Canada On **Tap**

The Environmental Implications of Water Exports

A Report Commissioned by
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Introduction

Research in Canada and elsewhere has identified numerous environmental concerns associated with inter-basin water diversions. It is on the strength of these concerns that, since 1987, the federal government has maintained a policy of opposition to large-scale water exports. (Environment Canada 1987) Yet, there remain serious doubts about the federal government's commitment to this policy. Recent media reports, for example, have indicated that Prime Minister Jean Chretien "has privately supported the idea" of diverting water from James Bay to the United States. (*Ottawa Citizen* 2001)

The possibility of smaller-scale water exports is also a concern. During the past decade, proposals have been made for exporting water by tanker from British Columbia, Ontario, Quebec and Newfoundland. In March 2001, Newfoundland Premier Roger Grimes announced his intention to allow the annual export of billions of gallons of water from Gisborne Lake. Although this project has been shelved, it and similar water-export schemes are likely to be revisited. Smaller- scale water-export proposals are predicated on the assumption that removing water by tanker from lakes or rivers would have negligible environmental consequences. As neither federal nor provincial authorities have addressed this question adequately, this paper provides a summary of some of the relevant scientific research.

Factors Motivating Scientific Study

Until quite recently, the ecological consequences of hydrological alterations caused relatively little concern among scientists. In general, the benefits of human disruption, either of the magnitude or of the timing of natural river flows, were presumed to outweigh any costs by far. During the past fifty years, however, the scale and extent of such disruptions have reached levels that have caused growing concern among the scientific community. Since the 1950s, for example, approximately 10 000 km^3 of the world's water — about five times the volume of water in all the world's rivers — have been impounded in reservoirs. (Rosenberg et al. 2000)

Much of this concern has focused on the environmental effects of large dams (15 m or higher), of which there are more than 42 000 worldwide. Large dams "have proven to be primary destroyers of aquatic habitat, contributing substantially to the destruction of fisheries, the extinction of species, an the overall loss of the ecosystem services on which the human economy depends." (Postel 1998)

Other forms of hydrological disruption, including water diversion, exploitation of groundwater aquifers, water withdrawals, and stream canalization, are also receiving increased attention from scientists. The prestigious journal, *Bioscience,* recently devoted a special issue to an investigation of the environmental impacts of these disruptions. It concluded that "ubiquitous hydrological alterations ... are producing global-scale effects on the environment." (Rosenberg et al. 2000)

Given the most recent scientific scrutiny, it is becoming increasingly difficult to be complacent about further alterations to hydrological systems. For example, the maintenance of natural flow regimes is now understood to be fundamental to the integrity of aquatic-ecosystem health in streams, rivers, estuaries, and even certain marine ecosystems: "Growing understanding of the ecological impacts of flow alteration has led to a shift toward an appreciation of the merits of free-flowing rivers." (Poff et al. 1997)

In the United States, almost every river and major stream has been regulated for purposes of transportation, water supply, flood control, agriculture, and power generation. This massive alteration of fresh-water ecosystems has elicited "widespread concern for conservation and restoration of healthy river ecosystems among scientists and the lay public alike." (Poff et al. 1997)

In Canada, the most significant factor motivating research on the impacts of altered stream flow has been the regulation of rivers by hydro-electric facilities, mostly on the Precambrian shield. In developing its hydro-electric facilities, Canada has dammed and diverted more water between river basins than has any other country. This leadership has been matched by a large body of excellent scientific study on the wider ecological effects of such hydrological disruptions. (Rosenberg et al. 1987; Rosenberg et al. 1995; Day and Quinn 1992) Consideration of the ecological importance of water levels and stream flow and of the significance of water removals from fresh-water ecosystems has also been prompted by concerns about exporting water from British Columbia, the Great Lakes, and elsewhere in Canada. (Bocking 1987; International Joint Commission 1999; International Joint Commission 2000; Farid, Jackson and Clark 1997)

Large- and Small-Scale Water Exports: Environmental Consequences

Proponents of water exports tend to dismiss potential environmental consequences of their proposals. Some are fond of claiming that Canada has "surplus" water that is being "wasted" by allowing it to run into the sea. (Bourassa 1985) Others disassociate water from the environment, asserting that Canadians enjoy a disproportionate share of the world's water, as if it were an isolable commodity. (Paley 1992) These notions are contradicted by a growing body of scientific research on the structure and function of aquatic ecosystems. Although the environmental impacts of water export would vary with the type of project involved, all water exporting raises potentially serious environmental problems.

Two main types of large-scale water export have been proposed in Canada: the diversion of rivers through channels or pipelines to markets in the United States; and the shipping of water to international markets via supertanker.

Based on Canadian experience, a partial list of the environmental consequences of large-scale impoundments and diversions of water includes the following:[1]

- Moderate earth-quakes and climate change in the vicinity of large impoundments;
- Reduced biological productivity in lakes and rivers due to erosion and increased turbidity;
- Loss of forest, agricultural land, and wildlife habitat, due to flooding;
- Destruction of fisheries habitat;
- Destruction of wetlands and freshwater deltas;
- Changes in water temperature and water quality;
- The release of methyl mercury into the water column, and its bioaccumulation in fish to levels that can make them unsuitable for human consumption;
- Alteration of stream flow, which affects such biological processes as salmon spawning;
- The transfer of fish, plants, parasites, bacteria, and viruses (exotic aquatic species) from one drainage basin to another, which can wreak havoc on ecosystems;
- Reduced stream flow in affected estuarine and marine environments, which may affect biological production in these important ecosystems; and
- Greatly increased emissions of greenhouse gases (CO_2 and methane) from reservoir surfaces. (St Louis et al. 2000; Rudd 1993)

Given the serious environmental implications of water export by river diversion, the Canadian consensus is that it poses an unacceptable risk to the environment. When he introduced the *Canada Water*

[1] All except the last item are discussed in Day and Quinn (1992). For a comprehensive review of environmental impacts of water impoundments in northern Canada see *Canadian Journal of Fisheries and Aquatic Science* (1984) as well as Rosenberg, Bodaly, Hecky and Newbury (1987).

Protection Act in the House of Commons in 1988, then Minister of the Environment Tom McMillan cited the "enormous harm to both the environment and society" that would be inflicted by these projects. (Cited in Day and Quinn 1992) Had it been passed, the Act would have prohibited large-scale water exports by diversion.

The environmental consequences of water export by tanker would occur on a smaller scale. Nevertheless these consequences would be considerable, given their potential cumulative effects. Exporting by tanker would involve withdrawing water from a lake or stream; however, we know that, after a certain point, the removal of water from a lake or stream constitutes a serious environmental problem. In British Columbia, where there have been many proposals to export water by tanker, the provincial government has considered the following questions:

- Most environmental experts agree that small amounts of water (less than 5% of the flow) could be extracted from a coastal stream without ecological damage. At what point could water removal result in ecosystem damage?
- Could foreign biota be introduced by the dumping of ballast water off the B.C. coast as a result of increased tanker traffic, and could accidents and minor oil spills be a possibility?
- What impact might the sight of large ocean-going tankers have on B.C.'s growing wilderness-tourism industry? and
- Could a change in salinity resulting from withdrawals of coastal-stream waters have an impact on salmon reproduction? (British Columbia Ministry of Environment, Lands and Parks 1992)

These were among the concerns that prompted the government of British Columbia to pass *The British Columbia Water Protection Act* in 1995, prohibiting all forms of water export in containers with a capacity greater than 20 liters.

Similar questions have been raised with regard to export-by-tanker proposals in other parts of Canada. Of primary concern are the possible *cumulative* effects of water removals. With respect to a proposal to export water by tanker from Lake Superior, Dr. Pierre Beland, an aquatic scientist and one of three Canadian commissioners on the International Joint Commission has commented: "As with many other things, you start taking a little here and a little there and eventually you find out that you're taking a lot of water... If you take enough, you end up lowering the level of the Great Lakes." (The Globe and Mail 1998)

The Importance of the Natural Flow Regime

Proposals for large-scale diversions of water from Canada to the United States have been in existence for many years. Although many still argue that such schemes are ecologically benign and that water left running to the sea is wasted, we now have sufficient experience with regulated rivers to know that there are always ecological consequences, sometimes severe consequences, from altering river flows. (Healey 1992)

Scientific research in recent years has increasingly underscored the links between the natural flow regime of rivers and the ecological health of the regions they support. Numerous studies have pointed to "the fundamental scientific principle that the integrity of flowing water systems depends largely on their natural dynamic character" and state that "stream flow quantity and timing are critical components for water supply, water quality, and the ecological integrity of river systems." (Poff et al. 1997) Merely satisfying basic water-quality objectives and minimum flow rates is not enough to maintain healthy aquatic ecosystems.

The flow of a river or stream has been likened to a symphony:

> ...with movements for each season. The symphonies or patterns of flow differ profoundly from region to region. In an Indian river the peak flow may be during the monsoon, in an Arctic river during snowmelt or ice break-up time. The expansion and contraction of the river controls living space and access to particular habitats. It is to these profound seasonal patterns that the species in a drainage basin adapt over thousands of years. It is from such events that life in the river takes its cue to migrate, court, spawn, or initiate other behavioral or physiological changes. The rhythm of the river is thus tied intimately to the life of river species. (McAllister et al. 1999)

In north-temperate rivers, including most Canadian rivers, the seasonal pattern of flows is an important influence on downstream deltaic, estuarine, and coastal areas. “The attitude that hydrological resources are wasted unless they are harnessed for industrial and domestic use is commonplace ... [however] ... modification of this natural run-off by inter-basin water diversion and water storage for power production can have severe environmental impacts.” (Rosenberg, Bodaly and Usher 1995)

For example, the effects of altering the flow of the Peace River in northern Alberta have provided one of many sharp object lessons for Canadians. Following construction of the W.A.C. Bennett Dam on the upper Peace River in 1967, normal spring flows were severely reduced, depriving the Peace-Athabasca Delta of its spring flood. The Delta landscape changed dramatically, with severe impacts on the flora and fauna of the entire region. (Prowse et al. 1996)

Merely reducing the flow of a river by damming or withdrawing water can have considerable impact on riverine ecosystems. An international study of the effects of dams, McAllister et al. (1999), pointed out that a reduction in the volume of water flowing in rivers can have negative consequences on biodiversity. In the channels of rivers and streams, larger aquatic species require minimum flows in order to navigate and feed. In Canada, some larger species of fish can be particularly susceptible to reduced flows. " Reduced flows mean reduction of area of habitat. Habitat reduction may mean simply smaller populations or reduced growth rates, or it may mean, where populations are already at risk, extirpation or extinction." (McAllister et al. 1999)

It is now beyond scientific dispute that the natural flow regime of a river or stream plays a critical role in sustaining biodiversity and ecosystem integrity, both in the body of water itself and in parts of the watersheds through which it runs. Growing awareness of the ecological impacts of flow alteration has led to an appreciation of the merits of free-flowing rivers, to the decommissioning of a growing number of dams, and to hydrological management techniques that attempt to mimic natural flow regimes. (World Commission on Dams 2000)

The importance of the natural flow regime is of obvious relevance to the water-export debate. It suggests that the withdrawal of even small amounts of water could have significant ecological consequences:

> No matter how vast the water system, it is the first removal, water taken "off the top," that will have the greatest perturbing effect upon it ... If the first removals are by far the most deleterious ones, those water-transfer proposals that speak in terms of withdrawing only small fractions of Canada's water supply, or of depriving a given system of only a limited percentage of its flow, are ignoring the most important aspects of a river's function as a living system and as a commercial and social asset in its present condition.
> (Bocking 1987)

Scientific awareness of the importance of maintaining natural flow regimes is beginning to be reflected in policy. In its final report to the governments of Canada and the United States on water removals and diversions from the Great Lakes, the International Joint Commission concluded:

> If all interests in the Basin are considered, there is never a "surplus" of water in the Great Lakes system. Every drop of water has several potential uses, and trade-offs must be made when, through human intervention, waters are removed from the system. Environmental interests, for example, require fluctuations between high and low levels to preserve diversity. Seemingly "wasted," the infrequent very high waters do, in fact, serve a purpose by inundating less frequently wetted areas and renewing habitat for their biotic occupants. Major outflows from the Great Lakes provide needed freshwater input to fisheries as far away as the Gulf of Maine. (International Joint Commission 2000)

The Natural Flow Regime: Extended Impacts on Estuarine and Marine Ecosystems

Scientists have become increasingly aware of the importance of fresh-water outflow in estuarine and nearshore marine ecosystems. (Neu 1976; Neu 1982; Rosengurt 1999) There is growing evidence that the natural flow regime of a river is crucial to the dynamics and productivity of marine ecosystems far from the river's mouth. As Michael Healey of British Columbia's Westwater Research Centre puts it, "Rivers simply do not end at the sea." (Healey, 1992)

One Canadian researcher whose work is particularly relevant to this discussion is Kenneth Drinkwater of DFO's Bedford

Institute of Oceanography in Nova Scotia. He has described the "profound effect river input to the oceans has on the physical, chemical and biological processes in coastal waters":

> Freshwater induces important circulation patterns, effects vertical stability, modifies mixing and exchange processes, and influences nutrients and primary production. Particular organic and inorganic compounds, as well as organisms, carried seaward in rivers, are incorporated into food chains. Physical and biological characteristics of coastal waters reflect the seasonal and inter-annual variability of the incoming rivers. This includes the fisheries as inter-annual fluctuations in the yields of certain commercial fish species are found to co-vary with runoff. These freshwater effects are not limited to an area close to the river mouth but can extend over a thousand kilometers in the case of large rivers. (Drinkwater 1986)

In a review of the effects of river regulation on fish and marine coastal invertebrates, Drinkwater and Frank (1994) strongly suggest "a linkage between fresh-water flow and the production of certain species of fish and shellfish." Drawing examples from Canada and elsewhere, they conclude "that massive reductions in freshwater discharge can alter, and in some cases destroy, the existing ecosystem in the adjacent coastal region." Nor do they dismiss the potential impacts of smaller removals of fresh water. Among the potential causes of alterations in fresh-water flows, they include those cases "where water is removed for industrial, residential or agricultural purposes, or where extensive evaporation occurs from the reservoirs."

There are no precise quantitative measures of the amount of water that may be removed from a river system without causing environmental damage to estuarine and marine ecosystems. Rozengurt and Haydock (1981) concluded that no more than 25-30% of the historical river flow to an estuary can be diverted or removed without disastrous ecological consequences. The effects of smaller diversions or removals are less well understood; however, the threshold for concern appears to be lowering with the advancement of scientific knowledge.

McAllister et al. (1999) note that at the mouth of a river, decreased discharge of fresh water can result in an increase in salinity; this, in turn, can affect species inhabiting deltas, estuaries, and near-shore marine areas. Reduced flows can also affect the discharge of nutrients from the mouths of rivers, and “entrainment,” by which the outflow of water from rivers results in the shoreward movement of deep, nutrient-rich waters. This process, which mixes waters of differing temperatures, nutrient compositions, and levels of salinity, is extremely important to the biological productivity of estuarine and marine ecosystems off the mouths of rivers.

Canadian research focused on the importance of fresh-water flows to estuarine and marine ecosystems has been carried out on the Pacific coast, in the Hudson Bay region, and in the Gulf of St. Lawrence. Harding (1992) sites numerous studies showing a relationship between fish populations and river discharge in the Gulf of St. Lawrence from the 1940s to the 1970s. For example, Bugden et al. (1982) found a strong correlation between river runoff and cod recruitment in the Gulf, between 1957 and 1976.

Harding also summarizes the effects of altered flow regimes on biological production in James Bay and Hudson Bay, where hydro-electric development has changed the seasonal pattern of freshwater runoff. There, the reduction in the springtime transfer of warmer waters into James Bay has an effect on the rate of ice breakup. Citing Morin et al. (1980) Harding suggests this “may be enough to delay the phytoplankton bloom and thereby shorten an already brief growing season for larval fishes and benthic invertebrates.” Researchers have shown that altered fresh-water runoff has had a considerable effect on the fish-species composition at the mouths of affected rivers running into James Bay. Others have hypothesized that the regulation of rivers in the Hudson Bay area, which reduces springtime stream flow may affect northern cod populations along the Labrador coast.

The Canadian aquatic scientist, Michael Healey, has examined the importance of fresh-water inflows to coastal ecosystems. He notes that the understanding of possible environmental effects of altering river flow is quite high with regard to the river itself; as well, the appreciation of the importance to estuaries of maintaining natural flow regimes of rivers is increasing. However, the role of fresh-water inflows in the circulation and biological productivity of marine ecosystems hundreds and even thousands of miles from a river’s mouth is “hardly appreciated at all … Yet the consequences of altering these processes could be the most biologically significant.” (Healey 1992)

Healey has studied the impact of fresh-water flows in Hudson Bay and farther seaward off Newfoundland as well as in coastal currents off Vancouver Island. He concludes that man-made reductions or disruptions in flows — even on a relatively small scale — could have significant effects on coastal fisheries: “Attempts to demonstrate unequivocal linkages between modest man made alterations to freshwater inflow and oceanic fisheries have not yet been successful. Prudence, however, dictates that we should not be complacent about the existence of such effects.”

Fresh water Removals: What are the

Environmental Consequences?

It is impossible to state with certainty at what precise point the removal of fresh water from a river or lake may cause environmental damage to ecosystems. Part of the difficulty lies in defining exactly what constitutes environmental damage; as well, ecosystems respond differently to such stresses as water removal.

West Coast

French and Chambers (1997) have examined the consequences of reduced flows in the Nechako River as a result of dams and diversions created in the 1950s, when approximately 50% of the River's flow was permanently diverted into another watershed. Their models suggest that reduced flows tend to increase aquatic plant (macrophyte) biomass in slow-flowing parts of the river. "Our predictions that macrophyte abundance has increased in reaches of the Middle and Upper Nechako River since the 1952 diversion and that macrophyte abundance will increase in these reaches once again if flows are further reduced, are consistent with observations made on other regulated rivers."

The ecological consequences of increases in the abundance of macrophytes have not been fully investigated. In some parts of the river, higher levels of biological production may result from increased food availability or habitat complexity. In others, the decomposition of extensive macrophyte beds combined with high water temperatures can result in severe deoxygenation and major die-offs of fish. "Given that macrophyte bottom cover in the Middle Nechako ... often exceeds 30%, past and future increases in macrophyte abundance in this reach may pose a threat to fish populations under conditions conducive to decomposition-related oxygen deficits."

Species such as salmon are extremely sensitive to alterations in environmental conditions, including stream flow. Several recent papers in the *Canadian Journal of Fisheries and Aquatic Science* underscore the significance of such environmental conditions to salmon and other species on Canada's Pacific coast. Studying the Fraser River in British Columbia, Beamish et al. (1994) identified a "connection between annual fluctuations in river flow and production of some marine fishes," notably Pacific salmon.

In another study, Yin, Harrison and Beamish (1997) found that fluctuations in the Fraser River's discharge have pronounced effects on biological production in the Strait of Georgia estuary. "The timing and magnitude of the May-June freshet could control the entrainment of nutrients and thus maintain high primary productivity in late spring-early summer."

Investigating recent declines of coho salmon in the Thompson River, Bradford and Irvine (2000) found that alterations in fresh-water habitat, ocean conditions, and over-fishing were responsible. Among other causes of damage to the fresh-water habitat, the authors identified "low flows and high water temperatures" resulting from "high rates of water withdrawal in summer for irrigation."

Great Lakes

Focused examination of environmental impacts of water removals in the Great Lakes basin reveals that even modest removals may have harmful consequences. As part of its investigation of the consumptive uses of water in the Great Lakes in 1999, the International Joint Commission invited ten Canadian and U.S. water experts to take part in a workshop on cumulative impacts. The participants were unable to quantify precisely the specific ecological and economic consequences of most water withdrawals, consumptive uses, and removals. They did, however, emphasize that: "Numerous studies to date — both localized and system-wide — suggest that adverse impacts are associated with even modest reduction in levels, flows and/or fluctuation range ..."

When asked what governments need to know in order to understand and evaluate the impacts of a diversion or consumptive-use proposal in light of cumulative impacts, the workshop participants responded that: “As a matter of policy, governments are advised to acknowledge that even modest changes in levels, flows, and fluctuations can have potentially significant adverse ecological and economic impacts.” (Cuthbert and Donahue 1999)

The transfer of foreign biota from distant aquatic ecosystems into the Great Lakes via ballast water from ships is of growing concern to aquatic scientists. (David Schindler, personal communication) For example, by the mid-1990s, it had been reported that at least 140 exotic species had been introduced into the Great Lakes basin, mostly through ballast water. (Koonce 1994) Should the export of Great Lakes water entail shipments by ocean-going tanker, potential biotic transfer would be an obvious concern.

Water Removals in the Context of Climate Change

It is useful to consider the ecological significance of water removals alongside other factors affecting fresh-water ecosystems. In a recent article in the *Canadian Journal of Fisheries and Aquatic Science,* one of Canada’s pre-eminent aquatic scientists summarizes current and likely future stresses on aquatic ecosystems. Describing fresh water as “the most important economic and environmental issue of the twenty-first century,” David Schindler includes water exports among the greatest threats to Canada’s water security and to the health of Canadian aquatic ecosystems. (Schindler 2001)
Schindler predicts the impacts of climate change on the use of water in Canada:

> Agriculture and forestry will be limited by water shortages. Canadian water abundance, pollutant concentrations, aquatic

> biota, wetland and riparian areas, agriculture, forests, arctic ice packs, and navigation will be affected. Each stressor viewed by itself does not seem all that harmful (at least to some), but the overall effect will be the degradation of Canadian freshwater on a scale that was not comprehensible to the average Canadian at the end of the twentieth century. (Schindler 2001)

In the context of the alteration and degradation of aquatic ecosystems that are likely to occur, exporting water, even in relatively small amounts by tanker, would only add to environmental problems. Schindler predicts that human population industrial growth, and climate change will increase worldwide demand for water. "[T]here are sure to be demands that we share our abundant waters with water-poor regions." Noting depleted water resources and growing water scarcity in parts of the United States and elsewhere, he adds, "These conditions will become worse as climate warms, and the demand for Canadian water will increase." (Schindler 2001)

Among the environmental and economic effects of reduced flows, Schindler notes the reduced capacity of rivers and lakes to tolerate pollutant loads and the likelihood that "the quality of water for drinking will deteriorate." He also suggests impacts on fisheries:

> Climate warming and the resulting changes in pollutant concentrations, communities, and water exports would all cause further depletion of freshwater fisheries that have already been savaged by overharvesting, destruction of habitat, dams, diversions, introduction of diseases, parasites, non-native fishes, and pollutant loads.

Conclusion

Recent scientific study provides no clear, quantitative guidance for the precise amount of water that can be removed from a river, stream or lake before harmful environmental impacts ensue. It does, however provide evidence that "there is never a 'surplus' of water" in lakes and rivers, and that "every drop of water has several potential uses." (International Joint Commission 2000) In particular, scientific research in Canada and elsewhere underscores the fundamental importance of natural rates and variations of stream flow as critical to the health of freshwater, estuarine, and marine ecosystems. Unquestionably, scientists have disproved the assumption, frequently uttered by proponents of water exports, that water left to run on its own is "wasted." Their work adds credibility to the precautionary principle that extreme caution should be exercised in considering removals of any quantity of fresh water from a lake, river or aquifier for any purpose, including export.

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