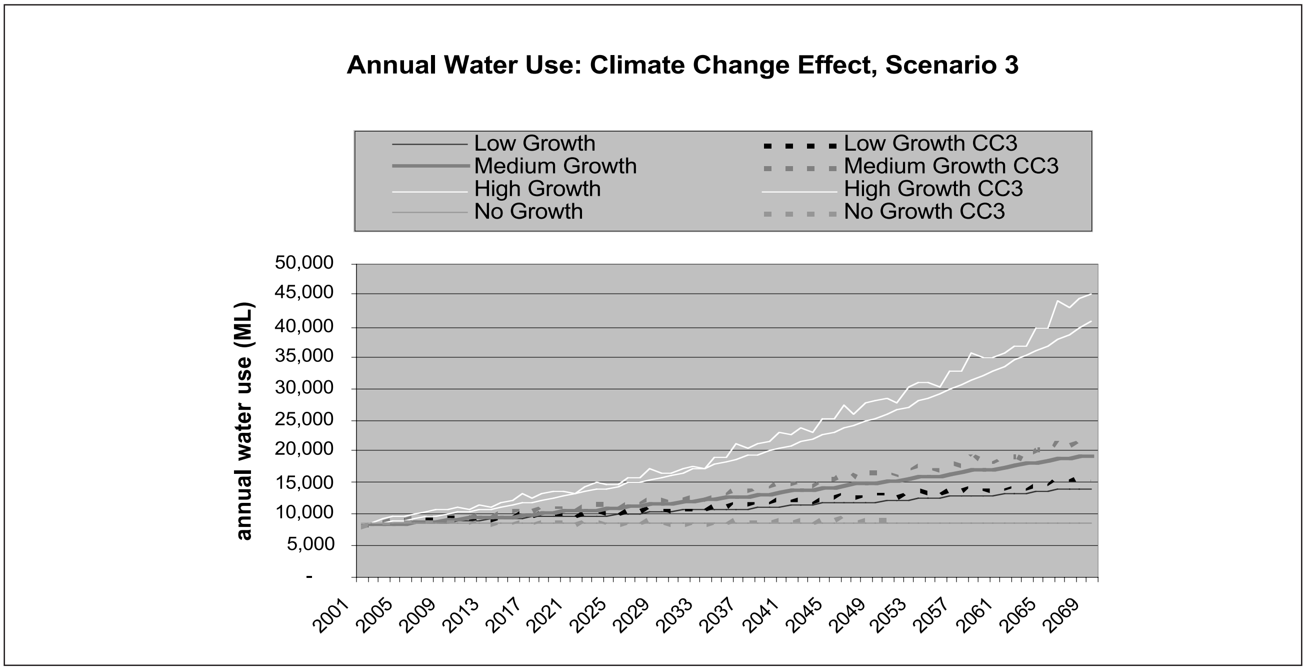

FIGURE A9.6

CSIROMk2-A21 climate change scenario.

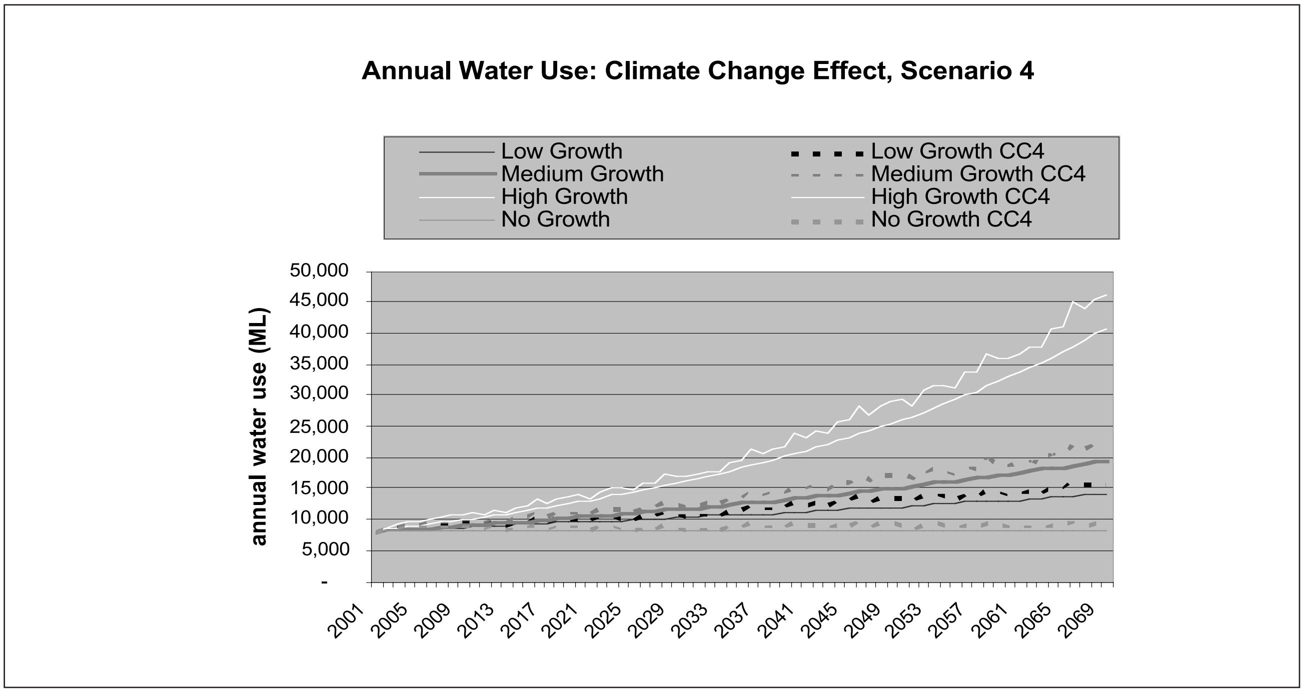

FIGURE A9.7

CSIROMk2-B21 climate change scenario.

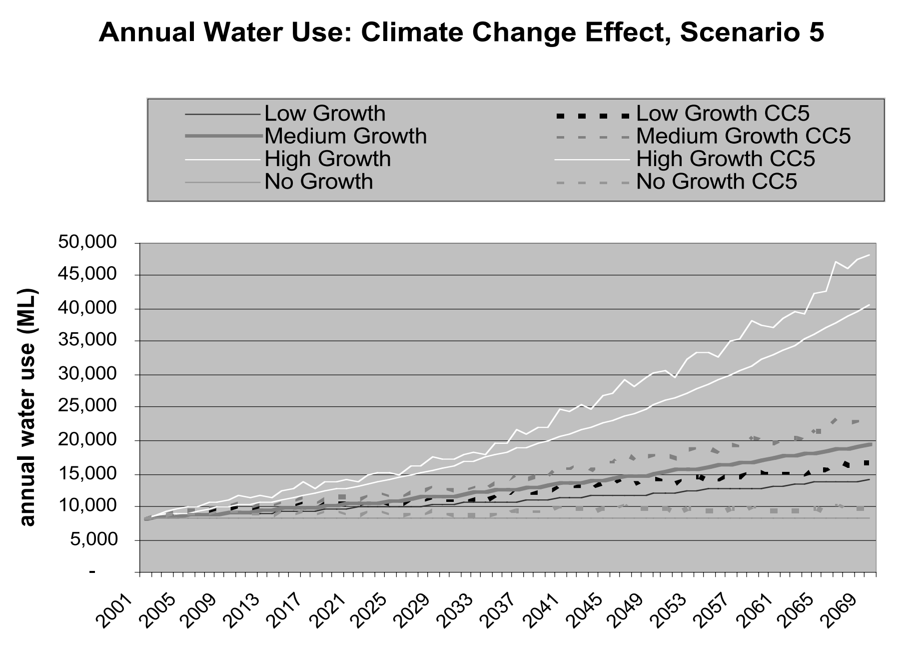

FIGURE A9.8

HadCM3-A22 climate change scenario.

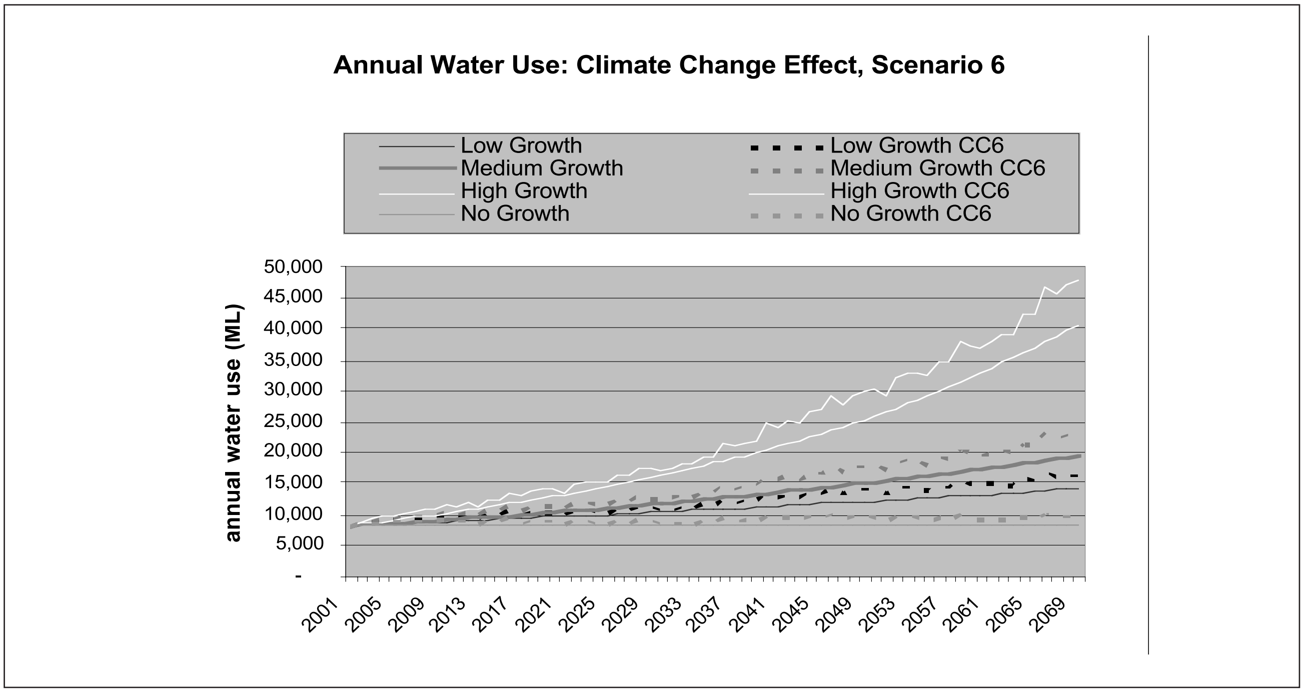

FIGURE A9.9

HadCM3-B22 climate change scenario.

appendix
chapter
10

Appropriateness and Effectiveness of Adaptation Experiences

TABLE A10.1: Appropriateness of adaptation measures.

	VERNON: *WATER RECLAMATION*	GVWU: *UTILITY AMALGAMATION*	SEKID: *METERING IRRIGATION*	KELOWNA: *METERING DOMESTIC*
No regrets: justified under existing hydrological conditions	**No regrets:** As these measures have been implemented without climatic change in mind, they are by default "no regrets" options. However, what repercussions they might have is yet to be determined, especially in GVWU case.			
Flexible: effective under different water regimes	**Flexible but:** If interpreting this approach as a "water producing" process, then it will work under different water regimes. However, the amount of reclaimed water available is at the mercy of the weather, therefore the extra supply isn't fully predictable or reliable.	**Flexible?:** There are too many aspects to this amalgamation to answer this question fully. Focusing purely on the local governance change, the question must be raised – will the governance structure hold (and be fair) as it becomes more difficult to meet rising demand, or if climatic change results in more drought episodes? The assumption is that by sharing supply, it will be used more fairly and more efficiently.	**Flexible:** As a purely monitoring tool, the effectiveness of metering is not compromised by changing water regimes. As a means to change consumption patterns in combination with a constant unit charge or similar fee structure, it is flexible as rates can be changed to further curb consumption or as a source of revenue (although only up to a point).	
Implementable: existing resources	There are different resources one can talk about. If there is local and provincial will, then financial resources will be made available. Affordable technology could be a limiting resource. Expertise and knowledge are another category of resources that could limit successful implementation. Some specific comments are made below.			
	Some absolute limits: Vernon was particularly suitable for water reclamation e.g. soil types. Armstrong now reclaims 100% of its wastewater while other authorities such as Penticton use some reclaimed water. If physical & infrastructure capacity allow, then there seem to be resources, and a desire, for its expansion elsewhere in the Okanagan.	**Some absolute limits:** In this case, financial resources e.g. provincial borrowing possibilities, were available. Again as regionalisation is a provincial agenda, other moves in this direction would probably receive positive provincial support (assuming this agenda stays the same). As with water reclamation, physical feasibility in terms of being able to interconnect infrastructure might be impracticable elsewhere in the Okanagan.	**Access to financial support:** Many Water Districts are small and probably would not have the financial means to implement metering. Unless another source of funding is easily accessible e.g. user pays, then this could be a significant barrier.	**No obvious barriers:** At least in Kelowna's case, resources were not inadequate. Other municipalities have implemented domestic metering, which suggest that it is a very feasible option.
Ease of implementation: feasible measures that do not require major financial outlays, institutional arrangements or radical shifts in behaviour.	**Perception barriers and financial outlays:** On the one hand, relative to wastewater treatment water reclamation was deemed no more expensive. On the other, much human dedication and financial resources were required to maintain 100% application. Water reclamation requires a perception change – that wastewater isn't waste but a valuable resource. This is a significant hurdle.	**Radical change:** Utility amalgamation (both supply and distribution) required a significant institutional re-arrangement and financial outlay.	**Shift in behaviour and perceptions:** Metering irrigation requires a significant shift in perception by agricultural users.	**Feasible:** No major financial outlays, institutional or behavioural changes required.

	VERNON: *WATER RECLAMATION*	GVWU: *UTILITY AMALGAMATION*	SEKID: *METERING IRRIGATION*	KELOWNA: *METERING DOMESTIC*
Responsive: consistent with community goals	**Responsive:** Protecting the water resource is consistent with regional goals as is using water efficiently.	**Questionable:** This is the challenge here – achieving consensus amongst multiple partners ultimately means compromising distinct needs and goals of each.	**A balancing act:** Achieving better control and more efficient use of water is a community goal. However, at the same time protecting farmers and ensuring affordable and ample water is also a goal. Currently, metering and definitely pricing are not acceptable means. For example, in the creation of GVWU, partnership was based on an agreement that farmers would be protected from increased water prices. This attitude will likely change.	**Responsive:** Penalizing over-users, better more efficient management and a more fair charging system is consistent with community goals
Reversibility: can be altered in the future as new information arises	**Aspects can be altered:** Can be altered and has been during the past 30 years with respect to type of land application of reclaimed water. Although not considered a significant risk now, health and land contamination i.e. off-speck cases, could be potential reasons for discontinuing water reclamation based on new found information. However, increased wastewater treatment could waive any fears.	**Difficult:** Such an institutional change alters the core method of decision-making and water management. It would be very difficult to reverse such a course of action. However, assuming the governance structure is unchangeable the infrastructural component could be tweaked and modified if necessary e.g. water prices, supply distribution, incorporation of reclaimed water.	**Aspects can be altered:** If necessary, metering could be stopped without significant repercussions, unless it becomes a significant source of revenue. Fees could be adjusted if required.	
Minimize environmental impacts: do not stress natural systems unnecessarily	**Reduces some environmental impacts:** Water reclamation is a process that is considered to reduce stress on natural systems in terms of pollution (although treatment followed by direct discharge is considered by many to be just as acceptable). Additionally, if water consumption did not increase, it could displace some use of fresh water.	**Difficult to comment regarding this adaptation it is still in the stages of implementation.**	**No significant environmental impact:** If metering results in a reduction in use, further supply expansion can be deferred and less water treated, which could reduce negative impacts on the water system in question.	
Cost effectiveness: economic efficiency, in other words benefits outweighs costs.	Only a brief look at the costs and benefits of each adaptation, in a broad sense, was carried out in this study (Table A10.2). Generally, the benefits seem to outweigh the costs. This is obvious in the Kelowna and SEKID cases. However, water reclamation met many obstacles and underwent many changes which cost is difficult to estimate. GVWU project is still under implementation, so ultimate cost is still unknown.			
Equity: beneficiaries accept costs, user pays, amount consumers' pay should capture full costs, no social subsidies i.e. no activities subsidised by others.	**Social subsidies:** Beneficiaries do not cover costs. Water reclamation in Vernon is still a burden for the City. This is a key disadvantage, although it will likely change in the future. However, it could take some time, and would require local political will or provincial intervention to ensure that the price of reclaimed water reflects its value.	**Social subsidies:** Significant cost burden between urban users and farmers. It was openly stated that farmers are being subsidised by urban users i.e. increases in water rates by domestic users will cover maintenance costs. Although the argument is that farmers don't need the same level of treatment for irrigation than urban users, therefore subsidisation is justified.	**Almost equitable:** Significant portion of implementation was borne by provincial government. However, maintenance covered by the Water District, although likely subsidised by domestic users.	**Equitable:** Cost of providing water to customers is covered by water rates.

	VERNON: *WATER RECLAMATION*	GVWU: *UTILITY AMALGAMATION*	SEKID: *METERING IRRIGATION*	KELOWNA: *METERING DOMESTIC*
Reduce vulnerability: does not increase sensitivity to climatic change	**Potentially but "rebound effect":** If climatic change in the Okanagan ultimately results in a reduction in total physical supply, reclaimed water could act as an additional source. If not exhausted on expanding irrigated area, then it could also be used as a backup during significant drought periods	**Questionable:** Amalgamation of utilities in Greater Vernon is considered the best option for securing water supply and meeting demand than continuing on as separate utilities. However, repercussions of institutional changes are harder to predict, especially as the project is still in its early stages. For example, Vernon's veto provides it with decision-making power, which could potentially cause difficulties later - or not i.e. under water-stressed conditions.	**Potentially but "rebound effect":** Although metering indicated that use was 10% lower than previously thought, and some farmers reduced use as a consequence of metering and scheduling, vulnerability has not been reduced. This is primarily because the "saved' water has been allocated to allow for further development in the region.	**Potentially but "rebound effect":** Although metering reduced peak demand ultimately these savings will go to fulfilling Kelowna's development agenda.
Increase adaptive capacity	**Coping capacity:** It improves coping capacity which under the "social resilience" definition an adaptive system, means it increases adaptive capacity.	**More rigid institutionally:** Although sharing supply and distribution increase some capacities e.g. financial, decision-making procedures might become more wrought with conflict under increased stress.	**Better management tool:** Metering provides the manager with more accurate information on where the water is going. This information allows for greater efficiency and flexibility in management, therefore increasing adaptive capacity.	
Relative effectiveness:	These cases have not been studied in order to discern which approach is the better. Table A10.2 shows the advantages and disadvantages of each approach.			

TABLE A10.2: Effectiveness of adaptation measures.

CASE	IDENTIFIED ADVANTAGES	IDENTIFIED DISADVANTAGES	ACHIEVED OUTCOME	WHO BENEFITS?	WHO PAYS/ DOESN'T BENEFIT?	SCALE OF IMPACT*?
VERNON	Expansion of irrigated areas Displacement of freshwater Local community benefits Reputation Avert discharge into the lake - environmental benefits Gaining benefits from a waste - efficient More economical: reduced treatment and reduced use of high quality water i.e. summer peak demand, therefore cost-saving. Cost savings for users i.e. avoid fertiliser costs	Cost Contentious politically Public perception Uncertainties - off-speck impacts, liabilities Unreliable - weather dependent Difficult to control use - as dependent on farmers Limited land base i.e. use - production balance Initial health issues i.e. quality of reclaimed water	100% re-use of reclaimed water after 1985. Avoidance of discharge into lake, except for 3 incidences.	Participating farmers All public interested in maintaining pristine quality of lake City of Vernon = environmental reputation Province: data and information on efficacy of water reclamation	Public (sewer fees) Province (initial capital costs) Those concerned with health implications of spray irrigation	Local
GVWU	Efficiency and optimization (less bureaucracy, duplication) More cost effective + greater pool of resources Flexibility in terms of water sources Greater water resource security Safeguard the rural/agricultural community (maintain low irrigation water rates) More expertise - advance management practises Same quality of water for all Fairness/equity Cost/burden sharing Better management - planning for long-term growth	Challenges of political attitudes Challenges of public attitudes Loss of control Higher costs - for better water quality Trade-off between future benefits versus immediate benefits	Too early to assess outcome.	All service users i.e. better water quality and services Each participating party: Vernon: access to supply Coldstream: financial support NOWA (agriculture): commitment to farming community & subsidisation of prices Province: observation of establishing a "model region"	Urban users: significantly higher water rates Province: funding provision Each participant: giving up autonomy and decision-making power (in terms of the latter except Vernon)	Regional
SEKID	Easier to police/control -better, more efficient management Leak detection Greater data accuracy - i.e. know exact water use Reduce time for maintenance/policing Reduce costs e.g. treatment, avoid upgrades Equity/fairness More environmentally appropriate Only over-users greatly affected Possibility of putting more land into production, or saving water for a drought year Tool for a decision support system - once have that can instil an ethic e.g. speed limits.	Cost Need for learning/training/expertise Data overload Attitudes Slow process Loss of freedom - more control Lack of uptake by other Districts Needs maintenance, reading, 'big brother' feel Trade-off with turtle Lake expansion	5-23% reduction in use. Realisation that actual use not as high, so reduced allocation to 2.2.5 ac-ft/ac.	District management: better policing, "savings" that can be used elsewhere or to carry the District through dry years Farmers if efficiency gains not wasted on expansion e.g. domestic users Management: more technical know-how MAFF: experience and data on metering agricultural use	Farmers: reduced water allotments and more fines (water becoming costly).	Local
KELOWNA	No change in average cost to customer Water reduction Accurate data Shows unaccounted for water Identify heavy users Could target education on heavy users Better planning tool for 20-year service plan 5-10 year deferral of capital investment Reduce design standards for new development	Cost of maintenance Time spent for public appeasement	Total annual average per capita consumption dropped by 24.29% between 1998-2000.	City of Kelowna: greater control, reduced infrastructure costs, water savings Average users: no impact All users: educational program on how to reduce water consumption to maintain low costs	Over-users: higher water prices	Local

* Although the direct impact is limited, one has to acknowledge that diffusion of knowledge and experience has a much larger impact. This is especially so with Vernon, GVWU and SEKID. Vernon has received national environmental awards for its commitment to water reclamation, MAFF has disseminated information about metering in SEKID and GVWU could potentially be used as a 'model' for future application.

appendix chapter 12A Oliver

Demand Side Interventions

	SOCIAL ACCEPTABILITY		LEGAL FRAMEWORK			POLITICAL REALISM AND ACCEPTABILITY		
	WHO MAY BENEFIT?	WHO MAY OPPOSE? WHY?	LAWS THAT EASE AND SUPPORT...	LAWS THAT PREVENT	NEW LAWS, ETC.	DO THE POLITICIANS & ELECTORATE SUPPORT...	WHAT LEVELS OF GOVT. HAS JURISDICTION? RESPONSIBILITY?	WHO IMPLEMENTS/ PAYS?
Increased Storage[1]	Everone[2] who need more water or more reliable water Users who do not have licenses Agriculture (because dependent on surface water) Those concerned with fish habitat	Those interested in fish habitat protection: minimum flow issues). Landowners impacted by the construction of reservoir Flooding downstream of dams Taxpayers (infrastructure costs) Anti-growth lobby Environmentalist because of habitat change Perception issues from public, anchored to the existing water level and may demand compensation. (happening in Summerland)	Water license under Water Act OCP could initiate a new reservoir, if within capacity Rights of expropriation	Water Act Fisheries Act CEAA, OCP Environmental Sensitive Areas Species at Risk Act Potential Future concern, aboriginal Act	Provincial laws under Liberals that can overrule other legislation (i.e. environmental) NAFTA-sale of water Development incentives for new residential	Short term-no because the mode of delivery is more expensive than groundwater for domestic Long term-yes if there is a need for more water; concern about costs Developers and residents may be opposed to extra costs	Oliver WW in negotiation with RDOS	Present: urban subsidy to rural users, which was part of legacy of agreement that altered water licensing in 1990. There was a single irrigation district from Osooyos south with the two municipalities responsible for supply. Altered by Vanderzalm so that Oliver in charge and irrigation issues transferred. Historical legacy for farmers[3]. 'The farmers were robbed of the water in this process'
Pump From Mainstem and Irrigation canal [4]	Agriculture Some residents Agreed that everyone would benefit from using the surface water to some degree; water is a necessity. Because of the existing infrastructure, is a cheaper, simpler way to access more water than drilling more wells. Concern about the enormous cost of having everyone using pumps all the time.	Salmon/environment advocates Lake shore residents Environmentalists and ONA (Okanagan Nation Alliance) would potentially oppose the increased use on surface water bodies (SWB) and pumping. Because of the potential negative impact on the salmon. Tourism industry and those earning a living from oppose this due to affect on the levels of the lakes and streams. Lakeshore residents would also oppose this because of lake level concerns and aesthetic values	Provincial license framework OBWB Provincial water licensing already in place so the framework is in place to issue further water rights to the SWB and irrigation ditches. Water consumption by-laws. OBWB – Okanagan basin water board supports this method currently.	OBWB (role would have to change for this to succeed) but is regarded as a key body. Instream flow requirement (MWLAP/ DFO). SARA (Species at Risk Act). Federal initiative concerned with lake and river level depletion. Drinking water standards that would have to be met and surface water may not be acceptable quality.	Extension of existing license. A body identified for the enforcement of the Water resource priority use and assurance that all user needs down stream are met.	Depends on lobby group support. Politicians not support because of recent focus on potable water quality issues and ground water quality in this region is very good. Politically unattractive to move from such an excellent source to one where human health could be negatively impacted. Politically attractive if the cost became very low relative to other alternatives, but pressure from urbanites (town folk) focused on clean drinking water. If there were lobbying groups that would pressure the government to move more to this solution it would be attractive and more feasible to them.	Municipal- drinking water quality – given the authority and responsibility by the provincial legislation to regulate and monitor quality. Responsible for managing the infrastructure. Infrastructure. Province-ALR Federal, Osoyoos Band - Fish. RD – Land use, OCP.	Water user fees (municipal) Local taxpayers Federal tax – BC AG Council Administrative funds would pay/do pay/have paid for the administration and infrastructure. License fees (provincial) Federal grants for fish maintenance and habitat protection/ restoration. OK Fish Alliance (ONA – Fisheries group). Gets funds through the Columbia projects and involved in managing the water with respect to fish and habitat.

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[1] For the agriculturalist, climate change could create conditions for expanded agriculture, it is a benefit to Oliver and could get vineyards higher up the valley.

[2] Considered which streams could have more storage: Vaseux Creek, Reed Creek, Testalinda, Shuttleworth Creek. Driven by supply reliability issues on other parts of the valley, but probably not here. Domestic water use here is from groundwater, irrigation comes from surface water. No great demand for fish habitat from reservoirs.

[3] Water reps in Osooyos appear to have more influence than farmers in Oliver.

[4] The current practice is that all irrigation and domestic water (excluding potable water) in the summer comes from the surface waterbodies that is transported by the irrigation canals (ditches) either by gravity (locations fed by lake water downstream) or pumps (upstream from lakes or fed by running water sources). In the winter, this practice ceases due to the fact that there is no longer demand for the water for irrigation and that the domestic demand can be accommodated by well water.

The group briefly explored if it would work to have the surface water as a source all year long and the question of potable water quality quickly became a key issue to the feasibility of implementation. The group went on the assumption that the current system of using surface water would simply increase and the stresses on the source would reflect the increased demand in the face of a decreasing supply.

	SOCIAL ACCEPTABILITY		LEGAL FRAMEWORK			POLITICAL REALISM AND ACCEPTABILITY		
	WHO MAY BENEFIT?	WHO MAY OPPOSE? WHY?	LAWS THAT EASE AND SUPPORT…	LAWS THAT PREVENT	NEW LAWS, ETC.	DO THE POLITICIANS & ELECTORATE SUPPORT…	WHAT LEVELS OF GOVT. HAS JURISDICTION? RESPONSIBILITY?	WHO IMPLEMENTS/ PAYS?
New Groundwater Wells	Better water quality for local water users, fish, downstream users; lower treatment costs; enables diversification of water sources	Existing groundwater users; Some neighbouring land owners (agriculture, industry) worried about effects on their properties	Health regulations—Safe Drinking Water Protection Act; Local govt. subdivision bylaws	Local govt. water service areas; Well construction and capping	Groundwater licensing. Protection of groundwater sources Infrastructure grants for purveyors outside of local govt.	Local govt. does support this; Province does not support groundwater licensing	If municipal: town, province Within purveyor: purveyor, province (water district) Outside purveyor: land owner	Water user pays User or purveyor implements Purveyor could not get federal/provincial infrastructure grant unless w/in local govt.
Irrigation Scheduling & Trickle Irrigation [5]	All users Domestic users because it frees up water for residential Suppliers of meters [6]	Agricultural users. Summerland able to cut back irrigation to 60% during drought but Farmers won't give up licensed amounts. Summerland was more sensitised because of the summer drought	OBWB has the legal authority but no technical capacity to act and is not empowered by Regional Districts. Never been a strong reason to push this. OBWB tends not talk about it and focus on weed mgt. etc. Provincial infrastructure grants	Upstream users do not have incentive, is an institutional scale issue. Upstream/ downstream issues and need for co-ordination, but focused on their own problems.	Independent technical advisory group Water credits within agr. community as a model; province pushing conservation. Give financial value to the agriculturalists but don't have incentive to sell to residential use. Need valley wide selling system for excess water because not enough local demand; need province to do this.	Opposition from farmers who use their hold on water to limit the expansion of residential demand: 'We'll open the taps and use up all the water if we think it will limit population growth'. Compared to EU and US, don't get the same subsides, so ensured water supply is the advantage they have. No big benefit to farmers of demand management under current price regime. Privacy issue is not a big one, control is more important		
Metering	Users (reduced pumping costs, reduced demand, improved equity, improved awareness of water availability) Purveyors—more control	High volume users Low volume domestic users incur costs	Access to federal & provincial infrastructure grants; Municipal by-laws	None	All users should be metered, not just domestic users;	Not supported by big (wasteful) users. Supported by environment interests Political support does increase after implementation (need to overcome initial concern about upfront costs and perceived threat to access to water)	Province-on licensee Purveyor-on individual user	Purveyor User pays
Public Education [7]	All, upstream and downstream Water purveyors/Local Government All water users would benefit from education – this received the highest number of votes Parents and older people would benefit indirectly from the knowledge of their children	Developers (land, high users of water that is visible) Food safety/ packing plants and the perception of the public once "educated" Golf courses (although they use grey water) Bottled water producers: use more water than what ends up product. Garden centres selling non-native, water intensive plants.	Mandatory education Federal infrastructure grants. Legal framework would support education through the product disclosure rules. Federal - Green Infrastructure Grant has requirements for an educational component. Existing certification programs associated with licensing..	None	Expand certification for licensing and requirement for some type of certification in issuing licenses i.e. for water quality and water management.	This was identified as a cheap option and very politically attractive	Group agreed that who ever wanted to undertake and education program or outreach could do so, including: regional district, Co-op, Municipal; School board, associations and stake holder groups, federal government	Government grants and NGOs. Grants – Government dollars. Foundations and NGO's like Ducks Unlimited

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[5] There is a lot more research around the water use issues in grape growing than in Orchards. i.e. they add water to one side of the vine only so get stressed by also get watered. Vineyards are higher up the side of the valley and already have to pump to get water up there, so they get their own pressure. Technical challenges because the calcium in the water, leads to need to change filters more often. Reclaimed water spread on golf course has been a problem because of high sodium from water softeners. Looking at options for softening water further upstream

[6] Requires groundwater and ET meters and technology installed at each farm

[7] The group tackled education as a whole with the ultimate goal of encouraging conservation whether by teaching farmers about better management or by teaching gardeners about xeriscaping.

	SOCIAL ACCEPTABILITY		LEGAL FRAMEWORK			POLITICAL REALISM AND ACCEPTABILITY		
	WHO MAY BENEFIT?	WHO MAY OPPOSE? WHY?	LAWS THAT EASE AND SUPPORT…	LAWS THAT PREVENT	NEW LAWS, ETC.	DO THE POLITICIANS & ELECTORATE SUPPORT…	WHAT LEVELS OF GOVT. HAS JURISDICTION? RESPONSIBILITY?	WHO IMPLEMENTS/ PAYS?
Water Recycling [8]	Agriculturalists Sewage users town of Oliver, could be a fire barrier through a green strip	Downstream well owners **Consumer groups** neighbours health groups environmentalists downstream well owners	Waste mgt plan Provincial mandate re. phosphates drove reclamation and made $20m available. Was a local lobby for water on the golf course; tertiary treatment more expensive.	Health ministry laws on reclaimed land	Health ministry: remove barriers for use of grey water on crops, make grey water free to get rid of it	Only if consumer groups support, perceived risks for agriculture., support for non-ag. use such as hay crops and cemeteries. Water for hay crops opposed because of possible effects on Antelope Bush due to over watering.	Municipal: Another drought year and people will start looking more closely at their licences	Provincial and Federal subsidies needed, one third local but former will make or break this. Sewer users
Block pricing [9]	Purveyors: extend life of the water xeriscapers /creative, conservative water users. Community: high water users will pay more for water for fire flows. Increase in local jobs due to the administration of the system and also metering jobs.	Agriculture Car washes, public pools, bottled water companies Low income, large families or water users. Farmers – unless there is a separate scale for them - this received the most votes. Administrators – work increases.	By-laws; Oliver –new construction requires meters. Water act: is already a fee schedule By-laws: council would vote on water pricing changes. Price today is arbitrary – could be reset. Areas with lots of water or water shortage pay same price.	Human rights to water?	Drought triggers legislation that gives the regions/municipalities the right to implement a strict water pricing scheme.	Some yes— sell on basis of possible environmental benefits Some no— administrative chaos, low income concerns, concern about scaring away industry.	Municipal: administration and enforcement OBWB – has taxing authority (not used) MCAWS (Ministry of Community, Aboriginal and Women's Services Town of Oliver Osoyoos Indian Band	OBWB BC-CAWS has taxing authority Town of Oliver Osoyoos Indian Band
Legislated domestic conservation [10]	All users, including in-stream uses (ecosystems); supports good watershed management	Infringes on rights of some users?	Local by-laws Province-metering laws on licensee	None	New by-laws?	Support in denser urban areas. Spurred on by crisis situations (e.g. 2003 drought). Level of support changes with every election	Local (municipal, regional district) through by-laws Province for licensee	User/taxpayer pays; Potential bonus on local applications for federal /provincial infrastructure grants; Local government

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[8] Much of the water is already being recycled through secondary and tertiary treatment of water. Chose to focus on agricultural uses of reclaimed water.

[9] We provided the following illustration below to start off the conversation: 1 – 50 units of water - $1 per unit 50 – 100 units of water - $ 1.50 per unit 100 + units of water - $ 5.00 per unit

[10] Includes banning domestic outside use during shortages, alternate day irrigation (due to capacity limits, energy use limits), low flow fixtures, xeriscaping, grey water recycling, rain barrels, flow control devices operating with meters

The adaptation option that wasn't discussed is population growth. We are locked into more growth and need to deal with the demand issues; we are going to the wall at the moment. There is only so much water to go around, challenge the idea that we can't stop growth. Stop building houses.

appendix chapter

12B Trepanier Landscape Unit

Supply Side Interventions

	SOCIAL ACCEPTABILITY		LEGAL FRAMEWORK			POLITICAL REALISM AND ACCEPTABILITY		
	WHO MAY BENEFIT?	WHO MAY OPPOSE? WHY?	LAWS THAT EASE AND SUPPORT...	LAWS THAT PREVENT	NEW LAWS, ETC.	DO THE POLITICIANS & ELECTORATE SUPPORT...	WHAT LEVELS OF GOVT. HAS JURISDICTION? RESPONSIBILITY?	WHO IMPLEMENTS/ PAYS?
Increased Lake Pumping[1]	Municipality may benefit from reduced turbidity from the lake reducing the treatment costs. Crown may benefit from a more stable supply. [2]	Residents would oppose if the costs are too high, other users may oppose due to lower lake and downstream supply. Possible recreational and fishery concerns. Ag. concern about water quality and chemistry. Alkaline water from lake might affect the ag. products. Residential perceptions of water quality related to lake compared to mountain sources.	Licensing system for lake supply. Summerland and Narmada applying for lake withdrawals but lake not fully recorded. Managed by Land and Water BC not WALAP. Health act regulates water	Health act Regulations within industry related to food production quality. BC GAP initiative supports lower pesticides and heavy metals:	There may be water conservation laws from the province. Regulations about industry that could affect lake or Ag. practices such as cattle farms that would alter quality. Irrigation districts may be transferred into municipalities in near future, which could allow for new by laws. Groundwater withdrawal near the lake could be a way of doing indirect withdrawals	Supported if the costs are right. May be environmental issues around siting of intakes. Is rising concern around supply, which will increase as the population and land use changes. Is upward pressure on water quality issues. Generally the electorate knows very little about water supply issues; perception of pristine water from mountains and dirty water from lake. Little perception of scarcity. Separation of ag. and domestic supply could reduce costs of water quality improvements. Why chlorinate ag. water. (80%) of summer use.	Irrigation district or the municipality. Need local control for effective implementation. May be cost sharing with different levels of government including federal infrastructure. Land	Users via the municipality
New Groundwater Wells [3]	All people would benefit. The environment may also benefit if the new wells are not taking the water directly from a stream or the lake. Benefit will vary depending on cost.	People who are already on the aquifer since concerned about water quality and quantity if more wells are added. Could be negative impacts on fish if well is drawing indirectly from a stream. Agriculture and Industry may have their activities limited by the perceived impacts on water quality (fertilizers, commercial soaps seeping into GW)	No laws that deal directly with groundwater wells and voluntary registration for wells. Current laws focus on quality of groundwater, not quantity. Indirect laws: Waste Management Act, the Drinking Water Protection Act (under Health). If you have a well right now, there is nothing to stop someone from drilling a well right next to you. DWPA governs the construction of wells and the capping of wells. Not know how much water coming out of aquifers, there are no regulations regarding quantity.	There are no laws regarding groundwater wells and there is no monitoring at this stage.	Mandatory registration. Need basic aquifer data (Part of the reason that GW has not been legislated is the fear of increased fees). Aquifer monitoring, specified ground water management area, recharge area protection.	Politicians and electorate would support new ground water wells subject to cost and water quality (currently the requirements to treat groundwater are less than to treat surface water).	GW is provincial responsibility however, they have historically ignored it so the local governments are taking it upon themselves to manage GW by restricting land use. GW issues are being driven from the bottom up (local to provincial). The problem with this is that land use impacts on GW may be beyond their jurisdiction (example: farm in adjacent area may be negatively impacting GW in this community)	Local governments are taking initiative with regards to GW in a vacuum. Who pays? Users pay for capital and for operating costs. The province will pay for basic aquifer data.

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1 Two of the areas already pump water from the lake and current supply for Westbank and Lakeview is sufficient; certainly were fine for the drought during the summer. Clarified that this would be increased additional supply if other sources pressured or if the population and agricultural demand increased significantly. Depends largely on how far up the mountain they want to pump. Upstream reservoirs may enhance fish habitat because stabilises the flow regime. A segregated system could reduce costs by only treating the water for residential use.

2 Quality impositions are coming down from the province and are widely expected

3 Trepanier watershed: 4 main aquifers identified. GW use in Trepanier not significant on a large scale but do have some in South Okanagan (Winfield, Armstrong). Presently, student discovering new springs that no one knew about because the Province's list of aquifers was based on well records. Most well systems only capture 5% of flowing water. Most recharge occurs above 1200m (net runoff comes from above this line).

Demand Side Interventions

	SOCIAL ACCEPTABILITY		LEGAL FRAMEWORK			POLITICAL REALISM AND ACCEPTABILITY		
	WHO MAY BENEFIT?	WHO MAY OPPOSE? WHY?	LAWS THAT EASE AND SUPPORT…	LAWS THAT PREVENT	NEW LAWS, ETC.	DO THE POLITICIANS & ELECTORATE SUPPORT…	WHAT LEVELS OF GOVT. HAS JURISDICTION? RESPONSIBILITY?	WHO IMPLEMENTS/ PAYS?
Irrigation Scheduling & Trickle Irrigation [4]	Agriculture, all users, government, equipment manufacturers	Agriculture (cost), local govt and the public, need to retool manufacturing	Improvement district by-laws, low flow standards (Plumber and building codes), Water act and licences	Right to Farm Act (does not force selection of technologies)	Change from voluntary to regulated regime.	May require a crisis. There is public support	BC and local. Possible role for OBWB.	Federal government through municipal programmes, CORD, Peachland or Westbank First Nation.
Domestic Metering [5]	Makes more efficient use of water so reduces costs. Cost effectiveness an issue. Quantity and quality benefits. Separation of systems may be important. Allows for better monitoring and surveillance: income source.	May be regressive so affects the poor. Water hogs would oppose. Growers would oppose because water is already cheap, so represents a new cost. Problem with a one size fits all approach since it prevents flexibility: won't work everywhere. Scheduling requires lots of research and data. Current system set up for flow rates at certain level and not work at lower levels. Some simply opposed to surveillance	Land and Water BC requiring meters for all new licences (policy not regulation). Nothing in 'Right to Farm Act', although others say can't impose a watering method on farmers.	Groundwater extraction may be a way of avoiding this. Have many purveyors, so may shift supplier to get the best conditions.	New rules would level the playing field by requiring that all have meters. Single water purveyor would help. In Surrey, jacked up the prices and offered reductions for those who install. Block pricing would help and education necessary. Crises may create attention around this.	Careful implemen-tation required to ensure that there is wide support for this	Municipality would implement. Westbank First Nation already on meters as well as Sunnyside. See as a good quick fix to address drought vulnerability.	Municipality would build costs into the rate structure plus federal and provincial funds available. Not clear that money available for installation of meters.
Public Education	Everyone. Owners/ purveyors: less need to build new infrastructure, taxpayers, environment (depending on what water savings are used for)	No one would oppose, however, there could be opposition to the impacts of education: agriculturalists who think that if they do not use the full amount allocated to them they will loose water. Also businesses that would be negatively impacted by increased quantity and quality of GW. There may also be opposition to the cost of implementing the program.	No laws directly deal with public education regarding water conservation measures. Some laws have conditions associated with water use: Fisheries Act (conditions associated with water licenses); Drinking Water Act (obligations for water system owners) Forest Range Practice Act (FRPA): legislation has passed but regulations still need to be enacted Land Resource Management Plan	None	Before implement new laws, need more applied research. Need to know what is effective so that can go directly to agriculturalists and say if you do this it is cost you x amount and you will save x amount of water. New laws: Area wide initiatives; Local bylaws; Building codes (example low flush toilets); Fish Protection Act (new licenses, has control on development, etc, many regulations not enacted) School curriculum;	Local government would support (example: Chilliwack). Higher government support (mainly provincial and a little bit federal) in order to coordinate different regions. Everyone would support (depending on costs and benefits) Electorate would support but education is limited by funds.	Owners/purveyors (SEKID example), Local government (don't water lawn), Provincial (have a role where gaps occur)	Local and provincial government (SEKID received grants), Users pay (surcharge on water bill). Owners/purve yors pay. Taxpayers (increase in property taxes)
Improved leak detection	All users due to reduced costs	None	Right to inspect in existing regulations? Local by-laws, leak reporting regimes.	Privacy laws	Mandatory timely reporting, Federal infrastructure policy, Life-age inspections	All	Local, licence holders	Pond: hard to detect and high cost makes it prohibitive for local govt. Pipe: easy and feasible

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[4] Issue arose again of water availability. Ag. users do not want to free up more water for development by initiating savings.

[5] Existing examples within the Okanagan may not compare well. 25% reduction in SEKID was high because the infrastructure was poor compared to Peachland. Savings here may be less; money might be better spent on improving lake supply. Support if domestic use is likely to rise.

Demand Side Interventions

	SOCIAL ACCEPTABILITY		LEGAL FRAMEWORK			POLITICAL REALISM AND ACCEPTABILITY		
	WHO MAY BENEFIT?	WHO MAY OPPOSE? WHY?	LAWS THAT EASE AND SUPPORT…	LAWS THAT PREVENT	NEW LAWS, ETC.	DO THE POLITICIANS & ELECTORATE SUPPORT…	WHAT LEVELS OF GOVT. HAS JURISDICTION? RESPONSIBILITY?	WHO IMPLEMENTS/ PAYS?
Water reuse [6]	Fish. Residential Users (lower cost for less treatment) and offset water supply. Large savings for avoiding treatment for residential.	Quality of water for ag. use important, depends on standards especially for food crops. Parks would use if for their land. Are perception issues that may be relevant.	Waste mgt Act already contains restrictions on the quality and application of water. Health Act.	Concerns about food safety, Health Act	Change legislation to allow use. May be crisis driven so that current environment receptive to reuse	If financial savings, then strong political support. There appear to be good current practices regarding re-use. Need r negotiation with ag. users who may want to be paid to take the water: Education and engagement around this. Segregated water system would help this	Municipality would lead it	Local and CORD (their sewage treatment plant), Federal infrastructure grants available for regional districts. Can't get these in TLU because no municipality
Landuse change issues [7]	Water users, depending on what the land use change will be. Owners and purveyors of water systems (from better or more optimum use) Environment – depending on landuse change	Those who are interested in development would be opposed (depending on the land use change) owners and purveyors. If there are restrictions placed on water access. As it is social change there would be initial resistance - gradual acceptance	Water Act (through water allocation) FRPA (watershed management – no clear cuts), Park Act, Forest Act, Local zoning (very important). ALR. Building codes OCP as they have environmental vision . Land Act (Controls development Fishers legislation (it is a reactive legislation – not proactive)	All of the previous	Fisheries Protection Act, Provincial FRPA – (riparian , set backs etc.) There should be no restrictions on crops – let economics drive crop choice. Some thought/ regulation looking at water capacity linked to carrying capacity – and population. Link resource data to local govt. development regulations Incorporate resource valuation and economization of water in cost benefit analysis (v. important)	Some would be for the implementation of land use change policies, some against it. Depends on the types of changes planned. Politicians would want to grow . Electorate may have mixed views.	Provincial Any agency concerned with the aforementioned legislation. Local and municipal governments.	Legislated provincially, and implemented locally Who would pay for the changes will depend on what changes are actually done.

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[6] Much of the water is already being recycled through secondary and tertiary treatment of water. Chose to focus on agricultural uses of reclaimed water.Use of tertiary post treatment waste and possibly from mine water. It may be potable and is used for agricultural users, golf courses and playing fields

[7] Defined as managing activities on land to have a positive impact on the water resources (principally with urbanisation and agricultural land use change). Water will not be valued till it becomes expensive (costs) and then policies will be easier to develop and implement.

appendix chapter 12C

Kelowna Basin Wide Workshop

	BASIN-WIDE IMPLEMENTATION		ENVIRONMENTAL SUSTAINABILITY		SOCIAL VIABILITY	
	NEED?	BENEFITS?	WATER QUALITY IMPACTS?	INSTREAM FLOW REQTS?	SOCIALLY ACCEPTABLE?	AREAS OF CONFLICT?
PLANNING & MGT SUPPORT GROUP I	• Integration of water use & land use basin-wide; draw on municipal expertise • Overcome local institutional barriers; needs to be part of local growth strategies • Need regional unanimity to overcome localism; foster sense of belonging to 'the basin'	• Regional leadership to overcome local political agendas	• Need to understand groundwater role in regional hydrology; • Non-human needs and issues need to be integrated into human activity-focused planning/mgmt	N/A	• No: Public perception is that quantity is not an issue; allowing additional pumping from lake would only reinforce this perception • Public are desensitized due to perception of 'easy' alternatives (e.g. bottled water) • How can we get public's attention and overcome political inertia? 1 Crisis 2 Tax 3 Concerted educational campaign	• Competing interests at all levels, particularly between localities

	INSTITUTIONAL VIABILITY		LEGAL VIABILITY		FINANCIAL VIABILITY	
	FRAMEWORK NEEDED?	EXISTING INSTITUTION?	CURRENT LAWS THAT SUPPORT?	NEW LAWS?	BENEFITS > COSTS?	HOW TO FINANCE?
	• Need to better integrate science, hydrology, and implementation options	• No institution for groundwater licensing • Basin-wide board in place, but needs unanimity of local representatives which is challenging; • How to drive local coordination? 1 Provincial oversees, or 2 Joint authority (DFO, Province, OBWB, …?)	• Okanagan-Shuswap Strategic Plan created but not implemented; needed taxpayer support—they could not see connection between financial commitment and results of plan • Licensing (land, water) • Drinking water	• Need Groundwater licensing; requirement for monitoring of extraction • Co-ordination of water use at the local level • Enforcement of existing laws	• Resources are not the problem, political will is	• Provincial incentives; too much focus on these? • Municipalities should raise money themselves (e.g. through water rate structure)…would promote local ownership and sustainability • People will only understand the importance of water measures if they are paying for them, which helps see the returns • Commodification of water needed

	BASIN-WIDE IMPLEMENTATION		ENVIRONMENTAL SUSTAINABILITY		SOCIAL VIABILITY	
	NEED?	BENEFITS?	WATER QUALITY IMPACTS?	INSTREAM FLOW REQTS?	SOCIALLY ACCEPTABLE?	AREAS OF CONFLICT?
PLANNING & MGT SUPPORT GROUP II	• Need groundwater data; how to coordinate info? • Supply systems should be integrated when technically feasible • Basin-wide mgt recommended in 1972 study	• potential	• Planning must look at surface water & groundwater together, and not as separate sources	• Fish and instream needs must be considered (recall Summerland 2003)	• Lack of awareness of problem (public, decision makers)? • Need to identify problem/crisis • Water culture does not match local environment?	• Purveyors & municipalities are independent; there is no cooperation in long term planning

	INSTITUTIONAL VIABILITY		LEGAL VIABILITY		FINANCIAL VIABILITY	
	FRAMEWORK NEEDED?	EXISTING INSTITUTION?	CURRENT LAWS THAT SUPPORT?	NEW LAWS?	BENEFITS > COSTS?	HOW TO FINANCE?
	• Groundwater; Need coordination between purveyors (e.g. 'water smart')	• Increase the role of OBWB as facilitator; OBWB effective in crises (milfoil, sewage); could be effective if supply seen as in crisis situation • Need groundwater data; WLAP initiative		• Need provincial laws for groundwater		• Tax for sewage treatment • Water use at 'market' rates, but cautioned to consider social issues

	BASIN-WIDE IMPLEMENTATION		ENVIRONMENTAL SUSTAINABILITY		SOCIAL VIABILITY	
	NEED?	BENEFITS?	WATER QUALITY IMPACTS?	INSTREAM FLOW REQTS?	SOCIALLY ACCEPTABLE?	AREAS OF CONFLICT?
SUPPLY DEVELOPMENT	• Big issue is not new storage but keeping existing reservoir levels higher for more of the year; flood hazard risk attached to this can only be addressed by increasing discharge capacity, which would require investment • Should be basin- wide or by existing purveyors but basin-wide makes most sense for OK Lake • Reduce leakage; improve efficiency (not the same as supply expansion) • Diversion from Shuswap (as in Vernon) is technically feasible; Might have the same snowmelt issues in the Shuswap as a result of future CC impacts; May be good for supply options but not good for flood management. • Manage on 5-year basis; allows significant declines within drought year • Need stronger integration with demand side options; land use planning must ask questions about water supply at a much earlier stage; Need 'action plan'	• potential	• Increasing discharge capacity would have environmental impacts • Storage can improve low flows (but not always). Brenda Mines is a unique case where discharge from the mine has been used to maintain minimum flows. • Lake levels will have a wide range of environmental impacts e.g. spawning			• Crown might lease land on lots around reservoirs. Land acquisitions for increased storage area is likely to be an issue. • Government plans to sell lots on crown land on lake shores may reduce flexibility to manage reservoirs when there is a property and amenity interest involved.

	INSTITUTIONAL VIABILITY		LEGAL VIABILITY		FINANCIAL VIABILITY	
	FRAMEWORK NEEDED?	EXISTING INSTITUTION?	CURRENT LAWS THAT SUPPORT?	NEW LAWS?	BENEFITS > COSTS?	HOW TO FINANCE?
	• Vernon already does some diversion from Shuswap but not clear that there is much political will to do this on a larger scale.		• Altering channels may trigger Fisheries Act issues.		• New approaches to management such as remote controlled systems can reduce costs. • Creating new reservoirs can increase costs.	

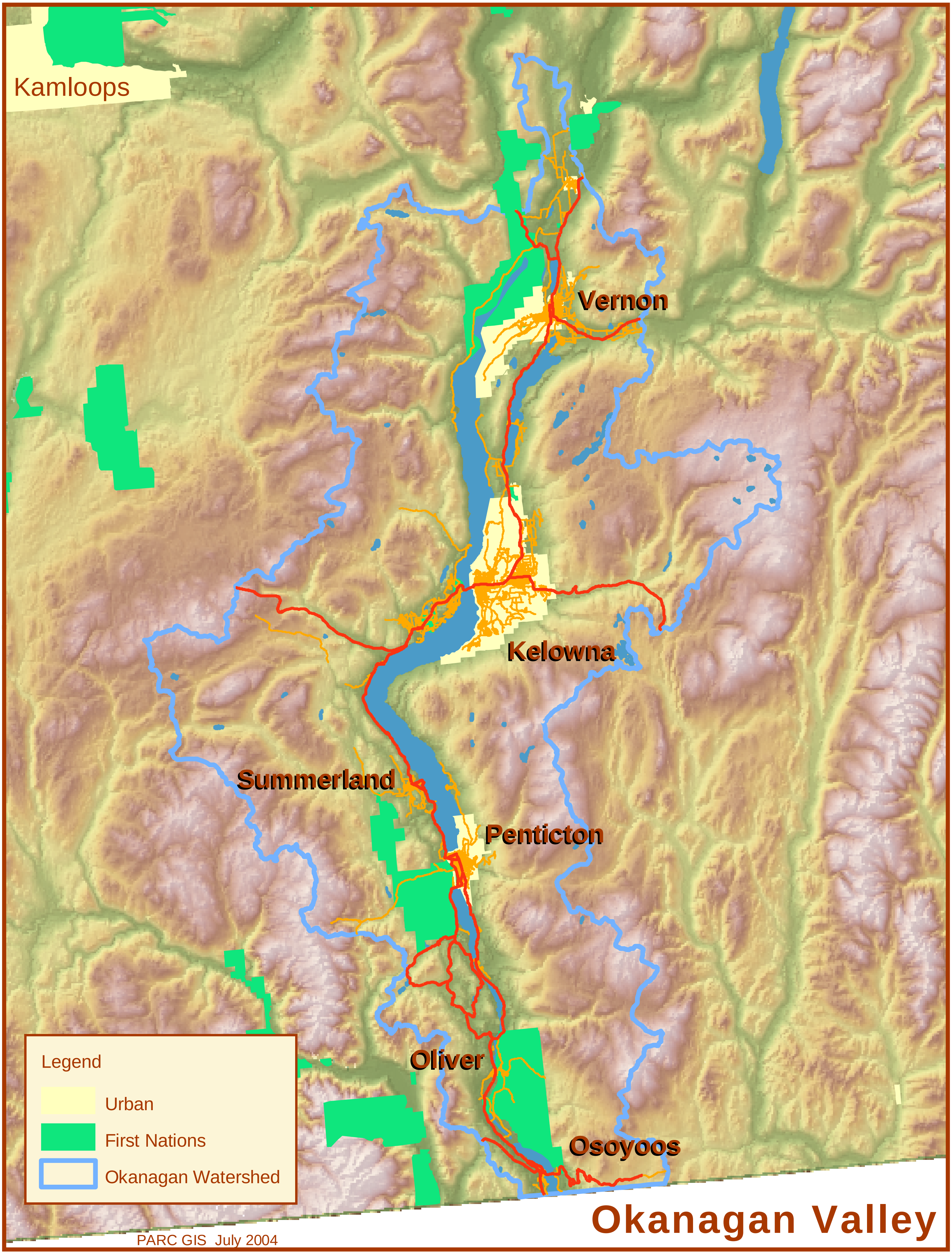
	BASIN-WIDE IMPLEMENTATION		ENVIRONMENTAL SUSTAINABILITY		SOCIAL VIABILITY	
	NEED?	BENEFITS?	WATER QUALITY IMPACTS?	INSTREAM FLOW REQTS?	SOCIALLY ACCEPTABLE?	AREAS OF CONFLICT?
SUPPLY DEVELOPMENT -- GROUNDWATER	• Important, particularly from the mapping perspective • Aquifers need to be managed by their hydrogeological boundaries, which may not be the same as the "basin scale" (Municipal and purveyor boundaries rarely consistent with aquifers, although many may fall into RD boundaries.) • Concern that new authorities would create more ambiguity and more problems. Do need a central repository such as OBWB that has taxing ability. • Province does not want to get involved in groundwater management because seen as a tax grab and could drive up the cost for agricultural users.		• Health regulations related to groundwater are very broad and subjective and are often down to the discretion of the officer involved.		• Recreation impacts significant. Needs to be acceptable to home/land owners as they have a lot of legal influence.	• Those with lakeside dwellings won't be happy especially when drawn down in the summer.
	INSTITUTIONAL VIABILITY		LEGAL VIABILITY		FINANCIAL VIABILITY	
	FRAMEWORK NEEDED?	EXISTING INSTITUTION?	CURRENT LAWS THAT SUPPORT?	NEW LAWS?	BENEFITS > COSTS?	HOW TO FINANCE?
	• Need groundwater mapping & inventory, repository of data • Should get municipalities to take more responsibility (remove subsidies)	• Groundwater—licensing? –Province not ready –Regional district?			• Groundwater is viable; would need to cover monitoring costs and mapping of the resource	• OBWB?

	BASIN-WIDE IMPLEMENTATION		ENVIRONMENTAL SUSTAINABILITY		SOCIAL VIABILITY	
	NEED?	BENEFITS?	WATER QUALITY IMPACTS?	INSTREAM FLOW REQTS?	SOCIALLY ACCEPTABLE?	AREAS OF CONFLICT?
DEMAND MANAGEMENT -- RESIDENTIAL	• A new basin-wide 'water smart' program similar to BC Hydro's "power smart " could help decrease demand through: –Education –Metering –Water recycling –Financial incentives (sliding scale, volume pricing)	• Economies of scale • More balanced growth • Easier to educate basin-wide • Political influence (have more power, more influence at the basin-wide scale) • If address/target entire basin, reduce conflict within the basin. • Watershed ownership: bigger body provides security and protection from outside influences	• Increased demand = less water in-stream = higher water temps = effects on fish	• Decreased demand = Increased flexibility to satisfy in-stream needs	• With financial incentives; metering, low flow technologies • Basin-wide communication and education; need to change perceptions; educate by example (select a small "test area" first); 'water smart' • Show cost savings (e.g. sewer costs reduced)	• There may be resistance in the short term, but in long term, with education and evidence of benefits, resistance expected to decrease

	INSTITUTIONAL VIABILITY		LEGAL VIABILITY		FINANCIAL VIABILITY	
	FRAMEWORK NEEDED?	EXISTING INSTITUTION?	CURRENT LAWS THAT SUPPORT?	NEW LAWS?	BENEFITS > COSTS?	HOW TO FINANCE?
		• No, OBWB does not have a water quantity mandate and does not have reps from each municipality. • Could create a basin-wide "Water Smart" board/ committee through OMMA (entire basin is represented)	• None support but none oppose	• Need new bylaws and policies at the basin-wide scale (need a buy-in from all communities, OMMA should be involved) –Building codes, plumbing codes (low-flush toilets) –Landscape bylaws –Water restriction bylaws –Metering –Water recycling bylaws	• Expect benefits > costs: –Decreased pumping costs –Electricity savings due to decreased pumping –Decreased capital costs –Decreased operational and maintenance costs –Increased growth (increased economic benefits of growth)	• Financed by future savings (will borrow on future savings, therefore ultimately the taxpayer will finance it)

	BASIN-WIDE IMPLEMENTATION		ENVIRONMENTAL SUSTAINABILITY		SOCIAL VIABILITY	
	NEED?	BENEFITS?	WATER QUALITY IMPACTS?	INSTREAM FLOW REQTS?	SOCIALLY ACCEPTABLE?	AREAS OF CONFLICT?
DEMAND MANAGEMENT -- AGRICULTURAL	• *Metering:* Catch abusers • *Pricing:* Not necessary everywhere, need fairness across & within districts • Role for *scheduling* by district; knowledge sharing, bulk buying of systems, consistent rules, cost sharing, report generation sharing, same set of rules for all	• *Scheduling:* Environmental benefits, knowledge sharing, bulk buying of systems, cost sharing, report generation sharing	• *Metering/pricing:* Salinity concerns (problem with flushing), but generally positive • *Scheduling:* –Generally positive (no specific examples) –Timing? What if everyone withdrawals at same time?	• Reduced demand = in-stream benefits • *Scheduling:* Possibility of negative impacts if timing of withdrawals leaves low water levels in the streams	• *Metering/pricing:* Complements residential demand management • *Scheduling:* Need for education (and consequent costs)	• *Metering/Pricing:* Resistance in short term; but in long term frees water for future users (many will advocate this) • *Scheduling:* Concern regarding how to handle flexibility (changing crops have different water needs)

	INSTITUTIONAL VIABILITY		LEGAL VIABILITY		FINANCIAL VIABILITY	
	FRAMEWORK NEEDED?	EXISTING INSTITUTION?	CURRENT LAWS THAT SUPPORT?	NEW LAWS?	BENEFITS > COSTS?	HOW TO FINANCE?
	• *Scheduling:* –Requires governing agency/board to educate, enforce, manage; Consequent coordination costs –Requires large amount of data (collection and maintenance costs)	• None	• *Metering/pricing:* Legal requirements of flow control may work counter to metering	• *Scheduling:* Concern that maximum application rates could be reduced. Mandated rate reductions?	• *Metering/Pricing:* –Expensive; slow turnover of fixed infrastructure (some exceptions-modifications are sometimes possible) –Lower pumping costs • *Scheduling:* By district or basin wide; enforcement & monitoring costs; sprinkler & pumping savings (cheaper than metering)?	



Okanagan Valley

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