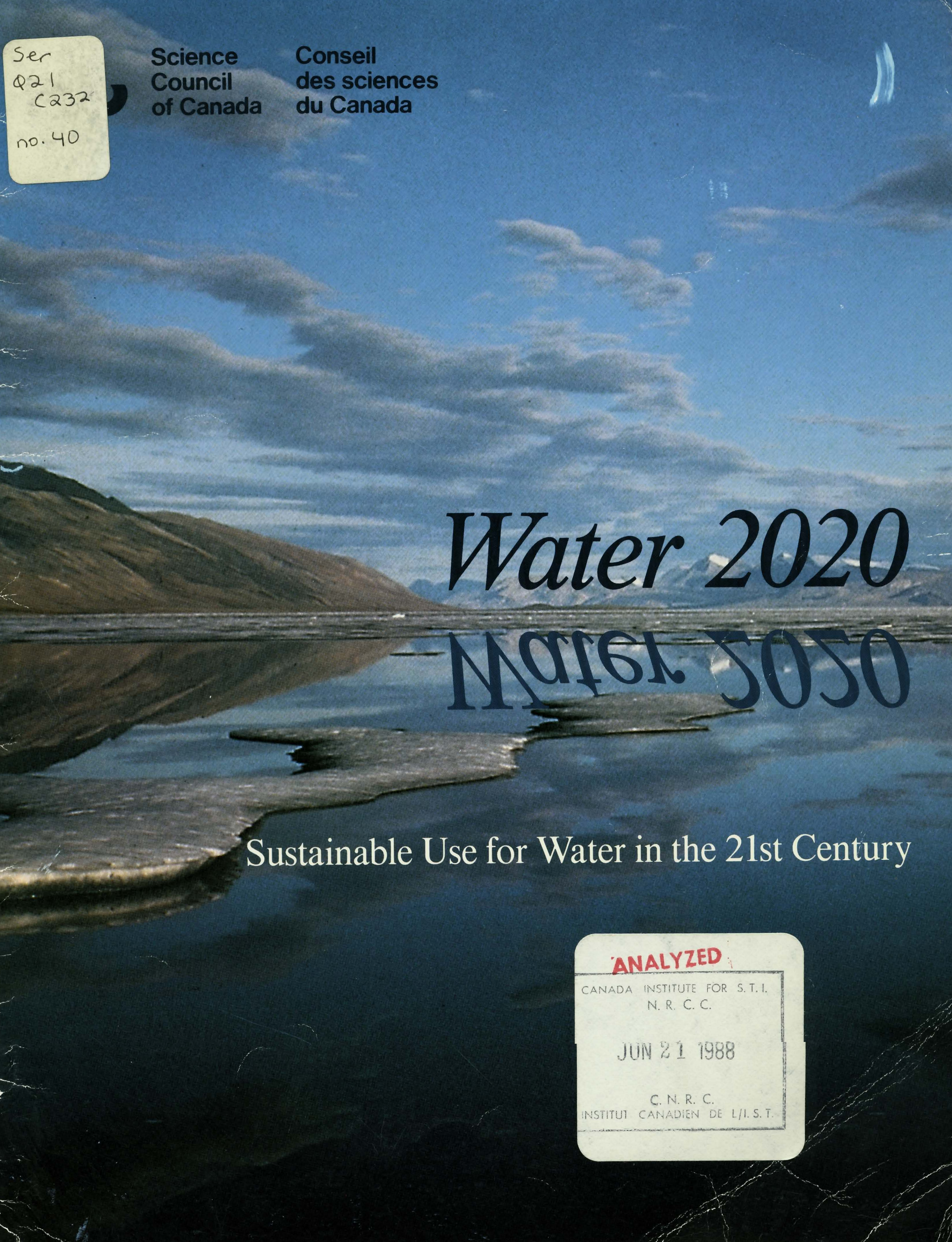

Science Council of Canada
Conseil des sciences du Canada

Water 2020

Sustainable Use for Water in the 21st Century

Water 2020

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Science Council of Canada Report 40

June 1988

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Sustainable Use for Water in the 21st Century

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June 1988

The Honourable Frank Oberle, PC, MP
Minister of State (Science and Technology)
House of Commons
Ottawa, Ontario

Dear Mr. Oberle:

In accordance with Section 13 of the Science Council of Canada Act, I take pleasure in forwarding to you the Council's Report No. 40, *Water 2020: Sustainable Use for Water in the 21st Century.*

Yours sincerely,

Geraldine Kenney-Wallace

Geraldine A. Kenney-Wallace
Chairman
Science Council of Canada

Contents

Where once water determined the pattern of exploration and settlement, it now enhances the beauty and character of the landscape and plays a powerful role in Canadian identity. For all these reasons, and in the sheer abundance of our waters, Canadians can and do take pride.

Foreword

Water is a vital element in Canada's past; it is equally vital for its future. Where once water determined the pattern of exploration and settlement, it now enhances the beauty and character of the landscape and plays a powerful role in Canadian identity. For all these reasons, and in the sheer abundance of our waters, Canadians can and do take pride. Thus it is cause for particular concern that the impact of current trends and future events on Canada's waters is uncertain. Climatic change, rising sea levels, increasing abuse, and a potential export demand all place the future availability of water in doubt. This highlights the fact that Canadians are not owners of water, but hold only limited stewardship rights. Water returns to us both the benefits and disasters of our civilization. Technology can and does impact on our waters in more than one direction. Given the importance of water, the development and application of science and technology to assure wise management is vital to meet national needs.

In launching a new water study in 1986, the Science Council recognized that the time was ripe to identify and examine the key issues facing water-use management and, in line with its achievements in the 1960s*, to set the agenda for water-use management into the 21st century. Three specific goals were established: to identify the critical aspects of the water resources problem; to encourage discussion about the role of science and technology in managing the use of Canada's water resources; and to make the necessary policy recommendations to meet research and management needs for the next 20-30 years.

During the study the Council held a workshop with participants from all parts of Canada to help identify emerging research needs. This was followed by six regional workshops that reviewed the key issues identified by Council and contributed to the development of policies that might aid their resolution. The Council also commissioned several discussion papers on topics ranging from conservation and demand management to the long-range transfer of pollutants. Project staff consulted water scientists in government, industry, and university, water-use managers, policy makers, and others across the country to get their opinions on the future of water science. Speeches and articles in journals and magazines kept the public aware of the study's progress. The Council listened to representatives of all the interests involved and encouraged discussion within the water community.

This report stresses the need to appreciate fully the relationship between the environment and economic development. It argues that Canadians must adopt a goal of sustainable use for water and shows how Canada can use and direct science and technology to this end. The report identifies a need for national leadership. But this kind of leadership in itself is not enough. Success will require determination and perseverence; this implies a concerted, national sense of purpose involving every sector of the Canadian community directed to a common end.

Robert O. Fournier
Chairman
Water Resources Committee

*In 1968, the Science Council issued Report 3, *A Major Program of Water Resources Research in Canada* and Special Study 5, *Water Resources Research in Canada* by J.P. Bruce and D.E.L. Maasland. These publications helped set the agenda for federal water research until now. In 1985, the Science Council cooperated with the Inquiry on Federal Water Policy to cosponsor a research paper *Water Resources Research in Canada: Issues and Opportunities* by B. Mitchell and E. McBean. The results of this work were incorporated into the final report of the Inquiry.

Water: the issues

Water is the life-blood of the environment. Without water no living thing, plant or animal, can survive. It is along the rivers and around the sea coast and lakes that life of all kinds is richest and most varied. Water plays a unique role in the traditional economy and culture of the Native peoples. It lies deep in the concept of Canada held by all Canadians.

Water is also a commodity: a renewable resource. The availability of an adequate and usable supply underpins our whole economy. Water is used for transportation and power generation, for waste disposal, recreation, agriculture, and fisheries, and is essential both in manufacturing and in the service sector. Happily, it is possible to use water without depleting its supply. But water is a fundamental component of a complex ecosystem. Its maximum sustainable yield is set by the effects of its exploitation in this total system.

Evidence of over-exploitation and, with it, evidence of the linked effect of environmental stress is all too clear.[1] Pollution from human activities has destroyed aquatic life, inhibited the reproductive capacity of mammals and birds, and threatens human health. Misuse of water resources causes widespread degradation of soils, disrupts the supply of potable water and generates massive economic losses. The movement of pollutants through the rivers and seas and through the atmosphere presents the world's ecosystems with a common threat.

Water facts: a national profile

Canada holds 20 per cent of the world's fresh water, but has only 9 per cent of the world's fresh renewable water; the rest is "fossil water," a legacy of the melting Pleistocene ice sheets.

- About 7.6 per cent of Canada is covered by fresh water; the nation's rivers and lakes contain enough water to flood the entire country to a depth of more than two metres.
- Sportfishing accounted for $1761 million in expenditures and investments in 1980, of which $300 million was contributed by foreign anglers.
- The measurable contribution of water to the Canadian economy is estimated to range between $7.5 billion and $23 billion per year.
- Approximately 90 per cent of Canadians live within 150 miles of the southern border, but 60 per cent of total river discharge runs north.
- In 1984 only 2164 of Canada's 3250 communities had sewers. Of these communities, only 1442 (or 44 per cent) had some kind of sewage treatment.
- Approximately 57 per cent of Canadians (1980-81 data) are served by wastewater treatment plants, compared with 74 per cent of Americans, 86.5 per cent of Germans, and 99 per cent of Swedes.

Sustainable development

To continue on our present path compromises the basic integrity of our total environmental system and, with it, our economic well-being. The report of the Macdonald Commission[2] recognized this threat. More recently, the report of the Brundtland Commission[3] stated bluntly that the planet cannot sustain current destructive industrial practices when its population will double in the next 35 years. As a solution the report calls for a new era of economic growth based on policies that will sustain and expand the environmental resource base. Such growth is essential if world poverty is to be reduced, but requires new policies that integrate environment and economy, and tackle the sources of environmental problems, not their symptoms.

The call for sustainable development has been strongly endorsed by Canadians. Last fall a coalition of Canadian environment ministers, business leaders, and environmentalists accepted the main conclusions and recommendations of the Brundtland report and urged the Prime Minister and the premiers to make fundamental changes in the way the country steers the economy.[4] The *Federal Water Policy*, also issued in the fall of 1987, takes as its overall objective the need to encourage the use of fresh water in an efficient and equitable manner consistent with the social, economic, and environmental needs of present and future generations.[5]

The health of our waterways is an index of the health of our environment as a whole. Consequently, water policy should be in the nature of a road map for the future, charting environmentally and socially desirable goals, purposes, and directions. We need to decide what is important and direct our science and technology policies for water accordingly. To fail is to jeopardize the future of our children; to succeed is to assure for them a healthy environment and economic prosperity.

Water is the life-blood of the environment. Without water no living thing, plant or animal, can survive.

The need to act now

Water shortages and pollution threaten not only the quality of human life, but the existence of fish and other aquatic species, birds, mammals, and plants. Shifts in species composition are one of the most sensitive indicators of stress in aquatic systems. In recent years, pollution from farming, forestry, mining, manufacturing, and other human activities has seriously disturbed the composition of species and greatly increased the rate of species extinction. For example, it is estimated that aquatic systems in some parts of northeastern North America have lost up to 20 per cent of their species because of acidification by the long-range transfer of air pollutants.[6] Ironically, at the same time as we adopt a goal of sustainability, we may already have altered many ecosystems to such an extent as to make sustainability difficult to achieve.

The need for urgent action to maintain the health of our water systems is already directly evident to Canadians. Shortages of fresh water and pollution threaten the quality of life of many Canadians, and the quality of drinking water is a problem in several parts of the country. Demand for water in the southern Prairies and the interior of British Columbia already approaches the limits of supply and shortages in dry years are increasingly common.[7] Northern and Native communities are particularly vulnerable. But a seasonal shortage of water can affect almost any part of the country with serious results. In the summer of 1987, for example, residents in parts of Newfoundland had to boil water for drinking, others had to travel long distances to obtain water; factories closed and buildings burned down, all because of a lack of adequate supplies.[8]

Pollution is more often the cause of water problems for Canadians than any absolute scarcity of supply. Sewage treatment is a case in point. Fifty-seven per cent of the population is served by sewage treatment plants. An additional 28 per cent is served by sewage collection systems but this sewage is discharged into a river, lake, or ocean without treatment. In Ontario and provinces further west, nearly all sewage collected receives treatment prior to discharge. But in Quebec, despite a program to provide at least primary

Native communities

The standards of water supply and sanitation on the Native reserves in some parts of Canada are much lower than in many developing countries.

- There are an estimated 330 000 Indians in Canada; approximately 70 per cent, or more than 220 000, lived on reserves in 1984.
- The majority of Indian reserves in northern Alberta lack proper water supply and sewage disposal facilities. In Saskatchewan and Manitoba, where Indians represent between 4 and 5 per cent of the population, fewer than 15 per cent of the on-reserve houses had running water in 1977 and fewer than 10 per cent of the houses had sewers or septic tanks.
- Only 50 per cent of the on-reserve Indian houses across Canada have running water; more than 100 000 Canadian Indians live in houses without running water.

treatment of all municipal effluents by 1990, and in parts of Atlantic Canada only a small percentage of sewage collected is treated.[9] Even where treated, the sludge dumped contains contaminants that generate water problems.

Diffuse pollution – from farming, forestry, urban discharge, transportation, construction, and sanitation landfills – into ground- and surface water supplies is also a major problem, and one much less amenable to management and control. Soil erosion from agricultural land is the major cause of non-point pollution.[10] The problem extends throughout the country. In Saskatchewan, annual losses of as much as 5.6 tonnes of soil per hectare have been recorded. In New Brunswick and Prince Edward Island annual losses of up to 20 tonnes per hectare are not uncommon.[11] The eroded material contains fertilizers and pesticides, causes severe sedimentation, and by its heavy demand on oxygen threatens aquatic life in streams.

The long-range transfer of pollutants through the atmosphere poses an additional threat to the quality of water. Sulphur and nitrogen oxides from smelter plants, coal-burning thermal power plants, and vehicle exhausts, as well as from industrial, commercial, and residential fuel combustion have been the cause of greatest popular concern. Yet acid rain is not the sole atmospheric pollutant. Other toxic organic substances, pesticides, and heavy metals threaten aquatic systems. Radioactive residues were found in lichens in the Canadian Arctic in the aftermath of the Chernobyl nuclear disaster in 1986, and industrial pollutants from Asia, Europe, and the southern United States are now traced to such previously pristine areas as arctic lakes and the headwaters of the Rocky Mountains.[12]

All these types of pollution lead to contamination of the groundwater on which more than one-quarter of all Canadians rely for their water supply. Pollution from agricultural sources is possibly the greatest and most intractable threat. The full extent of groundwater contamination in Canada is unknown and predictions of future contamination have not been made at either a provincial or national level. Where contamination has

Groundwater

The health of a million or more Canadians may be affected due to the consumption of contaminated well water, yet the extent of groundwater use and the extent of contamination is poorly understood.

- Twenty-six per cent of Canadians (6.2 million people) rely on groundwater for domestic purposes – up from 10 per cent in 1960.
- Eighty-two per cent of rural Canadians (about 4 million people) rely on groundwater for domestic purposes.
- Thirty-eight per cent of all Canadian municipalities rely partly or totally on groundwater.
- The total number of recorded wells in Canada is about 900 000. The true total is thought to be as many as 2 million.
- Groundwater provides nearly all the water used to produce livestock in Canada.
- Organic herbicides sprayed along transmission corridors for power lines have contaminated bedrock wells in Quebec.
- It is often impossible to restore polluted groundwater to potable quality.
- At any one time, groundwater represents about 37 times the total amount of water contained in rivers and lakes.
- Groundwater flows through the soil at rates as slow as 10 centimetres a day and may travel only 1-2 kilometres in a year, thus it may reside in the ground for thousands of years from time of entry to discharge.

already occurred, its removal, even where possible, is difficult, slow, and expensive. When discovered, it is usually because contamination has changed the taste or smell of the water or has had immediate effects on health.[13]

Although almost all Canadians have ready access to safe drinking water and are served by some form of sewage treatment facility, few Canadians are not directly affected by increasing water pollution or unaware of its most visible effects.

- Estimates of the lakes at risk from acid rain range up to 600 000; already as many as 100 000 lakes have been damaged.[14] Although all provinces have some cause for concern, serious damage to lakes and rivers is found in particular in Ontario, Quebec, and parts of Atlantic Canada. Hundreds of Ontario lakes have no fish because of acid rain. In Nova Scotia several rivers no longer have salmon runs, while others have salmon fisheries bordering on extinction. Acid rain is also threatening waterfowl and amphibians by destroying insects and small aquatic plants and animals vital to the food chain. In addition, there is recent evidence of acidification in shallow groundwater.[15]
- Between 1968 and 1972 the dumping of used oil wastes, mainly from the chemical and petrochemical industries, polluted the groundwater between the towns of Mercier and Ste-Martine, Quebec. Several thousand residents had to switch from local wells to supplies of water piped in from outside the region. More important, residents were subjected to potential health risks from the water they consumed before the contamination was recognized. By 1986 the direct cost of the contamination was about $10 million. Even the expenditure of many more millions of dollars may not ensure that the aquifer will once again yield potable water.[16]
- The International Joint Commission has identified more than 360 chemical compounds in the Great Lakes.[17] Many are potentially dangerous to humans. Their presence in fish has caused Ontario to set guidelines on consumption. Tumours and lesions have been found on various species of fish, including bullheads and salmon, and their capacity to reproduce has been questioned. Fish-eating birds such as

The Great Lakes: a stressed ecosystem

The Great Lakes, with a total area of approximately 246 050 square kilometres, are the largest freshwater system in the world. The lakes supply one-third of all Canadians with drinking water.

- More than 40 million people live in the Great Lakes basin. The basin contains three-quarters of Canada's industrial activity, almost two-thirds of the population, and almost half the dollar value of Canadian agricultural production. Various human activities within the basin have harmed the water quality and aquatic life forms.
- More than 350 chemical compounds have been found in the Great Lakes ecosystem. Among them are a number of persistent toxic chemicals, including:
  Alkylated lead
  Benzo(a)pyrene
  DDT and metabolites
  Dieldrin
  Hexachlorobenzene
  Mercury
  Mirex
  Polychlorinated biphenyls
  2,3,7,8-tetrachlorodibenzofuran
  2,3,7,8-tetrachlorodibenzo-p-dioxin
  Toxaphene
- The wetlands along the Canadian side of Lake Ontario covered about 4500 hectares in the late 18th century. Little more than 2500 hectares remain.
- While the commercial catch in Canada's Great Lakes fishery doubled between 1891 and 1980, the proportion of preferred, high value species fell from 50 per cent to approximately 3 per cent of the total catch.
- Of the 10 most highly valued species of fish in Lake Ontario, seven have now almost completely disappeared.

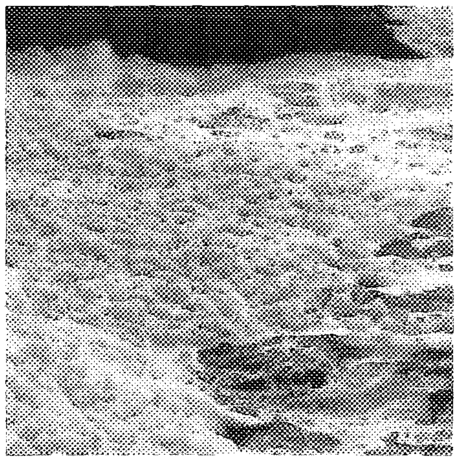
However, there are some positive trends:

- Phosphorous loadings in the Great Lakes and in the St. Lawrence down to Cornwall fell from 32 562 tonnes per year in 1976 to 28 786 tonnes per year in 1982 -- a reduction of more than 11 per cent.
- Concentrations of DDT in lake trout have decreased in lakes Superior, Michigan, Erie, and Ontario.
- Herring gull eggs indicate a significant decline in a wide range of contaminants between 1974 and 1986.

herring gulls and bald eagles have been affected and some of their populations around the Great Lakes have seriously declined. Regional declines in mink have been linked to contaminants in the fish they eat. Evidence also links a recent sharp increase in deaths among Beluga whales to the consumption of fish polluted by contaminated sediments in the Great Lakes-St. Lawrence system.[18]

These problems are immediate and real. In the longer term, no-one knows precisely what pressures on water resources future climatic change might bring. Projections of the "greenhouse" effect include increased precipitation in the Arctic and southeastern Canada, with no change or even a reduction in most of the rest of the country. The seasonal distribution of precipitation would change: winter precipitation is expected to increase dramatically in the west, with no change or a decrease in the east. Summers would be drier with more frequent droughts except in the Arctic and in the St. Lawrence-Atlantic region. Increases in winter precipitation would add to soil erosion and increase drainage problems. Irrigation could expand into southern Ontario and southern Quebec and the demands on water for irrigation in the West could increase and intensify. There could also be major adjustment problems in matching supply of water to demand as patterns of settlement and economic activity extend into new areas and as individual communities decline or increase.[19]

The future is unclear. What is clear is that water, already high on the list of public concerns, must move to the top of the political agenda. As its availability alters and demand shifts, conflicts between water users will increase. The availability of water and its quality will be recognized as a key determinant of economic and environmental health; its absence a pressing threat to national security and well-being. Scientific research is long-term and requires commitment. To avoid reliance on forced response under crisis and to use science and technology to anticipate and prevent problems requires that the necessary policies for water science are put in place now.



Pollution is more often the cause of water problems for Canadians than any absolute scarcity of supply.

Water facts: regional profiles

Canada as a whole has more than its share of fresh water. Unfortunately, this water is not always where we want it when we want it.

British Columbia

- B.C. has the greatest flow of water among the provinces. Half comes from the one-sixth of the province's area occupied by the Coast and Island ranges.
- Despite local water shortages, the province has 1600 times more water than it consumes.
- 100 000 hectares of land are under irrigation in B.C.

Prairie Provinces

- With only 2 per cent of Canada's water, Alberta in drier years accounts for more than 50 per cent of the water consumed.
- More than half of Canada's irrigated land and most of the water-intensive secondary recovery of oil and gas are in Alberta.
- More than 50 per cent of Saskatchewans rely on wells for household water.

Quebec

- Only 19.5 per cent of Quebeckers are served by sewage treatment plants, compared with the national average of 66.0 per cent (1986 data). Since the late 1970s Quebec has been undertaking a program to provide at least primary treatment of all effluents by 1990.
- Fish in the James Bay region contain higher levels of mercury than fish anywhere else in the world.
- Toxic chemicals originating at points along the St. Clair and Niagara Rivers have been found in water, sediments, and fish as far down the St. Lawrence as Quebec City.

The Atlantic Provinces

- Since 1979, 500 wells in New Brunswick have been contaminated by leaking petroleum tanks.
- The entire population of Prince Edward Island relies on wells for household water.
- Only 12.7 per cent of the population in Newfoundland is served by sewage treatment plants; the national average is 66.0 per cent (1986 data).

Ontario

- Almost 25 per cent of Ontarians rely on wells for household water.
- Northern Ontario alone could lose up to $230 million in income from tourism each year as a result of acid rain.
- In August 1987 all beaches in Toronto were posted as unfit for swimming because of the risk to health posed by pollution.

The North

- The Yukon and the Northwest Territories are home to fewer than one in 200 Canadians but contain 30 per cent of Canada's fresh water.
- Canada's glaciers contain more water than do the Great Lakes.
- The North is an arctic desert with low precipitation, so many communities find it difficult to get dependable supplies of safe drinking water. Some communities insulate or heat water and sewage lines and draw water from lakes and rivers below freezing depth.

A role for science

All the major environmental trends that threaten the planet impinge directly or indirectly on the availability of fresh water or the need for it: degradation of water, soil, atmosphere, and forests form interlinking processes of cause and effect that span the continents. Their impact, in terms of hunger, overpopulation, erosion, climate change, and species diversity are all major themes about which our water scientists must be concerned.[20] Policies to respond to these issues need to be long-term, comprehensive, and interrelated. And they should be based on science.

Recognition of the need for water science has already led Canada to build up internationally recognized expertise in physical hydrology, engineering applications to water management and development (such as in irrigation and diversions), and the treatment of conventional pollutants.[21] Past research has helped resolve many problems in these areas. For example, our capacity to manage conventional water pollution – such as contamination by bacteria, oil, phenols, and over-abundant nutrients from the traditional sources, such as sewage pipes – has been greatly increased. Scientists and engineers also know well enough how to predict the frequency of extreme droughts and floods, and how to determine water levels for optimum design and operation of dams and other river and lake control structures. There is considerable expertise in river basin planning for multiple uses. Some expertise also exists in the economic and social dimensions of water problems, such as pricing and allocation.

Nevertheless, more research related to the above questions is urgently needed. Basic gaps in understanding remain on key technical issues. For example, knowledge of pollution of the snow pack and its effects during spring melt is not secure. New knowledge can still lead to improvements and could avoid many millions of dollars in damage to the environment and to people. And in addition to new knowledge, more specialists are needed who have the imagination to predict and prevent conventional water pollution; expanded banks of observational data are needed to guide them. However, traditional lines of enquiry in water-quality research, hydrology, and the socioeconomics of water management should no longer be the main focus of Canada's overall research effort. A new agenda for hydrological and other water-related research is now required.

Depriving arctic waters of as little as 5 per cent of their supply of fresh water would warm the Arctic and trigger climatic changes over a wide area – possibly on a global scale.

The freshwater-marine environment

River water running into the sea is not wasted.

- Freshwater runoff into arctic waters helps maintain the low salinity upper layer. This acts like a lid preventing warmer, deep water from reaching the surface and increasing the flow of heat and moisture into the atmosphere, thereby altering global weather patterns.
- Depriving arctic waters of as little as 5 per cent of their supply of fresh water would warm the Arctic and trigger climatic changes over a wide area – possibly on a global scale.
- Even a minor reduction in fresh water runoff could affect ocean currents in the Arctic and patterns of formation and break-up of sea ice.
- The flow of fresh water into the oceans fundamentally affects fish populations. Dams and diversions have decreased the freshwater runoff into the St. Lawrence and reduced lobster catches along the Gulf.
- The creation of large dams and reservoirs in the Soviet Union has led to a serious decline in the Black Sea fishing industry. The level of the Caspian Sea has fallen and fisheries are threatened by increased salinity and altered water-flow patterns.
- Less than 3 per cent of the world's water is fresh, and most of that is inaccessible. Little more than 0.01 per cent of the Earth's water is in lakes, rivers, soil, and the atmosphere.

Research issues

Among the most evident, and most serious, unresolved research issues[22] facing Canadians are:

1. The transport of acidic and toxic substances from the atmosphere into water bodies; the effects of such substances on aquatic systems and fitness of water for various uses; and the volatilization of toxic substances from lakes and rivers to the atmosphere and their subsequent dispersion.
2. The changes in water supply, which will probably be brought about by air pollution-induced climate warming, and options for adaptation or responses to such changes.
3. The movement of toxic chemicals into groundwater from dump sites and underground storage and disposal sites; nonpoint sources of chemicals used in agriculture and forestry, the behaviour of these chemicals, and their impact on water supplies and uses; and the location of "safe" underground disposal sites for toxic and radioactive wastes.
4. The determination of the future economic and social value of water near its place of origin and in-channel, and the need to give proper weight to this in considering projects to withdraw or divert water.
5. The effect on aquatic ecosystems of increased ultraviolet radiation due to ozone depletion.
6. The relations between fresh water and the marine environment.
7. Mechanisms for resolving conflicts between competing users.
8. The ecological effects of diversions of water both from one river basin to another and out of one ocean drainage basin into another.
9. The ultimate fate and impacts of low levels of toxic chemicals discharged into the environment.

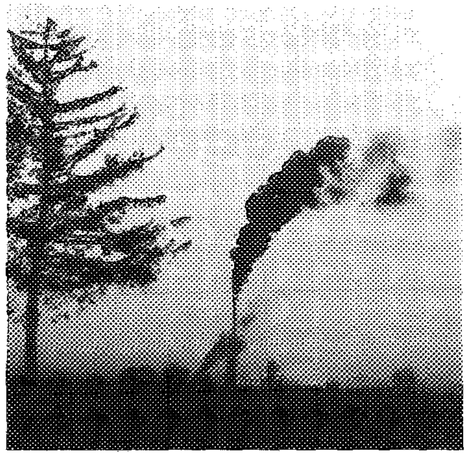
These issues all have two characteristics in common: they require an interdisciplinary approach to water research, to water policy development, and to implementation; and they are international in scope.

Acid rain: magnitude and costs

Acid rain is now a global phenomenon. Canada ranks as both contributor and unwilling victim:

- North American industries and automobiles annually discharge 50 million tonnes of acidic sulphur and nitrogen into the atmosphere.
- The INCO Ltd. smelter at Copper Cliff, Ontario is the largest point source of sulphur dioxide in Canada, emitting 866 000 tonnes per year. It would cost INCO about 3 to 23 cents per pound of nickel to reduce these emissions by 58 per cent (1980 values).
- Some parts of Eastern Canada receive as much as 45 kilograms of acid per hectare annually.
- Approximately 14 000 lakes in Canada are biologically dead and, unless acid depositions are reduced, another 10 000 to 40 000 will die.
- Twenty-four species of birds are endangered in eastern North America as a result of the impact of acid rain on the food chain.
- The growth rates of spruce, pine, and fir in some parts of Ontario and Quebec have more than halved. This dramatic decline, caused in part by acid rain, is bad news for the forest industry, which indirectly employs 1 in 10 Canadians.
- Half the automobile corrosion in Canada may be due to acid rain.
- Acid rain causes at least $285 million damage annually to building materials.

The planet cannot sustain current destructive industrial practices when its population will double in the next 35 years.



The institutional framework for research

Repeated reviews and inquiries have examined the state of Canadian water science and the organization of research.[23] Several of these studies have focused on the role of Environment Canada. As the department responsible for more than 50 per cent of all water research this is the lead federal agency. But many different federal and provincial departments and agencies are involved in water research, or in the use of research findings, as well as municipal governments, private firms, international bodies, and the general public. The very diversity of actors complicates analysis.

Federal departments involved include Environment, Fisheries and Oceans, Agriculture, Transport, Communications, External Affairs, Health and Welfare, Indian and Northern Affairs, and Energy, Mines and Resources. Environment Canada administers the Canada Centre for Inland Waters and the National Water Research Institute, both in Burlington, and the National Hydrology Research Institute in Saskatoon. Fisheries and Oceans administers the Freshwater Institute in Winnipeg. The Pacific and Freshwater Service of the department also carries out a number of activities related to water research. Other federal bodies involved include the International Joint Commission and the National Research Council as well as the major granting councils, especially the Natural Sciences and Engineering Research Council.

At the provincial level, key responsibility for water rests with departments of environment, natural resources, and agriculture. Most universities are involved in some water-related research. Major centres include the Westwater Research Centre at the University of British Columbia, INRS-Eau at the Université du Québec (Ste-Foy), and the Institute for Environmental Studies at the University of Toronto.

The federal government provides over 70 per cent of the funds used for water research and spends 50 per cent. Provincial governments contribute 16 per cent of the total. Industry provides about 4 per cent. The remainder comes from municipal governments, universities, and other groups.[24] The predominant role of federal funding and the importance of government research activities has left water research particularly vulnerable in the late 1980s period of financial restraint. The result is an ageing science population and low morale.[25]

The organizational arrangements that met past needs are ill-suited to future requirements. In particular, most emerging issues require that policy makers are able to use the basic research generated in many different disciplines. They also require a long-term commitment to research; a commitment that cannot be met under management practices designed to meet day-to-day regulatory needs.

Attempts to develop better institutional arrangements have foundered. The establishment of the Canada Centre for Inland Waters (CCIW) in 1966 was one attempt to encourage interdisciplinary work. Until 1972, the attempt was successful. Scientists from Energy, Mines and Resources, the Fisheries Research Board, and Health and Welfare worked together to address the problem of pollution in the Great Lakes. The signing of the Great Lakes Water Quality Agreement in 1972 did result in coordinated research on pollution in the Great Lakes, but departmental reorganization tended to discourage interdepartmental cooperation. This further discouraged scientists from different departments and disciplines from working together and the research effort at CCIW became fragmented.[26] Specific attempts to encourage cooperation met with only sporadic success. More recently (in 1987) the Marine Ecology Laboratory, an internationally renowned inter-disciplinary research centre at the Bedford Institute for Oceanography, was disbanded. These moves have pushed water science in Canada toward short-term, managed research with a narrow disciplinary focus and reduced its capacity to anticipate and prevent, and to respond to long-term strategic needs.

A vested interest

Maintaining the quality of the Canadian environment is primarily a domestic responsibility. But we are moving beyond a period of acute, localized, and relatively simple environmental problems to one of chronic, global, and extremely complex problems in which issues of ecological stability and economic development are closely intertwined. Just as water does not stop flowing at political borders, so pollutants transferred through the atmosphere are not necessarily deposited on their source region. If Canada is to assure and improve its own water resources it must increase its participation in bilateral and multilateral negotiations on environmental standards and controls.

Canada's international role in environmental issues takes many forms; it is evidenced in such achievements as the Great Lakes Water Quality Agreement[27] and in the leadership provided by individual Canadians in, for example, the World Climate Programme, and in the development of the Brundtland Report. Many Canadians also contribute their technical and managerial skills to other countries through the Canadian International Development Agency (CIDA) and through many other government and nongovernment organizations and agencies. Our image as an environmentally aware people (particularly with regard to water), the legacy of generations of good Canadian water scientists, and the importance of our engineering consulting firms all bolster our international reputation. Recognition of the global nature of many water problems now requires that to meet our own needs we assume an even greater responsibility – as leaders in a move to resolve the critical water problems facing almost all parts of the world.

Theoretically, global water resources might be sufficient to meet demand until 2015. However, the demand for water and its availability are unevenly spread. According to current projections, even comprehensive and well integrated water-management schemes will be inadequate to sustain the increase in population in Europe and South and East Asia. Africa will also face acute water problems. In addition, although levels of wastewater treatment will probably be much higher than they are today, continued growth in industry's need for water threatens a continued increase in the contamination of the world's fresh water.[28] Above all looms the threat posed by deforestation. Between 7.6 million and 10 million hectares of tropical forest are eliminated each year; at least a further 10 million hectares are grossly disrupted.[29] This is causing serious erosion and soil loss, disrupting complete drainage systems and destroying a large proportion of the world's plant and animal species. Deforestation threatens global climatic change and poses a long-term threat to ecological stability throughout the world.

Canada already plays a significant role in development projects related to water. Canadian involvement in the Third World combines idealism and some sense of moral responsibility with hard practicality. In the long run at least, the Third World offers an enormous market for Canadian technology, and work overseas provides invaluable training and experience for Canadian scientists. CIDA funds water-related programs under three main headings including water and sanitation, energy (hydroelectricity), and agriculture (irrigation). The total value of bilateral programs in the Water Sector in 1986 was $60.5 million or 3.2 per cent of the total CIDA budget.[30] But the total share of CIDA's budget for water resources is probably about 10 per cent.

CIDA's role in water development projects in the Third World links dollar aid to the provision of skilled personnel and technology; and in particular to training indigenous personnel. But if Canadians accept the need to pay greater attention to those ecological imperatives and planetary considerations on which sound policies depend, they must also strengthen their contribution to the resolution of water problems in other parts of the world. Canadian research on such issues as the pollution of the Great Lakes and St. Lawrence, groundwater contamination, industrial spills, acid rain, and sewage treatment is often more compatible with the needs of other developed countries than those of the Third World. Yet the ways in which Canadians might employ this expertise abroad are poorly defined.

Water and health in the Third World

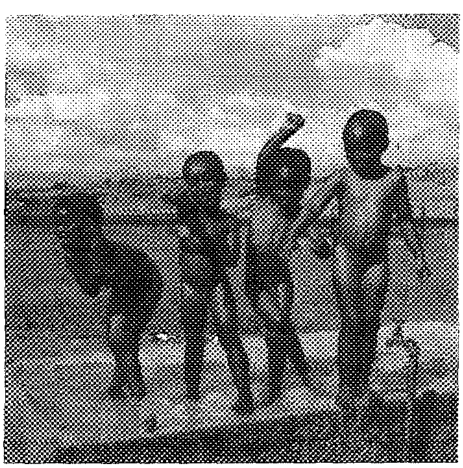
An adequate, safe supply of water is a basic human right, yet:

- Worldwide, 1.3 billion people (26 per cent) lack safe drinking water and 1.7 billion (34 per cent) lack water for sanitation.
- Eighty per cent of the rural populations of 73 African and Asian countries, whose populations are mostly rural, do not have access to safe drinking water.
- One-quarter of the world's people lack safe drinking water and sanitation. Water-borne diseases kill at least 25 million people in developing nations each year. An inadequate water supply is implicated in trachoma blindness (500 million sufferers), schistosomiasis (250 million), and elephantiasis (250 million).
- Diarrheal diseases resulting from impure water affect 500 million people each year and are the largest killer of children under 2 years old.

However, significant progress has been made:

- The proportion of rural people without access to safe drinking water decreased by 25 per cent between the 1960s and the 1980s. (However, the scale of rural to urban migration has prevented any increase in the percentage (approximately 70 per cent) of the urban population that has a safe water supply.)
- Between 1973 and 1978, 270 million people gained access to a safe water supply and 180 million obtained adequate sewage treatment.
- Third World governments and donor nations spend about (U.S.) $1500 million each year on rural water supply.
- The annual expenditure of $20 billion necessary to provide all people on Earth with safe drinking water and adequate sewage treatment by 1990 represents about 4 per cent of annual global military expenditure.

According to current projections, even comprehensive and well integrated water-management schemes will be inadequate to sustain the increase in population in Europe and South and East Asia. Africa will also face acute water problems.



Spin-offs from science

Science can clearly contribute to water policy by clarifying how much water there is, where it is, at what rate it is replenished and purified, the sources of its pollution, and how it can be cleaned up. But the results of research must also be put to full use. The application of science in new technologies provides a means to help preserve our environment and protect water resources against abuse. Such technologies could also create jobs and generate a valuable source of income.

To date, the quality of water science in Canada has allowed Canadians to contribute to the international pool of knowledge about water and water-related issues.[31] It has helped provide a basis for the development in Canada of some of the largest engineering consulting companies in the world. However, it has not led to the development of a strong, domestic manufacturing industry for clean-water technologies.

The treatment of water and wastewater involves a wide variety of different technologies.[32] Water treatment for most municipal and industrial applications has traditionally involved only simple methods of filtration and biological control. However, even this level of treatment has many variations and involves a wide range of technologies for filtration, pumping, instrumentation and control, and chemical storage and feed.

Canadian researchers are helping shape a number of different technological trends in water and wastewater treatment. These include the means to deal with synthetic organics, biological approaches to the removal of contaminants, and plant automation. Such trends are in response to more stringent regulatory requirements, the need to manage an expanding range of contaminants, and an increasing emphasis on product recycling and energy recovery. These needs cannot be met without the careful deployment of available technologies. Necessary upgrading and new plant construction is expected to increase to an annual level of $600 million during the next 5 years.

However, Canada's record of commercializing research results in the field of water science is as dismal as it is in other fields – few of the potential industrial benefits are realized in Canada. The artificially low price of Canadian water – at $0.33 per cubic metre compared to $4 in parts of the United States or $7 in Japan – has undoubtedly helped to discourage the commercial exploitation of clean water technologies developed in Canada.[33] Some of the work by the Canada Centre for Inland Waters and by the Ontario government – on wastewater treatment technology, developments in storm sewer design and river ice control, the microbiological degradation of wastes, and new or improved instruments for water measurements – has led to innovative products or concepts that had extensive commercial potential. In almost no instances have these innovations been turned into products, or consulting services exploited by Canadian companies.[34]

Water-related industries: neglected potential?

Canada has an international reputation in water science but has failed to develop a strong manufacturing sector to supply clean-water technologies. The potential is enormous.

- About 1000 jobs would be directly created by Canadian firms supplying just 1 per cent of the current U.S. demand for pollution abatement equipment. (Currently Canada exports less than $30 million worth of water resources equipment annually.)
- Only about 55 per cent of the Canadian water resources market is satisfied by Canadian equipment and this market share is declining.
- Canadian industry spends almost $100 million annually on water pollution control equipment.
- In the next 5 years, capital expenditures required by municipalities and industries to meet wastewater standards could create between 75 000 and 170 000 jobs in Canada.
- Canada imported more than $56 million worth of water and sewage treatment equipment in 1986 – at the cost of one Canadian job for every $50 000 worth of domestic production lost to imports.
- Between 1981 and 1985 approximately $2.2 billion a year was spent in Canada on water and sewage works including treatment plants and collection and distribution systems.
- The value of construction of all types of waterworks and sewage systems in Canada in 1986 was almost $3000 million.
- The market for water and wastewater treatment equipment in Canada will grow from its current level of at least $400 million per year to almost $600 million annually by 1992.

A national program for water

Evidence of a looming environmental crisis indicates a scale and depth of disaster far exceeding any met by earlier generations. The nuclear age holds the potential for total destruction. A more fundamental threat yet is the accelerating pressure of human activities on the natural resources and ecosystems on which life depends.[35]

Several recent reports have depicted the symptoms of the crisis that confronts the world community. Others have focused on particular Canadian concerns.[36] Such reports have heightened public awareness and raised environmental issues to a par with economic issues (and occasionally some other items) in their importance in public decision making. But this misses the point. The evidence suggests that human life itself is threatened unless we adopt a value system that places environmental integrity above all but the most basic human needs. This means treating the natural environment as a context for political and economic decision making rather than as merely one consideration among many.[37]

The water-use problems facing Canadians can only be solved when we decide what we want and apply science to achieve our goals. As an overall principle or objective, the Science Council considers it essential to:

Manage water use to meet present needs in an equitable manner and without compromising the ability of future generations to meet their own needs.

Such a principle is consistent with the overall goal set in the *Federal Water Policy* and provides an objective toward which policies for water science might be directed. The Science Council presents nine policy recommendations in three areas of critical importance to water science: science leadership; international affairs; and applied science. These recommendations are directed to federal government since it alone can provide the resources and the leadership needed to achieve the goal of sustainable use for water. However, the Council recognizes the need for all levels of government – federal, provincial, and municipal – as well as individual Canadians to play a part. The importance of national commitment and shared sense of purpose in tackling emerging water issues cannot be emphasized too strongly.

We are moving beyond a period of acute, localized, and relatively simple environmental problems to one of chronic, global, and extremely complex problems.

Science leadership and institutional change

Water science can play a crucial role in resolving many of the emerging issues in Canadian water use. Until now, however, water science has too often been viewed only as a remedy for environmental mismanagement. This has diminished its potential to anticipate and prevent problems. The growing scale of cultural and technological developments, which pose new threats to water quality and to the environment as a whole, requires that water science become central to policy decisions.

Emerging water problems are chronic, global, and involve a complex integration of ecological and economic components. Resolution of these problems requires long-term, strategic research on an inter-disciplinary basis. Such research must also be responsive to policy needs and able to meet the applied science needs of many different departments and agencies at all levels of government.

The power of all environmental research, and water research in particular, lies in its ability to influence decisions. Consequently, if science is to contribute fully to the resolution of future water problems, whether within Canada, internationally, or through the development of environmentally sound technologies, strong national leadership is essential. The *Federal Water Policy* acknowledges the need for federal leadership in water science. It was a need echoed across the country in a series of regional workshops on water science held by the Science Council in 1987.[38]

There is little evidence of federal leadership in water science today. The research effort is fragmented among many different departments and cooperation between departments is weak. The needed, wide-ranging, long-term ecological studies are absent, and the "big" issues such as ecotoxicology, the impact of river diversions, and studies of the marine-freshwater interface are neglected in favour of short-term operational requirements.

Similar problems plague other countries. There is international questioning of existing institutional and legislative arrangements as effective vehicles to tackle emerging issues and manage long-term research needs. In large part, the solutions proposed reflect the broad economic and social climate of the country concerned. In Great Britain, in particular, almost all water research is now client-oriented and many government laboratories have been privatized. However, privatized laboratories in Great Britain (as in the Netherlands and Denmark) continue to receive the bulk of their funding from government and seem to have at least as much security of funding as before.

Radical change has intrinsic appeal, but it risks the destruction of much that is valuable for uncertain gains. Moreover, it is also clear that the existing Canadian research system already permits the establishment of programs that meet long-term, strategic needs. The Atmospheric Environment Service (AES) of Environment Canada is a case in point; all deliveries of AES are science based, and its staff recognize this, as do its clients. Above all, AES has a clear sense of mission and agreement on that mission. And it has the necessary corporate structure to secure its goals.

Canadian water science requires strong federal leadership. Environment Canada is already the lead federal agency in spending on water research. However, the burden of its operational mandate has encouraged an unacceptable and unnecessarily narrow interpretation of its mandate for research. This limits its ability to influence the policy process in other departments and agencies at all levels of government. To help resolve this situation and to strengthen Environment Canada's own commitment to federal leadership in water science:

1. **Environment Canada should publish its strategic interests and long-term research plans in water science.**

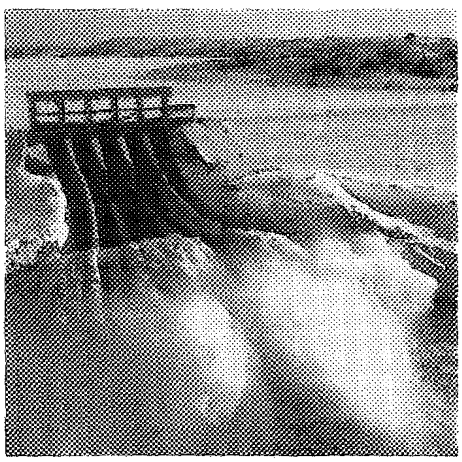
Such a move would help effect Environment Canada's own commitment to science leadership and in so doing, allow other federal departments and agencies, provincial governments, universities, and companies involved in water research and water management to coordinate their activities in ways that better meet national needs.

Water diversions

Canada transfers more water between basins than the combined total flow transferred in the next two leading countries for water diversions – the United States and the Soviet Union. If this flow were concentrated in a single river, it would be Canada's third largest after the St. Lawrence and the Mackenzie.

- More than 80 per cent of Canada's largest dams are used to generate electricity; 7 per cent supply water for irrigation.
- Three enormous hydroelectric projects completed in the 1970s together account for two-thirds of the water transferred in Canada before 1980.
- The Churchill River diversion on Southern Indian Lake illustrates many of the problems associated with large-scale diversions. Results include increased shoreline erosion, sedimentation, turbidity, and phosphorous availability. Water temperatures decreased. The mercury content in fish soared. And the quantity and quality of whitefish taken in the commercial fishery declined rapidly. The traditional Native economy was destroyed.
- There are 65 "high" dams (dams higher than 150 metres) around the world. Forty-four more are planned.
- Throughout the world, approximately 13 per cent of annual river flow is already interrupted by dams or some other construction.

A philosophy of supply management is no longer appropriate in the face of soaring construction costs, environmental degradation, and inadequate funds to maintain even the existing supply infrastructure.



A corporate structure

Canada's water institutions evolved with a philosophy of supply management that is inappropriate to solving emerging water problems. Reliance on such a philosophy – and continued attempts to augment available supplies – is no longer appropriate in the face of soaring construction costs, environmental degradation, and inadequate funds to maintain even the existing supply infrastructure.

The federal government has a dominant role in water resources research in Canada.[39] Today, in some federal departments, scientific excellence is imperilled by a dispirited research population struggling to find appropriate research challenges and an effective policy role. Cuts in research funding and in the number of research personnel provide an incomplete explanation. Other reasons include the failure to encourage and support experienced, reputable research scientists as senior managers and the reliance on administrators with no science background to be managers of scientists; the limited opportunities for good scientists to achieve the level of senior scientist in the public service due to Treasury Board quotas; the difficulties individual scientists experience in obtaining sabbaticals or permission to attend scientific conferences; and the overall low status accorded to water science even within Environment Canada. All these problems are fully documented and well known.[40] Although improvements have occurred, for instance, it is now easier for scientists to get permission to attend conferences, what stands out is how little has been done.

The greatest need in government water science is for its own management to act boldly – in carving out a unique research niche, attracting new programs to it, and in playing hardball bureaucratic politics to reinforce and strengthen these initiatives. Canada must invest in people, not buildings, if its water science is to achieve the results necessary to overcome future problems. Institutional change must be designed with this in view.

The Pearse Report recommended that *Environment Canada replace* the Inland Waters Directorate with a water service, headed by an assistant deputy minister. However, such a move neglects the fundamental role of scientific research in all aspects of environmental management, the need to coordinate environmental research, and the need for a long-term perspective.

To demonstrate that Environment Canada is a science-based department and to signal the importance of water to all Canadians:

2. **Environment Canada should:**
   (a) **appoint an assistant deputy minister for science;**
   (b) **replace the Inland Waters Directorate with a water service;**
   (c) **appoint a director general of water research.**

These changes would show that research was recognized as the foundation of good environmental policy; provide a suitable level of reporting for the directors of water research institutes; and offer an effective way to link the findings of research to policy development.

To support such changes and to ensure long-term improvement in the management of science:

3. **Environment Canada and the Department of Fisheries and Oceans should develop a clear policy to identify and train reputable scientists as science managers.**

There remains a need to establish institutions that provide a setting outside any line department for long-term strategic research on a multidisciplinary basis; responsive to policy needs; and able to meet the applied science needs of line departments. In a move toward a solution, the National Water Research Institute of Environment Canada has restructured its research groups on the basis of high priority research issues rather than on a common disciplinary focus. But despite this progress the expertise in the university community and in the private sector is not fully employed and the contribution of social scientists, at least in their own eyes, is neglected. Moreover, such reorganization remains vulnerable to the whims of the bureaucracy and does not resolve the need to integrate the disciplinary expertise scattered among different government departments. At present government researchers have trouble cutting across mandate lines, and this hurts research.

The example of groundwater research highlights many of these problems. Research is carried out by several different consulting firms and other private companies, as well as a number of universities, different federal departments, provincial governments, and crown corporations. Environment Canada has only five PhD-level scientists in groundwater working at its two national research institutes in Burlington and Saskatoon. There is no national long-term coordinated research program in groundwater. At least partly as a consequence of this, Environment Canada has lost many scientists to the United States in the last 5 years.[41]

The largest concentration of effort in groundwater research in Canada is at the University of Waterloo, which has about half of all the graduate students and one-quarter of the professors in groundwater science and engineering in Canada. The government of Ontario has recently designated the groundwater group at Waterloo as a "centre of excellence." This will go part way toward solving the research deficiencies in Ontario; it will not solve, however, all of Ontario's deficiencies in this area and will do little to resolve many of the specific problems in other provinces or meet broader, national needs. And although the Waterloo group has good links with the private sector, its links into the policy process are weak. Meanwhile, as many as a million Canadians may already be risking their health by drinking contaminated groundwater.[42]

A consolidation of federal water research should encourage more interdisciplinary work and a greater emphasis on long-term strategic issues. It would at least provide less excuse for neglecting issues that fall between the cracks in departmental mandates, and reduce any overlap in research efforts. By providing one focus for federal water research, consolidation might also make it easier to coordinate research with provincial management needs. But all vehicles to achieve consolidation – whether a new department or agency, crown corporation, or private water research centre – have substantial problems that could outweigh potential benefits. Any consolidation within government could narrow the perspective on water, whereas the development of any arm's-length organization could widen the gap between research and policy. Indeed, it might well be argued that instead of consolidation, water research in Canada requires more voices and more participants.

Equally, a simple, direct transfer of research funding to the universities cannot be expected to provide the necessary research to meet policy needs. Disciplinary boundaries and bureaucratic rigidities thwart long-term strategic research. Where universities have achieved success as centres of water research, as at INRS-Eau (Université du Québec), Westwater Research Centre (U.B.C.), the Institute for Environmental Studies (Toronto), and the Institute for Groundwater Research (Waterloo), it has been in spite of, not because of, the basic structure of the university system. Nor are the links between university research and government policy needs easily forged.

Much could be achieved without any new policies; what is needed, particularly in the federal government, is a fuller exploitation of the existing rules and regulations affecting scientists and research managers. Stronger links between university and government scientists – secondments and sabbaticals – should be encouraged. Joint research projects could be fostered using the existing systems of contract research. The Interdepartmental Committee on Water could be strengthened to ensure that work that crosses departmental mandates is done and research gaps are filled. And scientists could be better funded to visit laboratories whether run by their own department or another, to meet with their peers in universities, and to attend conferences. These actions would help promote a stronger water research community, stimulate research, and promote interdisciplinary work. All this could be achieved if there was the political will. But we need to go further.

To encourage long-term strategic research that crosses traditional disciplinary boundaries, is responsive to national policy needs, and not constrained by any narrow interpretation of the operational requirements of individual federal departments:

4. **Environment Canada should take joint action with the departments of Fisheries and Oceans, Agriculture, Health and Welfare, and all other federal departments involved in water research and should seek funding of $40 million a year to establish associate laboratories. These laboratories should be at least 50 per cent self-funding within 5 years.**

Each laboratory should be attached to one university and should include at least five scientists to ensure the necessary critical mass. Where possible the location of the laboratory should be linked to existing centres of expertise, but it may be necessary to initiate new centres to ensure all regional interests are met. Federal departments should be encouraged to manage and fund the laboratories on a joint basis. The private sector should be encouraged to participate in the research program; examples of participation might include personnel exchanges, funding, and involvement in research design. Government scientists should work in the laboratories for a fixed term; their departments should pay their regular salaries and benefits and cover their research costs. Government funding to academics in the laboratories should be determined by the extent to which their research meets long-term policy needs.

Strengthening research experience

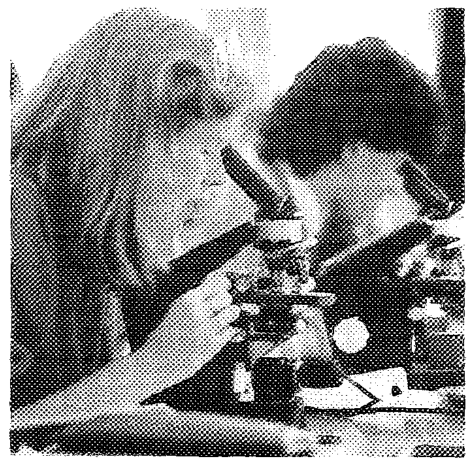
The capacity of water scientists to deal with future problems may be seriously reduced by the inadequacy of their basic training. Water science has failed to emerge as a university discipline in its own right and remains an appendage of other disciplines including geography, limnology, and civil engineering. Water science is generally unavailable as the focus of an undergraduate education. The reluctance of university scientists involved in water science to break away from their parent disciplines and come together as a unit or department promotes narrowness within water science. For example, an engineer may graduate and obtain employment in water science with no knowledge of biology; equally, a biologist may obtain employment in water science with no knowledge of engineering. Such inadequacies in basic training are particularly unsatisfactory in view of the complexity of emerging water problems.

To make research training in water science more interdisciplinary, university scientists must be encouraged to come together as research groups, to develop joint research projects, and to involve students in their work. One successful approach to resolving a similar problem is the Northern Scientific Training Program (NSTP) managed by the Department of Indian and Northern Affairs to foster research expertise in science and technology in the North.[43]

The NSTP helps Canadian universities to give students a training that includes professional experience in the North and encourages their commitment to northern studies. The aim is to increase the number of graduates who have specialized in some aspect of northern studies and who have northern research experience. Under the NSTP universities are encouraged to form interdisciplinary focal points for northern studies and are given financial assistance for students to help offset the cost of field research. Funding is allocated as a block grant to promote cooperation at the university level.

A program comparable to that for northern studies is required to increase the availability of personnel with appropriate research experience in water science and to encourage the development of university foci for interdisciplinary work in water science. To this end:

5. **Environment Canada should take joint action with all federal departments involved in water research to establish a water science research training program funded at a level of $1 million per annum.**



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Involving public interest groups

It has been powerfully argued with respect to the report of the Brundtland Commission that solutions to the world's environmental problems cannot be achieved by relying solely on existing government structures and that new mechanisms are needed to harness the knowledge and enthusiasm of the informal, nongovernmental sector.[44]

In Europe environmental interest groups commonly play an influential role in setting the agenda for water research. Government scientists monitor the interests and activities of the major environmental groups as a way to "keep ahead of the game." Many scientists are also active members of these groups and work to ensure that the issues raised by the groups are soundly based in science. Their participation is encouraged by their employers.

Many of the environmental interest groups and industrial associations in Canada have a particular interest in water issues. The fuller involvement of these groups in shaping the research and political agenda is necessary if Canada is to develop strategies to overcome current and future environmental problems and muster the political will for their implementation. Canada is already wrestling with a whole series of issues concerning water use, water science, and a range of international, national, and regional water programs. Just at the federal level, current initiatives such as the Freshwater Fisheries Policy, a federal water policy, the Drinking Water Standards Act, the Environmental Protection Act, the Arctic Marine Conservation Strategy, and a host of Native claims issues all require sustained and informed public participation and response.

Involving public interest groups, such as Pollution Probe, to best effect requires an informed public. In this, all scientists can play an important role. In particular, however, government scientists should be encouraged by their employers to participate in these groups and to voice their opinions in public as informed citizens. To date, there is little evidence that such encouragement is forthcoming. In only one area – agriculture – has the responsibility of scientists to work closely with public interest groups to ensure that research findings are widely understood and applied to maximum effect been fully accepted. In Alberta, the responsibility of agricultural scientists to communicate their research findings to the farm community is specified in provincial employment contracts. Such an approach must be extended to environmental issues. To this end:

6. **Environment Canada, the Department of Fisheries and Oceans and other federal and provincial departments and agencies involved in water research should recognize the right and responsibility of their scientists to participate in public interest groups. This right and responsibility should be included in all employment contracts.**

Public interest groups should also be invited to participate in the assessment of water research programs funded by governments. Recently, the federal government established external advisory boards for federal water research centres so that research could be better matched to policy needs. The Science Council supports the principle of such boards. But their value is at least partly determined by the criteria for membership. Some boards exclude members from other federal departments although these departments are often the main users of research results. No board has specifically recognized the need for representatives from public interest groups.

As an initial step to increase the participation of public interest groups in water research and policy development:

7. **Environment Canada and the Department of Fisheries and Oceans should ensure that public interest groups are represented on the external advisory boards of federal water research centres.**

Enlightened self-interest

CIDA is the dominant federal agency employing Canadian expertise abroad. But the Department of External Affairs, the International Development Research Centre, Environment Canada, and other departments and agencies are also approached to provide assistance to other countries and international bodies. Individuals are seconded – usually on a short-term basis (2 to 3 weeks) unless special arrangements can be made. There is little opportunity to offer a comprehensive package of expertise. Assistance is usually in response to a specific request, and in recent years of government "downsizing" even the short-term secondment of individual scientists has become difficult to secure. And when a department or agency wishes to meet a request it is not always easy to identify the necessary personnel.

CIDA has now gone some way to establish the range of expertise available. A recent report includes estimates of personnel in the Canadian water industry, grouped by economic sector, topic area, and region.[45] Compilation of these data was difficult. Over 100 000 individuals were identified, including those in more than 22 federal departments and agencies and over 200 private consulting firms. Data on personnel working in the water sector in nongovernment organizations are not readily available and were not included. The next step for CIDA is to establish precisely who is available for development work, their area of expertise, and their contact address. Only then can CIDA fully employ Canada's water expertise in its development projects.

Other countries have developed a more aggressive stance in deploying their indigenous expertise to meet global needs. Britain, Sweden, and Denmark, for example, all have active, profitable consultancy services that use government scientists. Privatization in Britain has strengthened this role and the Water Research Centre has recently opened an office in Philadelphia to help secure contracts in the United States. It recently bid on contracts in Ontario. Certainly, many countries see overseas experience as a vital element in attracting and maintaining top-flight personnel.

An international consultancy role for government scientists would meet many needs. It offers a source of revenue and a practical means of contributing to the resolution of global water issues. It presents an invaluable source of experience and training for Canadians and a shop window for Canadian water science to the world.

8. **The Department of Industry, Science and Technology should recognize the existence of an environmental technology and services sector. The department should take a lead agency role and establish a directorate to work with private enterprise in developing a strategy for this sector.**

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Applied science

The development and application of new and improved technologies can reduce water needs and demands, and prevent or relieve pollution. Technologies that we already possess or are developing could provide a means to avoid the problems of the past. Both the *Federal Water Policy* and the *Report of the National Task Force on Environment and Economy* recognize this fact. The development and sale of such technologies also presents an enormous opportunity to generate income from Canada's international reputation for leadership in water-use management and water science.[46]

The Canadian market for manufactured equipment in the water resources sector is over $400 million per annum. It is expected to grow to at least $600 million by 1992. Projected investment elsewhere in the world during the same period totals many billions. Yet this increase in demand is occurring at a time when Canada's position in commercial technology is weak; Canadian firms hold only 55 per cent of the domestic market and exports may total as little as $30 million per year.

Despite attempts by Environment Canada, the Department of Industry, Science and Technology, and provincial bodies in Ontario and Quebec to gather information, there is a lack of sound data covering most aspects of the water resources industry. The low priority of this industry in the planning process is reflected in the lack of an effective classification system for the water resources industry; Statistics Canada has no single standard industrial classification code for the products manufactured by this industry.

What we have in Canada is a small number of individual firms with disparate roles and little sense of common identity as an industry. Approximately 390 companies manufacture, sell, or distribute equipment to reduce water pollution. An additional 36 companies sell treatment chemicals. A few companies provide both equipment and chemicals. Out of all these firms, probably fewer than 20 per cent manufacture products in Canada; of those that do only about 30 control any unique or proprietary technology.

Few firms carry out research on water and wastewater treatment. In 1984 the industry invested only $2.4 million of its own funds on research. This represents only about 0.6 per cent of the value of annual product sales. The remaining $5.6 million invested in research was spread among several different federal departments, a few provincial and municipal governments, and universities. Yet despite a weak industrial structure and a low level of investment in research, Canada could still establish manufacturing industries for clean water technologies and capture more of the burgeoning domestic and international market.

To be in the forefront of the water industry during the next few decades the Canadian industry must exploit the most up-to-date research in areas including reverse osmosis, adsorption, advanced separations, biotechnology, plant automation software, and membrane technology. Canadian researchers are actively pursuing most of these areas, but there is little evidence of the necessary facilities to transfer the knowledge gained to the manufacturing sector.

The example of membrane technology illustrates the general case. A synthetic membrane material that permits membrane desalinization systems to be economically viable was discovered in the early 1960s. The inventor was Dr S. Sourirajan at the University of California in Los Angeles. Shortly afterwards he joined the National Research Council in Ottawa where he built a strong technical group in membrane science. Although their work continues and Canada remains near the forefront in membrane science, commercial production is dominated by the United States and Japan. Canada is an importer of commercial membrane products. Instead of being a front runner, Canada is now left in a "catch-up" position.

The opportunity for Canadian science and technology is enormous and warrants a close partnership between governments and the private sector to encourage and support research on water technology, to ensure the transfer of results to industry, and to support the commercial development and marketing of water technology to meet Canadian and world needs. Such a view is echoed in the *Federal Water Policy* and is supported by the Science Council's own work for this report. What is now urgently needed is a development plan to consolidate efforts by interested federal and provincial departments and agencies, and individual firms. This requires a meeting of all the players. To this end:

9. **The Minister for Industry, Science and Technology should task the Science Council to hold a workshop to advise on a strategy to develop a Canadian water resources industry.**

Such a workshop should:

- identify the urgent problems in water purity and availability;
- identify the gaps in water science;
- identify existing technologies and their markets;
- suggest future technologies and their markets;
- clarify policy needs for industrial development.

Even if politically acceptable, traditional solutions to problems of water supply will be difficult and costly to implement. A change in water-use practices is inescapable in the face of evidence of increasing ecological damage, the cost of maintaining the existing supply system, and the need for careful husbandry of resources to ensure a sustainable economy.

Science and technology are powerful tools to help secure our goals. This report supports the Brundtland Commission, the Canadian Council of Resource and Environment Ministers, and the *Federal Water Policy* in the need for a radically new attitude toward our environment – and water in particular.

But the chronic, complex, and global problems that face our water resources are quite different from the relatively simple, acute, localized problems of the past. Their resolution requires a national commitment to align the actors in a common purpose and a number of important changes to realign our resources for science and technology. In brief:

- The federal government must implement its commitment to Canadian leadership in water science.
- Institutional changes must be made to ensure that the necessary research is put in place now to tackle future problems.
- The fragmented water community must be encouraged to come together in a concerted effort to resolve water use problems.
- Canada must capitalize on its reputation and expertise in water science to meet global needs.
- The results of water research must be commercialized to promote economic growth in a healthy environment.

The recommendations in this report support these imperatives. In presenting them, the Council recognizes that many of the threats to water quality and availability are essentially irreversible. Moreover, for many of the key water issues facing Canadians there remain profound scientific uncertainties. There remains a continuing challenge to develop policy objectives that can encompass uncertainty, especially for those water issues for which the consequences of policy inaction are too great.

Summary of recommendations

1. **Environment Canada should publish its strategic interests and long-term research plans in water science.**

2. **Environment Canada should:**
   a) **appoint an assistant deputy minister for science;**
   b) **replace the Inland Waters Directorate with a water service;**
   c) **appoint a director general of water research.**

3. **Environment Canada and the Department of Fisheries and Oceans should develop a clear policy to identify and train reputable scientists as science managers.**

4. **Environment Canada should take joint action with the departments of Fisheries and Oceans, Agriculture, Health and Welfare, and all other federal departments involved in water research and should seek funding of $40 million a year to establish associate laboratories. These laboratories should be at least 50 per cent self-funding within 5 years.**

5. **Environment Canada should take joint action with all federal departments involved in water research to establish a water science research training program funded at a level of $1 million per annum.**

6. **Environment Canada, the Department of Fisheries and Oceans and other federal and provincial departments and agencies involved in water research should recognize the right and responsibility of their scientists to participate in public interest groups. This right and responsibility should be included in all employment contracts.**

7. **Environment Canada and the Department of Fisheries and Oceans should ensure that public interest groups are represented on the external advisory boards of federal water research centres.**

8. **The Department of Industry, Science and Technology should recognize the existence of an environmental technology and services sector. The department should take a lead agency role and establish a directorate to work with private enterprise in developing a strategy for this sector.**

9. **The Minister for Industry, Science and Technology should task the Science Council to hold a workshop to advise on a strategy to develop a Canadian water resources industry.**

Notes

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7. See, A.H. Laycock, "The Amount of Canadian Water and its Distribution," in *Canadian Aquatic Resources*, M.C. Healy and R.R. Wallace (ed.), Canadian Bulletin of Fisheries and Aquatic Sciences 215 (Ottawa: Supply and Services Canada, 1987), 13-42.
8. See, *The Evening Telegram*, 22 August; 6 October; and 21 October 1987.
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14. D.W. Schindler (Freshwater Institute, Winnipeg), personal communication, 1987.
15. See, P. Stokes, op. cit. (note 12); and House of Commons Sub-Committee on Acid Rain, *Still Waters: The Chilling Reality of Acid Rain* (Ottawa: Supply and Services Canada, 1981).
16. J.A. Cherry, "Groundwater Occurrence and Contamination in Canada," in *Canadian Aquatic Resources*, op. cit. (note 7), 387-426.
17. Great Lakes Water Quality Board, *Report on Great Lakes Water Quality*, report to the International Joint Commission at the Biennial Meeting on Great Lakes Water Quality (Windsor, 1987).
18. For a full review of the impact of toxics on wildlife, see M. Gilbertson, "Effects on Fish and Wildlife Populations," unpublished paper, 1987; and P. Beland et al., *International Association for Great Lakes Research 30th Conference, Program and Abstracts*, 30th Conference on Great Lakes Research, University of Michigan, Ann Arbor, 11-14 May 1987, A-4.
19. See, A.H. Laycock, "The Amount of Canadian Water and Its Distribution," 13-42, and D. Tate, "Current and Projected Water Use in Canada 1981-2011," 43-69, in *Canadian Aquatic Resources*, op. cit. (note 7); John Lewis, *Climatic Change and its Effects on Water Resources for Canada: A Review*, unpublished paper prepared for the Science Council of Canada, 1987; and World Meteorological Organization, *Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts* (Geneva, 1986).
20. See, The World Commission on Environment and Development, op. cit. (note 1); and the International Union for Conservation, op. cit. (note 1).
21. See, J.P. Bruce, *The Organization of Water Science in Canada*, unpublished paper prepared for the Science Council of Canada, 1986.
22. These issues are drawn from views of participants at a national workshop held by the Science Council entitled "Changing Times, Changing Needs; Managing Water Use for the 21st Century," held in Hull, Quebec, 4-5 November 1986; and from J.P. Bruce, op. cit. (note 21), K.S. Davar, *Research Needs: A National Perspective*, unpublished paper prepared for the Science Council of Canada, 1986; and E.D. Ongley, *Water Research to 2020: Issues and Opportunities*, unpublished paper prepared for the Science Council of Canada, 1986.
23. See, for example, P.H. Pearse, et. al., op. cit. (note 10); Gore and Storrie Ltd., *Review of Current Systems in NHRI and NWRI and Alternative Systems for Water Management Research*, unpublished paper prepared for Environment Canada, 1985; and J.P. Bruce and D.E.L. Maasland, *Water Resources Research in Canada*, Science Secretariat, Privy Council Office, Special Study No. 5 (Ottawa: Queen's Printer, 1969).
24. B. Mitchell and E. McBean, "Water Resources Research in Canada: Issues and Opportunities," Inquiry on Federal Water Policy, Research Paper 16, 1985.
25. This is the conclusion drawn from field survey. But evidence of an ageing science population and concern over lack of openings for young scientists is

supported by data from individual federal departments and has been recorded in several reports; see, for example, Gore and Storrie Ltd., op. cit. (note 23).

26. See, J.P. Bruce, op. cit. (note 21).
27. Canada, International Joint Commission, *Agreement* (Windsor, 1978), 19.
28. M. Falkenmark and G. Lindh, "How Can We Cope with the Water Resources Situation by the Year 2015," *Ambio,* 3, 3-4 (1974), 116-117, 116.
29. The World Commission on Environment and Development, op. cit. (note 1), 151.
30. Data provided by the Water Sector, Canadian International Development Agency.
31. The excellence of Canada's water research is attested to by the international reputation of its laboratories and the standing of individual scientists. Water research groups at federal institutions, such as the National Water Research Institute (Burlington) and the Freshwater Institute (Winnipeg), and at universities including McMaster, Waterloo, Toronto, New Brunswick, British Columbia, and the Université du Québec (Ste-Foy), are all recognized as world leaders in such disparate areas as wastewater technologies, freshwater ecology, groundwater hydrology, and water management systems. Individual Canadians, many with particular expertise in water science and policy development, shoulder international responsibilities for resolving environmental issues – J.P. Bruce (World Meteorological Organization); L.M. Dickie (International Maritime Organization); J. MacNeill (Organization for Economic Cooperation and Development, and the United Nations); and C.S. Holling (International Institute for Applied Systems Analysis) are four examples.
32. Zenon, op. cit. (note 9), 16, 43.
33. Zenon Environmental Inc., corporate data.
34. See, Zenon, op. cit. (note 9); and J.P. Bruce, op. cit. (note 21).
35. Maurice Strong, "Managing our Planet's Future," *Policy Options* (July 1987), 3-10.
36. See, for example, P.H. Pearse, et al., op. cit. (note 10); D.F.W. Pollard and M.R. McKechnie, *World Conservation Strategy – Canada: A Report on Achievements in Conservation* (Ottawa: Environment Canada, 1986); and Royal Commission on the Economic Union and Development Prospects for Canada, op. cit. (note 2).
37. This point is effectively developed by G. Stewart, "Gaining Perspective on Environmental Issues: A Fresh Look at Familiar Problems," *Focus* 10, 1 (1985), 14-16.
38. Workshops were held in Halifax, Montreal, Toronto, Regina, Vancouver, and Yellowknife during October and November 1987.
39. See, B. Mitchell and E. McBean, op. cit. (note 24), 34.
40. See, for example, Ministry of State for Science and Technology, *Report of the Task Force on Federal Policies and Programs for Technology Development* (Ottawa: Supply and Services Canada, 1984); and Gore and Storrie Ltd., op. cit. (note 23).
41. See, J.A. Cherry, S. Feenstra, R.V. Nicholson, *Groundwater in Canada,* contract report for the Science Council of Canada, 1988, 40.
42. See, ibid.
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44. A.D. Crerar, "Follow Through on Brundtland," *Policy Options* 8, 7 (1987), 14-17.
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46. For a full discussion of the potential of Canadian water science as a basis for new industries, see Zenon, op. cit. (note 9).

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2. Canadian Encyclopedia (Edmonton: Hurtig, 1985), 966.
3. Environment Canada, *Canada Water Yearbook 1985* (Ottawa, 1986), 77.
4. P.H. Pearse, et al., op. cit. (note 1), 44.
5. J.C. Day, "Canadian Interbasin Diversions," Inquiry on Federal Water Policy, Research Paper 6 (Ottawa, 1985), 5.
6. P.H. Pearse, et al., op. cit. (note 1), 55.
7. Organization for Economic Cooperation and Development, *O.E.C.D. Environmental Data: Compendium 1987* (Paris: O.E.C.D., 1987), 53.

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3. J.A. Cherry, "Groundwater Occurrence and Contamination in Canada," in *Canadian Aquatic Resources,* M.C. Healey and R.R. Wallace (ed.) (Ottawa: Fisheries and Oceans Canada, 1987), 387.
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