C-CIARN Water Resources

State-of-Play Report

2006-2007

C-CIARN

C-CIARN Water Resources – State-of-Play Report

The Status of Climate Change Impacts and Adaptation from the Perspective of C-CIARN – Water Resources

Table of Contents

Preface

In the last year of C-CIARN's mandate (July 2006-June 2007), each C-CIARN office was asked to write a report summarizing their perspectives on the state of climate change impacts and adaptation within their region or sector.

The resulting State-of-Play reports identify, from the point-of-view of C-CIARN, the key climate change impacts, as well as the key stakeholders and adaptation decision-makers (including how these stakeholders/decision-makers were most successfully engaged) of each representative region and sector of Canada. The reports also include a description of the important research questions which, from the perspective of C-CIARN, need to be answered, as well as the steps that need to be taken to both increase the level of engagement on the issue and to facilitate the decision-making that is needed to reduce vulnerability, across Canada, to the impacts of climate change.

It is anticipated that the State-of-Play reports will serve as a valuable point of reference for climate change impacts and adaptation initiatives carried out across Canada, post-C-CIARN.

1. Introduction

The C-CIARN Water Resources sector of the Canadian Climate Impacts and Adaptation Research Network (C-CIARN) was set up in January 2002, and is housed at the Brace Centre for Water Resources Management at McGill University. The Water Resources Sector facilitates impacts and adaptation measures by hosting workshops, special sessions at conferences, and presenting at climate change venues. Through these initiatives, the network increases researcher and stakeholder participation in climate change research and helps to identify research priorities to better adapt water resources to climate variability and change.C-CIARN is a national network that facilitates the generation of new climate change knowledge by bringing researchers together with decision-makers from industry, governments, and non-government organizations to address key issues.

C-CIARN provides a collective voice for this community to:

- improve our knowledge of Canada's vulnerabilities to climate change;
- identify ways to minimize the negative effects of future impacts; and
- explore opportunities that take advantage of any positive impacts

WORKSHOPS & EVENTS

National workshops:
Water Resources at Risk due to Climate Change (*September 9 & 10, 2002. Montréal, QC*). The first sector workshop was held in Montreal entitled “Water Resources at Risk due to Climate Change”. This national workshop identified impacts climate change would have on Canadian water resources, and identified possible adaptation strategies. Furthermore, research priority issues were determined, based on knowledge gaps existing in the water resources sector. Six themes were tackled: Ecosystems & the environment; Transportation & navigation; Communities & municipalities; Hydro power & energy; Agriculture and rural areas; and Natural resources. Approximately 80 participants attended the workshop. Participants included representatives from universities, utility sectors, transportation, municipalities, consultants, all levels of government, policy divisions of several government ministries, funding agencies and students. The workshop received funding support from the BC Ministry for Land Water and Air Protection (MLWAP).

Application of Climate Models to Water Resources Management (*November 18 & 19, 2004.Victoria, BC*). The workshop was held on November 18 & 19, 2004 in Victoria, BC. This national workshop focused on how water mangers use climate models, and how the hydrological cycle is represented/incorporated into the regional climate models. Furthermore, the limitations of the climate models with respect to predicting hydrological regimes were examined. Presentations by climate modellers were given on the first day, and on the second day, the users of climate and water models presented their experience with respect to the decision making process. Discussions centered on coupling climate models and hydrological models, and the usefulness of climate models to water resource managers and purveyors. It was

found that there still is a gap between modellers and hydrologists, and more coordination between hydrologists and the atmospheric community is needed. This workshop provided the first time climate modellers interacted with hydrologists, and water purveyors. Approximately 75 participants attended the workshop.

Hydropower and Climate Change (*March 2 & 3, 2006. Winnipeg, MB*). This national workshop was geared towards hydropower representatives and practitioners to examine the impacts of climate change on hydropower in Canada and share adaptation strategies that currently exist, whilst determining knowledge needs to facilitate future adaptation. It was the first workshop in Canada, to our knowledge, that focused on impacts and adaptation for the hydropower industry. A workshop steering committee was set up made up of C-CIARN Water Resources Advisory Committee members and hydropower stakeholders, to assist with putting on a successful workshop that met the objectives. A total of 20 presentations gave an overview of the current state of knowledge on science and impacts and adaptation issues pertaining to the hydropower sector in Canada. Presentations were given by hydropower representatives on the vulnerabilities they were facing, in light of climate change, and presentations also described some of their ongoing projects surrounding this issue. Group breakout sessions further enabled specific impacts and adaptation to be identified relating to hydropower and climate change. Over 80 participants attended the workshop. The workshop received sponsorship funding from Manitoba Hydro; the Manitoba Climate Change Branch; and PARC.

Sector-specific workshops held in conjunction with other events:

Urban Drainage and Climate Change (*April 12, 2002*) session held at the Salon des Technologies Environnementales, in Québec City in conjunction with Réseau-Environnement and Ouranos.

Water, Climate, Energy (*April 2003*) in Montréal, as part of the Human Dimensions of Global Change conference. Panelists included René Roy, Linda Mortsch, David Layzell, Louis Molgat, Nigel Roulet, and Louis Fortier. Some of the institutional and socio-economic constraints to climate change impacts and adaptation were highlighted. The impacts of climate change on the energy sector was discussed, and the potential for further hydroelectric energy and sources of renewable energy was touched upon.

Adapting to Climate Change in Canada 2005: Understanding Risks and Building Capacity (*May 4-7, 2005 Montreal, QC*) The Water Resources Sector involved in the local organizing committee of this conference

Water, Agriculture & Climate Symposium (*November 9, 2005*) held in conjunction with the Brace Centre for Water Resources Management, at McGill University. Presentations from six leading experts were given. Over 70 participants attended.

Living with Climate Change; Sharing Adaptation Experiences (*December 2, 2005. Montreal, QC*). The C-CIARN Water Resources sector was designated to lead the efforts of organizing and hosting the C-CIARN parallel event at the Eleventh Conference of the Parties (CoP11) to the United Nations Framework Convention on

Climate Change and the first Meeting of the Parties (MoP1) to the Kyoto Protocol. As one of the Conference parallel events, Natural Resources Canada and C-CIARN organized a full day focusing on domestic and international case studies of adaptations case studies, and sharing the lessons-learned. The four themes in this session were: Food Security; Water Resources; Coastal Zones; and Communities/Infrastructure. Over 20 invited panel members from developing countries, countries in economic transition, and developed countries presented their experiences.

PUBLICATIONS on climate change impacts and adaptation that were produced:

- *Water Resources at Risk due to Climate Change: Identifying Knowledge Gaps and Research Needs.* December 2002. The report highlighted priority climate change impacts on five sectors (navigation & transport, hydroelectricity & energy, municipalities & communities, ecosystems & environment, agriculture & rural areas), and identified knowledge gaps.

- *Managing the St-Lawrence* October 2002. Proceedings of a Brace Symposium held on climate change and the St-Lawrence

- *Adapting Urban Infrastructure to Climate Change* – workshop summary April 2002.

- *Application of Climate Models to Water Resources Management* workshop report. Dec 2005

- *Hydropower and Climate Change* workshop report. May 2006

- *Canada's Climate is Changing*. Municipal World, May 2006 issue, p.21-23. Co-wrote an article on adaptation for municipalities with David Noble.

- *Coping with the Impacts of Climate Change on Water Resources: A Canadian Experience*. Mehdi, B.B., L. Connolly-Boutin, C.A. Madramootoo. 2006. World Resource Review. 18 (1):231-251

- *Adapting to Climate Change: An Introduction for Canadian Municipalities.* Document for local governments and elected officials. March 2006. 32p Over 5000 copies were printed and distributed through Municipal World and Forum magazines.

- *Water, Agriculture and Climate*. November 9, 2005. Brace Symposium. Proceeding in process.

- Adapting to Climate Change: An Introduction for Canadian Municipalities" C-CIARN 2005

The "Adapting to Climate Change: An Introduction for Canadian Municipalities" publication was spear-headed by the C-CIARN Water Resources office, several C-CIARN offices contributed to the publication. Several consultations were held within C-CIARN and with FCM, and other stakeholders. The document provides the broad strokes for implementing adaptation into decision making for local governments. It also contains six examples of municipalities that have adapted to climate change; three of these examples focus on water. It is primarily a tool for decision makers. The first

draft was completed by late 2005, and the final document was released in March 2006 (release on March 27, 2006 http://www.c-ciarn.ca). Over 5000 copies were printed and a CD version of the document was distributed by insert into *Forum* magazine June's issue. The publication was officially launched at the FCM conference in Montreal, on June 2-3, 2006.

CONFERENCE PROCEEDINGS (selected):

- Mehdi, B., and C. Madramootoo. Addressing the Research and Management Needs of Adapting to Climate Change in the Water Resources Sector. Confronting Water Scarcity Conference, Lethbridge, AB July 13, 2004

- Mehdi, B. Facilitating Climate Change Impacts and Adaptation Research for Canadian Water Resources. AMERICANA conference Montreal, QC. March 20, 2003

- Mehdi, B., Bourque, A., St-Hilaire, A., Roy R. Moving Forward with Adaptation to Climate Change in the Water Resources Sector: Synthesis of Selected Presentations from the 57th Annual CWRA Conference. Canadian Water Resources Association conference proceedings, 58th Annual Conference. Banff Centre, Banff, AB. June 15-17, 2005.

FACTSHEETS, POSTERS, SHORT PUBLICATIONS, etc.

- Climate Change Impacts to the Water Resources Sector. (Fact sheet for stakeholders, researchers, decision makers)

- Impacts of Climate Change on Canadian Water Resources. (Poster)

- Climate Change Impacts in the Great Lakes Region. (Poster)

- Climate change and water resources in the Canadian North. (Poster)

- Knowledge Gaps and Research Needs Ensuing from "Water Resources at Risk due to Climate Change" (short publication)

PRESENTATIONS

Over 30 in various parts of Canada. Selected presentations include:

1. Mehdi, B. Water Resources and Climate Change Issues: Identifying Knowledge Gaps and Research Needs" Presentation to the National Liberal Water Caucus at the House of Commons, Ottawa, ON. April 5, 2006 (invited)

2. Mehdi, B. & R. Doria. Adaptation Measures for the Ontario Tender Fruit Industry due to Climate Change. Ontario Fruit & Vegetable Convention, St. Catharines, ON, Feb 15-16, 2006 (invited).

3. Mehdi, B. Adaptation to Climate Change: An Introduction for Canadian Municipalities. Sustainable Communities National Conference .Ottawa, ON Feb 1-3, 2006.

4. Mehdi, B. the Great Lakes' Waters. Canadian Federation of Universities Women's Association. Beaconsfield Golf Club, Qc. April 23, 2005 (invited)

5. Mehdi, B. Research and Management Needs for Climate Change Adaptation in the Water Resources Sector. Confronting Water Scarcity Conference Lethbridge, AB. University of Lethbridge, July 15, 2004. (invited)

6. Mehdi, B. Water Resources at Risk due to Climate Change: Identifying Research Needs and Knowledge Gaps. CWRA 57th Annual Conference, Hyatt Hotel, Montreal QC. June 17, 2004.

7. Mehdi, B. Johannes, M., McKenzie, K. The role of C-CIARN in identifying research needs related to Canada's Water Resources and Fisheries. Climate Change Impacts and Adaptation: Water Resources and Fisheries in New Brunswick. Moncton, NB. March 15-16, 2004. Department of Fisheries and Oceans.

8. Mehdi, B. Facilitating Climate Change Impacts and Adaptation Research for Water Resources. Climate Change Session of AMERICANA, March 20, 2003. Palais de Congrés, Montreal, Qc.

9. Mehdi, B. Facilitating Climate Change Impacts and Adaptation Research for Canadian Water Resources. Canadian Water Quality Association in conjunction with the National Water Research Institute (CWQA-NWRI), February 10 - 11, 2003. Centre for Inland Waters, Burlington, On.

10. L'impact des changements climatiques sur la gestion de l'eau. Forum Québécois sur la gestion de l'eau, de L'Institut Canadien. 4 decembre 2002. Hotel Omni Mont-Royal, Montréal, Qc.

11. Impacts of Climate Change on Canadian Water Resources. Session A8 of the Canadian Water Resources Association, 55th Annual Conference. June 11-14, 2002. Fairmont Hotel, Winnipeg, MB.

12. A Research Network on Climate Change Impacts and Adaptations: Water Resources Sector. Canadian Society of Civil Engineers, June 8, 2002. Queen Elizabeth Hotel, Montreal, QC.

13. Introduction à C-CIARN Ressources Hydriques: un réseau de recherche sur les impacts climatiques et l'adaptation. Salon des Technologies Environnementales, Centre des Congrès de Québec, Québec April 12, 2002.

2. Key Impacts on the Sector

A) List of Impacts on the Water Resources Sector by Activity

The C-CIARN Water Resources sector looked at impacts and adaptation issues based on five sectors of water users: Agriculture and Rural Areas; Hydropower and Energy; Navigation and Transport; Municipalities and Communities; Ecosystems and Environment. Examining each of these individually, the sector identified the most pressing climate impacts being felt by each.

AGRICULTURE

- adapt to drought effects on soil moisture balance, irrigation and water supply/demands
- improve water use efficiency e.g. adopt irrigation processes from country's accustomed to drought conditions
- adapt to more/less water
- adapt to increasing rainfall intensities
- adapt to less surface water availability. Groundwater use has recently increased threefold. (currently 14% of groundwater is used by industry, 43% is domestic use and 43% is used by the agricultural sector).

ECOSYSTEMS & ENVIRONMENT

- adapt to the impacts of very large floods on vulnerable river systems
- adapt to the impacts of changing stream flow regimes and lake levels on ecosystems (fish, wildlife, erosion & sediment deposition).
- adapt to the impacts on wetlands/bogs/peatland disappearance
- adapt to the increase groundwater withdrawal effects on loss of wetlands and riparian ecosystems, reduced stream flows and decreased groundwater.
- adapt to impacts of the concentration and fate of contaminants in streams, lakes, etc.
- adapt to saltwater intrusion to groundwater and land subsidence
- integrate and downscale hydrologic, climate, and ecosystem models
- communicate and educate stakeholders regarding ramifications of adaptive solutions

MUNICIPALITIES AND COMMUNITIES

- improve design standards for water distribution, use systems
- make water allocation (licensing) and management systems more flexible and adaptable to change
- use economic and social info / costs from climate change – and to associate priorities M&C's
- allocate costs associated specifically with climate change compared with market conditions and economic growth
- provide technical, scientific, biological and engineering support for small to intermediate rural communities.
- protect and maintain quantity and quality of drinking water sources from climate change and human use
- adapt to the increasing demand of groundwater use
- make M&C's more aware of water quality and quantity issues and engage them in resolutions of those issues – some or many of these related to climate change and impacts on quantity and quality
- make water valued in a proper context both in social and economic
- determine whether present water supplies are adequate under climate change and that M&C's develop appropriate strategies to incorporate change
- reduce flood hazard in urban communities while maintaining and enhancing aquatic ecosystems
- improve information for M&C's - empirical observations lacking
- integrate / incorporate spatial scales and their importance – expand to include communities, municipalities, region districts and provincial governments.

TRANSPORTATION AND NAVIGATION

- cope with a potential new pathway for exotic species along new transportation corridors
- adapt to the availability of the Northwest Passage
- cope with the impact of extreme events - in terms of public safety issue
- improve our ability to evaluate the navigability of rivers and lakes under climate change
- understand the physical and chemical impacts of dredging?
- improve the efficiency of shipping with short-term water level forecasts
- factor in the extra cost of shipping and transportation brought on by adaptation

HYDRO POWER AND ENERGY

- adapt to the impacts of droughts on long term water supply for hydro generation
- adapt to the impacts of extreme meteorological events (e.g. ice storms, tornadoes, etc) on electricity power production.
- adapt to the impacts of changing stream flow regimes and lake levels on electricity production
- prepare for increased climatic variability and extreme meteorological events (e.g. ice storm or wind storm or extreme drought)?
- enhance the capacity for decision-making through use of climate and hydrological models?
- adapt and rationalize increased use of water by multiple users (irrigation, industrial uses, municipalities, First Nations, recreation, etc.).

In summary, important priority areas for agriculture are to cope with a diminished water supply and to identify best management practices on the farm and to implement water conservation strategies which will enable producers to better adapt to the variations in climate. For ecosystems and the environment, the priority is to determine the relationships between water (quantity and quality, timing, etc.) and ecosystem dynamics/functioning, particularly in southern watersheds which have been greatly altered. It is important to determine the groundwater recharge which is affected by factors that are linked to climate: 1) changes in precipitation, evapo-transpiration and temperature, and 2) changes in surface waters and land. Therefore, we need to examine the sensitivity of aquifers to future recharge rates and consider ground and surface waters together. The artic should receive high priority, as little is known about the cryosphere, and the north is where the greatest impacts of climate change may be felt. Municipalities and communities need improved meteorological and hydrological predictions of impacts to incorporate these into their decision making processes. Risk management tools for stakeholders must be developed, and tools for water managers to cope with conflicts must be developed (water licenses, and allocation). Lastly, research on municipal water conservation issues is needed. The greatest challenge for the hydro power and energy sector is to make accurate forecasts of power demands under climate change scenarios. New technologies are needed that will operated under changing streamflow conditions, and an adaptation of the existing operations and planning is needed to deal with more severe droughts in the future. For the navigation and transportation sector, adapting to fluctuating water levels in the Great-Lakes/ St.-Lawrence waterway is of great concern to the navigation industry, and how to resolve conflicts arising between water users is of prior importance.

B) List Some Major Impacts from a Cross-Cutting Perspective in the Water Resources Sector

1. Drought occurrences. Drought can be in the form of a hydrological drought, a meteorological drought, or an agricultural drought. The occurrence of any type of drought affects many stakeholders. Most notably, crop and livestock producers, hydropower facilities, navigation and transport industry, and municipalities. All have identified this event as a major concern which requires planning and preparing for in advance.

- The greatest vulnerability to climate in the hydropower industry for both planners and for operators was to drought, or to any event which threatened ensuring a long-term (reliable) water supply in general. Water is their source of income, as such, drought is perceived as a major threat.

- In times of drought, producers require more water for irrigation and livestock to keep the crops alive and not water-stressed. Crop losses entail millions of dollars of losses, and payments in crop insurance.

- In the municipal sector, water is often taken from surface water sources (anywhere from 69% (Y.T.) to 100% (N.W.T, and Nun.)). Lower water flows in times of drought means less water to draw from, and water that is of a lower quality. A drought further increases water use in other sectors, especially agriculture and this can entail an increase of conflicts. In both the municipal and the agricultural sector, there is less reliance on surface water and more reliance on ground water in times of drought because groundwater is less affected by climate change than surface water. The impacts of climate change on groundwater will depend on the time scale as well as on the type of aquifer.

Case in point: National Drought, Canada 2001

In the spring and summer of 2001, Canada experienced a nation wide drought, as well as its third overall warmest year on record. The growing season across southern Canada was the driest in 34 years. The Prairies were the hardest hit; some regions were suffering their second or third straight year of drought. The drought and already low grain prices are estimated to have cost Western producers $5 billion (Phillips, 2002).

British Colombia experienced its driest winter on record. Rain and snowfall were half of their historical average for the region. Snowpacks were at or below their lowest levels on record, consequently, in Victoria, at the end of the wet season, the main reservoir's drinking water levels were more than 30% lower than full capacity (Phillips, 2002).

Alberta declared a drought before the first day of summer and rationed irrigation water in the spring for the first time. Officials estimated that the region would need an unprecedented 50% to 70% more precipitation the following winter and spring to replenish water levels for the 2002 growing season (Phillips, 2002).

The Great Lakes/St-Lawrence region endured its driest summer in 54 years of records. From March to August, the Lake

Ontario region received only 256.0 mm of precipitation. Normally, it receives 413.7 mm during this period. Montreal experienced its driest April on record (only 13.7 mm of precipitation fell on the city compared to an average of 76.1 mm) followed by a record 35 consecutive days with no measurable rainfall (Meteorological Service of Canada, 2005).

Atlantic Canada was also affected by the drought. It experienced its third driest summer on record, totalling four dry summers out of the last five. Only a quarter of the normal rainfall fell on Charlottetown (49 mm compared to an average of 173.1 mm) and Moncton (47.6 mm compared to an average of 182.8 mm) in July and August, causing those months to be the driest recorded (Meteorological Service of Canada, 2005). As a result, it was estimated that potato yields in the Atlantic Provinces were 35-45% lower than average (Phillips, 2002).

2. Increase in precipitation intensities.

The Soil and Water Conservation Society conducted a study in 2001 (*Conservation Implications of Climate Change: Soil Erosion and Runoff from Cropland*) that found precipitation intensities since the 1930's have increased in short duration storm events in the north eastern USA and in south eastern Canada.

- Increased precipitation entails less water infiltrating into the soil, and a higher amount of agricultural erosion and runoff, and ultimately a loss of crop productivity.

- Urban infrastructures also need to handle excess water and runoff from it built up areas. Coping with older, combined storm sewer systems can be problematic when large storms occur. Combined sewers may pose the largest threat under a changing climate as they carry both wastewater and stormwater runoff in the same pipe to the treatment plant, meaning that should a large precipitation event occur that exceeds the treatment plants' design capacity, the excess combined wastewater and stormwater will overflow, and be discharged into the receiving water body (i.e. river) untreated.

- With the increase in heavy rainfall events, the possibility of flood occurrences also increases. Mid-winter or early spring melting events can also contribute to more frequent occurrences of extreme ice jams on rivers and trigger flooding events. Flooding can cause damages to ecological systems, built infrastructure (residential and commercial buildings, bridges, roads, railways, storm sewers) as well as taint the quality of drinking water.

Case in point: Flooding in British Columbia, 2005

On January 18, 2005 a rainfall event causing 320 mm of rain to fall in 48 hours wreaked havoc. A warming trend in British Columbia led to high rainfalls and early snowmelt, which caused destructive runoff. The runoff brought on landslides, road closures, avalanches, flooding and power outages throughout much of southern B.C., the lower Fraser Valley and Vancouver Island (MPSSG, 2005). The region usually receives 153.6 mm of precipitation in the entire month of January (Meteorological Service of Canada, 2005). The heavy rainfall in North Vancouver caused a massive landslide that destroyed two homes, caused one death and

was responsible for the evacuation of over 70 homes. British Columbia announced a state of emergency in the area (NHER, 2005). The extreme weather also caused ice jams, avalanches and flooding in other parts of the province. A number of communities were affected by the ice jams and the flooding that took place across the province, and over 500 people had to evacuate their homes (MPSSG, 2005). The Ministry of Public Safety and Solicitor General estimates that total damages were in the order of $20 million (MPSSG, 2005).

3. Less winter snowfall. This issue is of particular relevance in western Canada, where snowfall and glaciers supply water to some downstream municipalities by replenishing a portion of the drinking reservoirs during part of the year (especially in summer). Glacier ablation rates over the past century have been taking place at unprecedented levels. There is less snowfall accumulation on the glaciers, which leads to smaller snow water equivalent on April 1. Glacier fed streams and rivers have been declining in flow. Parts of glacial streamwater are used for agricultural irrigation (in the Prairies) and municipal uses (notably Calgary) and also for tourism & recreational purposes.

References:

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3. Key Stakeholders

In general, stakeholders who hold decision-making powers in any company, organization or institution that has a vested interest in water resources must be engaged in order for actions to be taken related to adaptation to climate change, and strengthening of climate resiliency. To manage climate risks to the water resources sector, the stakeholders have to be in a position of decision making as well as authority to disburse funds that are necessary for appropriate action to be taken (e.g. vulnerability study, infrastructure strengthening, etc.). They must be educated and aware on the science of climate change, and be conscious of the realities (potential impacts) of climate change. Ideally, they also should have identified risks to their company, organization or institute (real or otherwise) in order for them to take the appropriate adaptation action.

It goes without saying, the absolute key stakeholders that need to be involved to move the adaptation agenda forward are the politicians. They posses the power, the money the contacts and the knowledge to

mobilize necessary resources to address such a complex issue as climate change.

From our sector experience, we found the following to be amongst the most engaged stakeholder groups,

- Hydropower stakeholders
- Engineers
- Municipal stakeholders

There is no key leader in any of these groups; rather it is a collective group effort and consensus that has been reached amongst these to address the need to identify potential impacts of climate change and to strengthen their resilience to climate change.

STRATEGIES FOR STAKEHOLDER ENGAGEMENT

The first year of the Water Resources sector inception, the Coordinator spent a fair amount of time and energy meeting with key stakeholders and researchers to:
1) introduce the C-CIARN network,
2) to find out the climate issues of concern to the respective groups. These meetings were very effective to accomplish both goals. However, most of the stakeholders and researchers who were met already bought into climate change issues, and as such needing little convincing of becoming engaged. All stakeholders met have joined the C-CIARN Water Sector, and have been active to varying extents.

Face- to-face meetings in 2002 were with held with the following groups (date):
Ouranos Consortium (Dec 10, 2001)

Québec Minister of the Environment (Jan 18, 2002)

Hydro Québec (Jan 30, 2002)

Federation of Canadian Municipalities
(Feb 14, 2002)

University of Ottawa
(Feb 14, 2002)

University if Waterloo
(Feb 27, 2002)

University of Guelph
(Feb 28, 2002)

Nova Scotia Agricultural College
(Mar 13, 2002)

Réseau-Environnement
(Mar 15, 2002)

In consequent years, membership was increased through presentations at conferences, and workshop; hosting of workshops, etc. All of these were very effective strategies for engaging stakeholders with several new members joining after each of these events.

Overall, the more challenging stakeholders to engage in the Water Resources Sector activities were those living in provinces where climate change is not politically supported as openly as in the rest of the country (e.g. Alberta). The Coordinator experienced this from attending events in these parts of Canada; climate change issues were received with scepticism and a lukewarm degree of interest, at best. The membership numbers are perhaps a reflection of this phenomenon. For example, for the size of the province, Alberta has

relatively few members in our sector (see Table 1).

Table 1. Distribution of Water Resources Sector Members, since inception (January 2002 to July 2006)

Political Region	**Number of Members**	**% of Members in Sector**
Alberta	43	5.8
British Columbia	152	20.4
Manitoba	34	4.6
New Brunswick	33	4.4
Nova Scotia	54	7.2
Northwest Territories	11	1.5
Newfoundland & Labrador	32	4.3
Nunavut	2	0.3
Ontario	167	22.4
Prince Edward Island	6	0.8
Québec	82	11.0
Saskatchewan	53	7.1
Yukon	4	0.5
Other (outside of Canada)	73	9.7
TOTAL	**746**	**100**

From the sectors' experience, the most effective strategy for engaging stakeholders was meeting them directly via face to face meetings, or through the workshops we organized. Overall, since membership was free, most stakeholders joined readily. Stakeholders from areas which had experienced unusual or extreme weather events in the past were more apt to join, as well as those from areas which experienced water shortage problems were also more likely to join.

It should also be stressed that the C-CIARN Water Resources Advisory Committee played a considerable role in broadcasting the C-CIARN Water Resources image and activities across Canada and attracting stakeholders. The C-CIARN Water Resources Advisory Committee is made up of distinguished and renowned researchers and stakeholders in the field of water. They have helped to raise the profile of our sector through their presentations, and mentioning it to their colleagues, and word of mouth in general.

One challenge we faced in the Water Resources sector, was conducting similar I&A work as the Ouranos Consortium, and being located in the same city, we found created a challenge for attracting stakeholders from Québec (the access to funding for I&A was a big draw). However, this proximity to Ouranos was very effective for mutual collaborative efforts (e.g. hosting joint workshops). The stakeholders who worked in water, tended to join both networks, as C-CIARN Water Resources offers a more tailored focus on the water issues.

From the perspective of C-CIARN Water Resources, in order to improve and expand engagement on coping with climate change there is a need to provide tools for adapting. The best case would be the creation of a National Centre on Impacts and Adaptation with perennial funding which can provide guidance to stakeholders on managing risks, providing adaptation tools, expert advice, research funding, consulting personnel, and other similar resources, would attract a lot more stakeholders to the issue.

4. Engaged Stakeholders

The hydropower stakeholders belong to the group that is most keen to reduce their vulnerability to climate change, and amongst one of the more eager stakeholder groups to determine future impacts of climate to their operations and planning, and to examine ways to strengthen their resilience. The industry is without a doubt at the forefront of confronting the climate challenge in the water resources sector.

The Canadian Electrical Association - Water Management Interest Group (CEA-WMIG) has embarked on the production of a Water Management Roadmap which garners input from all the WMIG companies (18 globally) on moving forward with their priorities. On the top of their list of Roadmap recommendation priorities was that "WMIG benchmark the current state of knowledge and investment in the determination of the impacts of global climate change on a regional scale", as well as a project suggestion "To develop an enhanced research program to establish reliable evidence of climate change impacts" related specifically to hydroelectric power production. Climate change was the number one priority of concern for this group. Future collaborations with CEA- WMIG are expected.

The engineering stakeholders are also a group that is highly interested in climate change impacts and adaptation. The Canadian Council of Professional Engineers (CCPE) has expressed interest in this topic and is considering incorporating climate change in the engineering courses' curriculum. To this end, the Canadian Standards Association (CSA) is examining changes in design structures to cope with climate change. They are also developing a pilot project to identify climate change education needs for engineers. This project will be completed by mid-2007. For more information on this project: www.infraengineers.ca

Although these are engaged stakeholders, they are not implementing adaptation explicitly with climate change in mind.

It is our belief that research institutions will be called upon to play a greater role in providing the science to answer these stakeholders' climate related concerns, and also in facilitating adaptation for the industry, by providing plausible climate scenarios with minimal uncertainty for example.

Outstanding Needs of Engaged Stakeholders

Most stakeholders that are aware (to some degree) of the potential impacts of climate change on their operations are also interested in knowing how to move forward in order to reduce their vulnerability. In workshops that we undertook, it was often stated that stakeholders are interested in reducing vulnerabilities on all fronts, including climate change, even if uncertainties are present. However, undertaking proactive and planned climate change adaptation is not evident, as this is a relatively new challenge for the industry and some scientific ambiguity still surrounds the climate change models and scenarios. As well, the science to determine climate change impacts remains uncertain.

Currently, there is a lack of information on how to adapt to climate change, and also a

lack of case studies on adaptation mechanisms and adaptation implementation in the industry. To address this issue, it was often stressed during our workshops that adaptation to climate change should be integrated into current risk management strategies and planning processes, and not be a stand-alone issue, but part of a larger strategizing progression. Adaptation should be an iterative procedure that is constantly being evaluated and adjusted with new information being assimilated and integrated.

Stakeholders depend on the scientific community to provide some of the answers they need to adapt and to incorporate climate change into their decision making. In this respect, the adaptation community needs to develop qualified personnel in Canada to provide guidance on climate change issues. This includes providing climate change scenarios, with the relevant expertise on how to interpret and apply the results. As well as providing advice on how to conduct a vulnerability assessment. And being able to provide (or point to) any necessary and relevant data (i.e. climate, hydrometric, etc.).

Some collaboration is forming between the industry and the research community to examine the impacts and the significance of climate change on their systems more closely, as well as to implement adaptation strategies (e.g. Ouranos and PCIC). Government working with science and the industry is considered vital to address the science issues and to provide funding for answering some of the questions. Collaborations are also forming between utilities (i.e. in the hydropower industry) to determine impacts of climate change. For example, the hydropower industry has a scenarios based approach, whereby they look at the future climate and other factors to determine the long-term water supply. IISD is currently helping to put together this approach.

Communication of climate science remains a cross-cutting issue of primordial importance not only between the scientific community and the users of the information, but also within the industry itself. Experiences amongst stakeholders can be shared and lessons learned from past weather events. Within companies, management needs to be informed of the latest science and how to best incorporate this into the company. And between companies, climate information can be shared based on various experiences and research projects.

From the *Hydropower and Climate Change* workshop, ongoing communication between the hydropower industry and the scientists was deemed essential to acquire and apply the necessary tools for coping with climate change (making decisions, dealing with uncertainty), and to obtain main messages of what future climate to expect. Communication of the latest science was deemed important, to all levels of the industry.

Communicating results and also sharing results and creating new linkages is important for adaptation. An example of the communicating results that occurred in the C-CIARN Water Resources sector, was during the workshop on *The Application of Climate Models to Water Resources Management*, held in Victoria, Nov 18-19, 2004. At this particular workshop, the climate modelers (researchers), hydrologists (researchers) and water managers (stakeholders) were made aware of the other

group's activities (summary in Table 2) at this unique workshop that would not have been taken place were it not for C-CIARN. It was commented after the workshop, that because the groups circulate in different spheres, were it not for this event, the groups would probably never have interacted with each other, and it was deemed highly important that they finally did; mainly to have a better understanding of the applications, and the end results.

Table 2. New level of awareness achieved during *The Application of Climate Models to Water Resources Management* workshop

Stakeholders were made aware of:	**Researchers were made aware of:**
The development of climate models	The application of the climate models
The limitations of climate models	The needs of the decision makers
Where the future of climate modeling is going	Knowledge gaps in their application

5. Unengaged Stakeholders

Stakeholders who are forward-thinking are already planning for adaptation. Those that are short-sighted, you cannot convince. In order for the non-engaged to become engaged, they need to experience the need to adapt to climate change first-hand by living through a climate event and witnessing the consequences of climate-caused havoc. Until then, their immediate bottom line will be the most important priority for them.

Raising awareness of existing adaptation tools and / or various actions that can be undertaken to address climate change impacts will engage stakeholders. Often, they are unaware of how to start adapting, and are overwhelmed with the scientific information. Showcasing concrete examples (e.g. "Adapting to Climate Change: An Introduction for Canadian Municipalities") is of great value too.

Perhaps the most efficient way to sell adaptation is to show the unengaged stakeholders the impact that climate change will have on their bottom line. Show the stakeholders that adapting will actually pay-off in the long (or short) term; an economic cost benefit analysis.

Another barrier to the unengaged stakeholders becoming engaged is that they sometimes do not believe that climate change, climate variation, or global warming is occurring. As such, their attitude is "why do anything about it"? The most effective way to compel them to take action would be

if they experienced the effects of an unusual climate event first hand.

Education and communication of climate change impacts is also a key factor, I believe that if they were more informed on the issue, they would see the overwhelming amounts of information that are showing that climate change is real. So, in that respect, more direct communication about the science would certainly be helpful.

6. Unanswered Research Questions

LIST OF IMPACTS AND ADAPTATION ISSUES IN NEED OF RESEARCH (AS PER REGION IN CANADA)

Atlantic

- Streamflows: Shifting streamflow regimes could have ecological impacts, cause water apportionment issues, and lessen the hydroelectric potential (Lemmen, 2004)

- Ice cover: Changes in ice freeze-up and break-up timing can have implications for spring floods or coastal erosion (Lemmen, 2004)

- Groundwater: Loss of potable water caused by saline water intrusion. Resulting water conflicts could be a problem (Lemmen, 2004)

- Especially in PEI, examine the sensitivity of aquifers to future recharge rates and consider ground and surface waters together in managing resources (Rivera, 2002)

- Flooding: Increase in the occurrence and the severity of flooding events could cause an increase in water borne health effects (Lemmen, 2004)
- More frequent and severe ice jams could cause more flooding (Beltaos 2004).

Québec

- Québec City has seen a 30-40% decrease in streamflow. People are using deeper wells and the city is facing a problem of saline waters rising to meet the freshwater. This problem may be worsened by extreme events: the saline water could reach the surface, whereas the system can cope under normal circumstances. (Mailhot, 2002)

- Stream flow could be reduced by 30-40% due to climate change. It could then be further reduced due to drinking water demands. This decrease in flow will lead to water quality concerns. (Mailhot, 2002)

- Flooding and the resulting overflow of sewers could occur more frequently (Mailhot, 2002)

- Change in thermal regimes could affect demand for hydroelectricity, and could cost $500M (half of all profits) (Roy, 2002)

- Extreme events such as the 1996 Saguenay flood, the 1998 ice storm, and the 2001 drought could become more frequent (Bourque, 2002)

Saint-Lawrence and the Great Lakes

- A decrease in the extent of lake-ice, as well as the occurrence of some years without ice cover can impact ecosystems and navigation by increasing water loss through evaporation (Lemmen, 2004)

- Lower water levels, caused by increased evaporation and dry spells, will impact municipal water supplies (less available and lower quality water due to pollutant concentration), navigation, hydroelectric power generation, recreation and natural ecosystems (Lemmen, 2004)

- Changes in precipitation intensity could increase erosion, cause land and water quality degradation, flooding, and infrastructure failure (International Joint Commission, 2003)

- Longer periods of dry weather could cause an increase in the contaminants on roads and land, which will cause a greater unloading into the land and water when precipitation finally occurs (International Joint Commission, 2003)

- Increasing air temperatures, which cause an increase in evaporation and evapotranspiration and changes in precipitation amount, timing and duration could possibly affect water supply variability in the GL region. The frequency of droughts and flooding is expected to increase. Stream flow regimes, lake levels and groundwater are affected by these changes. (International Joint Commission, 2003)

- Less rainfall, higher evapotranspiration, and lower soil moisture during droughts reduce recharge and lower water levels in aquifers. (International Joint Commission, 2003)

- Ground water inputs into the Great Lakes Basin is unknown (Rivera, 2002).

- The low water levels experienced in the Great Lakes during 1999 to 2001 could occur more frequently. These low levels can affect the aesthetics of recreational property along the lakeshores and impede the use of summer recreational boats and marinas. Low water levels restrict access of commercial navigation vessels in shipping channels, locks and ports. The shipping industry will have to reduce ship loads, incurring additional costs. (International Joint Commission, 2003)

- Low lake levels may put pressure on governments to dredge. However, dredging is very expensive and causes concerns for ecosystems and human health because of contaminated sediments. (International Joint Commission, 2003)

- Lower water levels may decrease coastal erosion in the Great Lakes. Erosion losses are high at the moment because of development on the coasts (USEPA, 1995)

<u>Ontario</u>

- Flooding and the overflow of sewers could occur more frequently (Pang, 2002)

- Communities and municipalities may experience flash floods (McBean, 2002)

- Due to drought, increased demand on groundwater supplies, warm summer temperatures increasing drinking water demand, less water available for hydroelectricity, and irrigation, we may experience water restrictions and apportionment challenges. (Water Resources, Group 1, 2002)

- Decreased water quality will affect recreation (Water Resources, Group 2;, 2002)

- Changing lake levels will affect harbours and channels (Water Resources, Group 2, 2002)

- The ability to meet peak water demands will be challenged (Water Resources, Group 2, 2002)

Prairies

- Droughts could cause losses in agricultural production and changes in land use (Lemmen, 2004)

- Prolonged droughts in northern Great Plains affect water resources (Sauchyn and Skinner, 2001)

- Examine the sensitivity of aquifers to future recharge rates and consider ground and surface waters together in managing resources (Rivera, 2002)

- Changing streamflow regimes could affect agriculture, hydroelectric generation, ecosystems and water apportionment (Lemmen, 2004)

- With the potential decrease in river flow regimes, water allocations based on a percentage basis will be more robust than volume-based apportionments

- The mean flows and peak discharge of the Milk River at the border have decreased in the past 30 years, in part due to climate change. Future changes in the apportionment rules may be brought about (Bruce, 2003).

- Along the eastern slopes of the Canadian rocky Mountains, glacier cover is now approaching the lowest experienced in the past 10 000 years. The glacier retreat is causing a decrease in the downstream flow volumes. This trend in low flows is expected to continue and will exacerbate drought-caused water shortages already occurring in many areas in Alberta and Saskatchewan. (Lemmen, 2004)

- The impact of more persistent and frequent occurrences of droughts are a concern for future hydropower production (Mehdi, 2002)

British Columbia

- Glacier retreat in Yukon and BC could increase spring flooding risks (BC) and impact river flow regimes. This would reduce hydroelectric potential, impact ecosystems such as the fisheries, damage infrastructure and cause water apportionment problems (Lemmen, 2004)

- Reduced flows could affect spawning grounds for certain fish species. The timing of the low flows (summer) coincides with salmon spawning season. Changes in water temperature could also affect the distribution of these species (Petticrew, 2003)

- Warmer winters are resulting in earlier spring melt and rain instead of snow winter precipitations. Given BC's reliance on gradual snow melt to sustain summer flows, these trends can be expected to lead to reduced summer water supplies (Government of BC, 2004)

- Water allocation could become a problem between communities (distribution, licensing) and hydropower (Lemmen, 2004)

- If precipitation increases from 5%-10%, whether due to seasonality, intensity and duration or a net increase in yearly precipitation, there will be a great increase in the number of landslides. (Clague, 2003)

- Wetter winters (more rain as opposed to snow), rain at higher elevations that affects snowpack, the occurrence of smaller snowpacks, and earlier spring freshets will all change the timing of the water entering BC Hydro's reservoirs (Smith, 2003)

- Columbia River Treaty may require renegotiation based on future flows (Power, 1985)

- More extreme rain events will affect flood protection planning for BC Hydro (Smith, 2003)

- Reduced summer flows will affect BC Hydro because they have many downstream fisheries and may have to supplement summer flows with water from their reservoirs (Smith, 2003)

- In the Okanagan Basin, population growth is causing a rising demand in water. Water supply is changing due to climate change: snowpacks are smaller and spring melts come earlier resulting in a change in water timing (Cohen, 2003).

- Water management in the Okanagan Valley in response to the potential of higher evapotranspiration, increasing population, increased conflicts among water users and transboundary implications related to shared water resources within the US-Canada Columbia Basin system (Taylor, 2004)

- GVRD reservoirs, such as the Capilano Reservoir, could encounter increased turbidity problems due to increased landslides. Such problems already cause the reservoir to shut down an average of 55 days per year because the increased turbidity impairs water treatment (NRC, 2003)

- Increased precipitation could cause more frequent avalanches and landslides (Geertsema, 2003)

<u>Arctic and Subarctic</u>

- Thinner ice cover and an increase in the ice-free season are having ecological impacts and impact the traditional way of life (Lemmen, 2004)

- Thinner ice cover might result in improved navigation, changes in viable road networks (Lemmen, 2004)

- Ruptures of drinking water and sewage lines from permafrost degradation could occur (Lemmen, 2004)

- Increased turbidity and sediment loads in drinking water (Lemmen, 2004)

7. Advancing the Impacts and Adaptation Issue

The C-CIARN network was a useful vehicle for promoting climate change impacts and adaptation and liaising with stakeholders with researchers. The C-CIARN network has been successful (and continues to be successful) at creating forums for discussion between researchers and stakeholders; providing contacts/references to both groups; and reaching out to the adaptation community in general.

C-CIARN Water Resources provided a mechanism to facilitate some of the research required for decision-making through:

- drawing together researchers and stakeholders;
- identification of key knowledge gaps and research priorities;
- promoting access to data, resources and groups of experts

The main vehicle for facilitating the research, were the C-CIARN workshops organized; which tended to be planned around calls for proposals (LOIs) to provide a valuable reason for both researchers and stakeholders to come together and discuss how to move forward on the issue of adaptation. C-CIARN workshops were also organized because of a particular stakeholder group need to address a particular issue of climate concern for their sector. A general outcome from these workshop events was how the scientific community is aware that adaptation is just as necessary as mitigation. For the stakeholders, although disparities about adapting to climate change remain, adaptation is now on the radar screen of many stakeholder groups.

In the near future, institutional capacity must be increased to help stakeholders deal with climate events not previously experienced. In order to move forward in coping with climate change, it is important to involve stakeholders in the planning process. A partnership between stakeholders, government and researchers is required, where all parties are working towards a common goal. This type of collaboration with an effective dialogue between researchers, stakeholders and government produces results that are applicable to the industry.

One of the biggest constraints to the network is that C-CIARN does not have any monies to fund research; as such it is difficult, even challenging, to continuously attract researchers and stakeholder alike to the adaptation cause. If there was funding made available for adaptation research, then researchers and stakeholders would be apt to collaborate - more often- because they would have a common goal in sight. However, as it stands the one, or two, workshops that each office organizes annually are the maximum feasible number (to link researchers with stakeholders), given the limited number of workshops any researcher or stakeholder is able to (financially and time-wise) partake in.

The Ouranos Consortium is an example of a Québec organization that is able to successfully link stakeholders with researchers, primarily because both groups are able to gather around a pool of money, and brainstorm major needs, knowledge gaps and consequently conduct the

appropriate, targeted research with the given means.

As a final comment, my feeling is when you are called a research network, but don't have the funding to support research, there will be some level of confusion and limited longevity of the network (principally due to the waning interest of the members of not being able to push the agenda further by building projects and collaborations with limited resources). One approach to remaining attractive to members is to provide the latest, innovative adaptation information to members. So far, the successful strategy of C-CIARN has been to hold workshops which bring together the researchers and the stakeholders on the climate change adaptation platform, in the hopes of facilitating dialogue on the issue. In the long-term, there has to be buy-in at the higher echelons of all levels of government for adaptation to take on a great priority.

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