The Walkerton Inquiry

Commissioned Paper 22

Water Quantity and Related Issues: A Brief Overview

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Toronto

2002

Published by Ontario Ministry of the Attorney General

This paper and other Walkerton Inquiry Commissioned Papers are available on the Walkerton Inquiry CD-ROM and at <www.walkertoninquiry.com> with the complete final report.

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Abstract

Donald Tate provides an assessment of Ontario's water sources and discusses the impact of current and future demand on supply. He includes information on the relationship of the price of water to consumption in domestic, industrial, and agricultural use. The author adds a short examination of the impact of climate change on the availability of water.

Contents

Figures

1 Introduction

1.1 Purpose of the Paper

"The Walkerton Inquiry requires a marshalling of evidence on the question of whether there is any real or serious (as opposed to hypothetical) threat to the quantity of freshwater available in Ontario for domestic use. This is best approached from an overall quantitative assessment of stocks and flows available to the Ontario population, set against broad measures of demand and the trends in demand."[1] The author was asked to assemble the underlying factors related to this issue and to prepare a short brief summarizing its findings.

The answer to the issue posed above seems quite straightforward in a relatively humid area, especially one virtually surrounded by the world's largest freshwater sea, the Great Lakes. Indeed, in a situation similar to that of the proverbial carrier of coals to Newcastle, the tempting answer is a short one; namely, that there is no shortage currently, nor is there likely to be. However, like many simple answers to complex questions, this one is incomplete and needs to be examined by looking at the factors underlying the issue.

1.2 Scope of the Paper

As suggested by the initial request, the first step is to examine some of the salient factors characterizing Ontario's water supply – both surface and groundwater (Section 2.1). These factors can then be interpreted in the context of current and future water demands (Section 2.2). To expand slightly on the water demand dimension, Section 2.3 examines briefly the main economic issues influencing water demand. This discussion is included because economic factors are major ones underlying the levels of water demand but are often overlooked in analyzing future levels of water use. Issues of climate change are also important in assessing both water availability and demand and are examined briefly in Section 2.4. Water quality is also an important dimension of an overall quantitative assessment, but this issue is beyond the scope of this paper.

Section 3 presents the conclusions of the paper.

This paper has been prepared for the Walkerton Inquiry for discussion purposes only and does not represent the findings or recommendations of the Commissioner. Donald M. Tate is president of GeoEconomics Associates Incorporated.

[1] Harry Swain, Chair of the Research Advisory Panel, the Walkerton Inquiry, January 22, 2001, letter to Donald M. Tate, initiating this project, [author's files].

2 Water Quantity, Demand, and Climate Change

2.1 Water Quantity

The atlas-like publication, *Water Quantity Resources of Ontario* contains an overview of facts on the physical water resources of the province.[2] It divides the province into five large hydrologic regions: Hudson and James Bay, Nelson River basin, Lakes Superior and Huron, Lakes Erie and Ontario (including the St. Lawrence River), and the Ottawa River. This grouping seems to be an appropriate geographical basis on which to compile the basic quantitative facts about Ontario's water resources.

Table 2-1 shows a few of the important factors that illustrate Ontario's abundant water resources.

From this table, several factors emerge. Ontario is a huge province in terms of area, encompassing about 973,000 square kilometers (km^2). It has abundant precipitation, which falls both as rain and snow. Roughly 40% of precipitation comprises runoff, which is that portion of precipitation that reaches rivers and lakes from both surface runoff and groundwater flows. The remaining 60% is

Table 2-1 Selected Water Quantity Characteristics by Hydrologic Region

Region	Area (km^{2}x10^3)	Mean Annual Precipitation (mm)[a]	Mean Annual Runoff (mm)[b]	Mean Annual Evapotrans-piration (mm)[b]	% of Mean Annual Runoff Volume[c]
Hudson-James Bay	571	650	300	350	59
Nelson River[d]	122	660	210	450	9
Lakes Superior and Huron	175	850	400	450	21
Lakes Erie and Ontario	56	820	300	520	6
Ottawa River	49	810	310	500	5

Source: Ontario, 1984. (see footnote 2)
a. Interpolated from ibid., p. 16.
b. Interpolated from ibid., p. 22.
c. Ibid., p. 26
d. This hydrologic area in Ontario includes the headwaters of the Winnipeg River basin, which is a major tributary of the Nelson River.

[2] Ontario, Ministry of Natural Resources, 1984, *Water Quantity Resources of Ontario* (Toronto: Ministry of Natural Resources).

accounted for by evapotranspiration and is thereby lost for direct human use. Finally, the table shows that over 68% of the flow (i.e., that in the Hudson-James Bay and the Nelson River regions) is toward the north, away from the populated areas of the province. In other words, nearly 70% of Ontario's water is unavailable for use in the most populated parts of the province.

Not included in this table is the large storage capacity of Ontario's lakes. Thousand of lakes dot the province, but the jewels in the crown are the Great Lakes, the world's largest system of freshwater lakes. Total water storage in these lakes is estimated at 22,680 km^3, measured at the low water datum.[3] The estimated Canadian portion of mean annual runoff at Cornwall is 3,070 m^3/s or 96,720 million m^3/y.[4] This runoff comprises less than 1% of storage. The latter fact is important in assessing water availability. To draw an economic analogy, storage would be the total capital possessed by an individual or corporation. Annual runoff would be the annual interest earned on this capital. In order to preserve wealth, a useful objective is to live off the interest. If this analogy is accepted, it is the annual runoff (i.e., the flow), not the total storage (i.e., the stock), that is most important in assessing water availability. This flow criterion is used throughout the remainder of the paper, while recognizing that stocks of the resource are huge.

Annual surface water runoff, defined above as that portion of precipitation that reaches rivers and lakes from both surface runoff and groundwater flows, is quite variable from year to year in Ontario. Table 2-2 provides data on this flow variability.

In addition to surface water runoff, varying proportions of Ontario's water supply are derived from groundwater. With respect to the latter, precise data are significantly harder to obtain because flow patterns are not well defined in many areas, and because measurements are discrete, not continuous. *Water Quantity Resources of Ontario* contains a number of plates and charts from which some basic facts can be derived.[5] (Table 2-3).

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[3] Ibid.
[4] P. H. Pearse, F. Bertrand, and J.W. MacLaren, 1985, Currents of Change: Final Report of the Inquiry on Federal Water Policy, Catalogue No. En 37-71/1985-1E, p. 28 (Ottawa: Environment Canada). The figures developed by Pearse et al., are estimates of the Canadian portion of total runoff.
[5] This table is based on have a visual, non-quantitative inspection of Plate 17 (p.47) of Water Quantity Resources of Ontario (1984) and is an estimate of groundwater contributions to stream flow.

Table 2-2 Annual Runoff (m^3/s) for Major Ontario Hydrologic Regions

Region[a]	Reliable[b]	Mean	High[c]
Hudson-James Bay[d]	3,730	6,000	8,260
Winnipeg River drainage basin[e]	380	760	1,140
Great Lakes[f]	2,400	3,070	3,730
Ottawa River	1,390	1,990	2,590
Total	7,910	11,810	15,720

Notes:
Source: Pearse et al., 1985. Note the contrast between the flows given here and the measurement of runoff in *Water Quantity Sources in Ontario*, as sourced in Table 1. This discrepancy is due to the different measurement units used, and not to any significant variations in basic data. The data of Table 1 are volume-based, whereas those of Table 2 are flow-based. All figures are rounded to the nearest 10.
a. The region names from Table 1 have been retained, with the exception of the Great Lakes, which are treated as a unit in the source for this table
b. Flows equalled or exceeded 19 years out of 20. In other words, these flows are available statistically at least 95% of the time.
c. Flows equalled or exceeded 1 year out of 20. In other words, these flows are available statistically at least 5% of the time.
d. Called Northern Ontario in the source for this table.
e. Measured at the Lake Winnipeg outlet point; accordingly, the figures are biased upward due to the inclusion of a minor amount of runoff rising in Manitoba. This measurement point was used in the Pearse et al. paper, as being the outlet point for this basin region.
f. Includes four Great Lakes, and measured at Cornwall. This measurement point was again used in the Pearse et al. paper and is commonly accepted as the outlet point of the Great Lakes basin.

Table 2-3 Estimated Groundwater Contributions (%) to Streamflow

General Area Description	Range (%) of Contribution	Estimated % of Ontario[a]
Most of the province; all of Northern Ontario except clay belt area	0 – 20	85
Clay belt areas plus much of south-central Ontario	20 – 40	10
Extensive areas south of Georgian Bay and west of the Niagara Escarpment	40 – 60	5

Notes:
Source: Ontario, Ministry of Natural Resources, 1984, *Water Quantity Resources of Ontario* (Toronto: Ministry of Natural Resources).
a. Percentages estimated from a non-quantitative examination of Plate 17 and comprise approximations only.

Groundwater yields are conditioned typically by geology; for example, in Northern and Eastern Ontario, where Precambrian and Ordovician rock formations are at or near the surface, groundwater yields tend to be low. On the other hand, where thick overburdens of glacial materials exist (e.g., those found in lacustrine deposits, kames, eskers, moraines, etc.), yields are much higher. The clay belt areas of Northern Ontario and the Oak Ridges Moraine are clearly visible on Plate 17 of *Water Quantity Resources of Ontario* as having relatively high groundwater yields. Groundwater is important to the water supply of many smaller communities and almost all of rural Ontario, but may also be the source of water in larger urban centres. The largest urban area in the province that relies principally on groundwater is the Regional Municipality of Kitchener-Waterloo. Approximately 80% of municipal water supplies are abstracted from groundwater with the remainder coming from surface waters.

2.2 Water Demand

In 1999, GeoEconomics Associates prepared a study to analyze the current and emerging water demands in the Canadian portion of the Great Lakes basin.[6] This document is the most recent comprehensive report on water demands in the basin and, with adjustments, can be used to add the demand side to overall water availability conditions in Ontario. The base year for this study was 1996, the last year for which measured water demand data are available in a systematic manner (Table 2-4). For the purposes of the current paper, the water demand forecasts for 2001 and 2021 (the study's end year) are also used. The study looked at a number of alternative scenarios for water demands in the Great Lakes basin. Water demand forecasts based on past trends (trend line), and the high and low projections are summarized in Tables 2-5 (2001) and 2-6 (2021) to show the uncertainty in the forecasts of demand.

Data are given in both volume and flow form, because the volumetric form was used in the source document while the flow form permits comparisons with the hydrologic flows provided in Table 2-1. In Tables 2-4, 2-5, and 2-6,

[6] D. Tate and J. Harris, 1999, *Water Demands in the Canadian Section of the Great Lakes Basin, 1972– 2021* (Ottawa: Canadian Section, International Joint Commission).

Table 2-4 Water Use in Ontario by Hydrologic Region, 1996

	Volume-based (m^3 x 10^6/y)		Flow-based[e] (m^3/s)	
	Intake	*Consumption*	*Intake*	*Consumption*
Hydrologic Region				
Lakes Superior and Huron[a]	9,720	330	310	10
Lakes Erie and Ontario[b]	19,730	680	630	20
Great Lakes Sub-total[c]	29,450	1,010	940	30
Rest of province[d]	2,950	100	90	0
Total	**32,400**	**1,110**	**1,030**	**40**

Notes:
All figures rounded to nearest 10. 0=<5
a. 33% of Great Lakes total.
b. 67% of Great Lakes total. Includes St Lawrence River drainage.
c. Tate and Harris (1999)
d. Estimated as 10% of Great Lakes total
e. 1 m^3/s=31.536 m^3 x 10^6/y

Table 2-5 Projected Water Use in Ontario, 2001

	Volume-based (m^3 x 10^6/y)		Flow-based (m^3/s)	
	Intake	**Consumption**	**Intake**	**Consumption**
Trend Line[a]				
Great Lakes	31,670	1,040	1,000	30
Rest of Province	3,170	100	100	0
Total	34,840	1,140	1,100	40
Low Projection				
Great Lakes	30,790	1,000	980	30
Rest of Province	3,080	100	100	0
Total	33,870	1,100	1,080	30
High Projection				
Great Lakes	33,010	1,050	1,050	30
Rest of Province	3,300	110	100	0
Total	36,310	1,160	1,150	40

Notes:
Basin proportions are same as Table 3.
a. Projected volumetric data taken from Tate and Harris, 1999.
Figures may not add due to rounding. All figures rounded to nearest 10. 0=<5

'intake' refers to water withdrawn from water sources, and 'consumption' to water used up during use (e.g., evaporated) and is effectively lost from an area.[7]

Tables 2-4, 2-5, and 2-6 demonstrate that consumptive use ranges between 30 and 50 m^3/s throughout the 1996–2021 period. These flows are less than 1% of Ontario's average annual runoff (11,810 m^3/s – Table 2-2). Even for the Great Lakes, where most of Ontario's consumption takes place, the range of water consumption is still just over 1% of water availability. This estimate has led many authors, including the present one, to call the Great Lakes a water rich environment. This finding must, of course, be qualified in light of basic geographical factors. For example, a community adjacent to a large river or

Table 2-6 Projected Water Use in Ontario, 2021

	Volume-based ($m^3 \times 10^6/y$)		Flow-based (m^3/s)	
	Intake	**Consumption**	**Intake**	**Consumption**
Trend Line[a]				
Great Lakes	43,040	1,200	1,360	40
Rest of Province	4,300	120	140	0
Total	47,340	1,320	1,500	40
Low Projection				
Great Lakes	37,860	1,020	1,200	30
Rest of Province	3,790	100	120	0
Total	41,650	1,120	1,320	40
High Projection				
Great Lakes	49,940	1,390	1,580	40
Rest of Province	4,990	140	160	0
Total	54,930	1,530	1,740	50

Notes:
Basin proportions are same as Table 3.
a. Projected volumetric data taken from Tate and Harris, 1999.
Figures may not add due to rounding. All figures rounded to nearest 10. 0=<5

[7] The assumption that water consumed is lost to a basin is open to discussion, but is generally accepted among those who study the water demand field. For example, water evaporated at an industrial plant may fall as precipitation within the same basin. (For an example, see International Joint Commission, 2000, p. 9.) The reason for questioning the assumption relates to the reality of the hydrologic cycle, which shows that water is generally neither created nor destroyed, but merely changes its form. It is true, however, that water can be 'lost' to local environments through usage; hence, the assumption made here.

lake will have a relatively smaller problem in acquiring water supplies than one located inland and away from large water bodies, or dependent on groundwater supplies.

2.3 Water Resource Economics and Municipal Water Demands

Water demand has an important economic dimension that may be useful in managing water in the future. The demand for water is a function of price: as price rises, demand falls. Also, low prices lead to excessive use. These basic economic assertions are important in considering water management issues.[8]

The price-quantity relationship is measured using a concept called the price elasticity of demand, which denotes the percentage change in the quantity of a good (in this case water) divided by the percentage change in price.[9] Elasticities vary among water uses and reflect the availability of alternatives to current usage. For example, elasticities are normally low (0.2–0.4) for in-house domestic use.[10] A simple interpretation is that a 10% rise in real water price will produce a decreased water use of 2%–4%. For outdoor domestic uses (e.g., lawn or garden irrigation), these values are higher, averaging around 0.6; that is, a 100% rise in water price typically produces a 6% decrease in water use; for industry higher still (from 0.6–1.0), and highest for agriculture (up to 1.2). The important point is that water demands are price responsive. This fact could be usefully exploited by water managers.

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[8] This discussion is based on: D.M. Tate, S. Renzetti, and H.A. Shaw, 1992, "Economic instruments for water management: the case for industrial water pricing," *Social Science Series* (Ottawa: Environment Canada, Ecosystem, Sciences, and Evaluation Directorate). Augmented by materials from: D.D. Baumann, J.J. Boland, and W.M. Heinemann, 1998, *Urban Water Demand Management and Planning* (Toronto: McGraw Hill); R.B. Billings and C.V. Jones, 1996, *Forecasting Urban Water Demand* (Denver: American Water Works Association); and Organization for Economic Cooperation and Development (OECD), 1999, *The Price of Water: Trends in OECD Countries* (Paris: OECD).

[9] For most goods, price elasticities are negative, denoting that as price rises, demand falls. It is common however to discuss price elasticities of demand in absolute terms, with the negative sign being inferred. This convention is followed here.

[10] These figures are averages based on many studies contained in publications; for example, *Water Quantity Resources of Ontario.*

[11] D.M. Tate and D.M. Lacelle, 1995, "Municipal water rates in Canada: current practices and prices, 1991," Social Science Series (Ottawa: Environment Canada, Inland Waters Directorate), p. 30.

Water price levels are low in Canada relative to the prices for other goods and services.[11] Low water prices cause excessive demands over-expansion of municipal infrastructure, insufficient funds for effective system maintenance, practically free dumps for industrial and agricultural wastes, and water systems that are unsustainable financially and environmentally.[12] This economic behaviour whereby low water prices generate excessive demand is a structural problem of water management that poses a significant challenge for the future.

2.4 Climate Change

The issue of climate change is a relatively new and complex one, dominated by uncertainty and disagreement, even among experts in the field.[13] Debates include such factors as the magnitude of the implied threats to ecosystems and socioeconomic activities, the timing of the effects, and how to mitigate them. One of the major modelling problems has been the estimation of sea-air energetics,[14] or energy exchanges, with the result that none of the current large global climatic models has a precipitation module, and, accordingly cannot accurately predict changes in precipitation patterns. Also, the four dimensional problem (i.e., variations across three dimensional space through time) nature of predicting present and future climates causes substantial difficulties. Of all the problems of science, examining the issue of global climatic change is one of the most complex. The following brief discussion is included in this paper because of the potential for climate change to affect water availability in Ontario.

There are some areas of agreement in approaching this issue, according to the panel of experts who advised the International Joint Commission (IJC) in its recent study of the Great Lakes.[15] First, the rate of accumulation of greenhouse gases in the atmosphere is occurring at a rate such that concentrations will double during the 21st century if preventative and ameliorative steps are not taken. Second, in North America, average temperatures will rise in a range from 1 to 4 °Centigrade, with the larger increases occurring in the higher lati-

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[12] OECD, 1999.

[13] This section is based on: International Joint Commission, 2000, Protection of the Waters of the Great Lakes: Final Report to the Governments of Canada and the United States (Ottawa and Washington, D.C.). This climate change part of the report included the input of well-known professionals in the climate change field in North America, as well as a thorough investigation of this field.

[14] A term used to describe the exchange of energy between atmosphere and water over ocean areas.

[15] International Joint Commission, 2000, p. 15.

tudes. Third, professionals agree that the science is sound and that human activity is having a noticeable effect on the earth's climate.[16] Finally, there is also agreement that changes in atmospheric composition are beginning to have an effect on the hydrologic cycle.

However, there is still much uncertainty about the effects on specific geographical areas, such as the Great Lakes basin. One basic problem is the difficulty posed by including precipitation in the global climatic models currently being used. This modelling problem is partially a measurement one because of the difficulties of separating the effects of natural variability from those of climate change. This natural variability behaves much like the effects predicted by the climate change models. Thus, enhanced variability is likely. In addition to this variability, the models predict a lowering of water supplies, average lake levels, and outflows from the Great Lakes.

Research by Environment Canada and the U.S. National Oceanographic and Atmospheric Administration shows the water resource effects of global warming and provides an example of the effects of climate change on the Great Lakes. These effects can be summarized as a lowering of lake levels of up to one meter,[17] giving rise to serious economic, social, and environmental impacts. Many analysts also recognize that global warming will lead to changes in global precipitation patterns.[18] Effects on the Great Lakes region may include: increased precipitation falling as rain; less snow cover; a shorter duration of snow and ice cover; earlier snow melt and onset of spring; and less water availability during the summer months. The latter, in turn, suggests a possible increase in water demand for irrigation, as well as the need to reconstruct municipal and industrial intakes.

The impact of climate change on drinking water availability in Ontario is uncertain, for there has been little research in this area. A few possible effects can

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[16] Intergovernmental Panel on Climate Change (IPCC), 1996, IPCC Second Assessment Synthesis of Scientific-Technical Information Relevant to Interpreting Article 2 of the UN Framework Convention on Climate Change (New York: Cambridge University Press).

[17] L. Mortsch and F.H. Quinn, 1996, "Climate change scenarios for the Great Lakes basin ecosystem studies," Limnology and Oceanography, vol. 41, no. 5, pp. 903–11; T. E. Crowley II, 1992, "CCC GCM 2xCO2: hydrologic impacts on the Great Lakes," Climate, Climate Change, Water Level Forecasting and Frequency Analysis: Supporting Documents Vol. 1, Water Supply Scenarios, Task 2, Working Committee 3, IJC Levels Reference Study, Phase 11.

[18] For example: F.H. Quinn and B. Lofgren, 2000, "The influence of potential greenhouse warming on Great Lakes hydrology, water levels and water management," *Preprints, 15 Conference on Hydrology*, January, pp. 271–74.

be deduced, however.[19] An increase in water acquisition costs is a real and potentially expensive threat, because water intake facilities and sewage treatment plant outfalls will require extension. Lower water levels will also reduce the assimilative capacities of surface streams. This fact implies a need for improved waste treatment to maintain water quality. This situation applies not only to municipalities, but especially to industrial and agricultural operations. Decreased water availability will also lower water tables, again increasing the costs of water acquisition. Some of these effects could be mitigated by an increasing effort to manage water demands, through actions such as increased water prices, effluent discharge fees, universal water metering, better education, and other measures to increase the levels of water conservation.[20]

Climate change is a slow-acting process and, as the references in this paper point out, is presently underway. The full effects of the current rates of change will be felt only after many decades have passed; however, public policies may be introduced now that mitigate the negative impact of climate change.

3 Conclusion

- Ontario has an abundant water supply. Even under conditions of high water demand projection and the onset of climate change, total consumption remains below 1% of renewable supplies, and will remain so for the foreseeable future. There appears to be no shortage of drinking water, except possibly in localized areas served in part or wholly from groundwater.
- Pricing that reflects at least the full cost of water servicing (including waste treatment) is necessary to moderate demand. Full cost pricing will prevent unwarranted expansion of water infrastructure. Underpricing leads to waste.
- Global warming appears to be a reality and may have long-term adverse effects on water availability. These effects will be felt over several decades and will have impacts upon the drier areas of North America before being felt in Ontario.

[19] These deductions are based on the professional experience of the author, not on any peer-reviewed literature.

[20] For a full discussion of water demand management, see: D.M. Tate, 1990, "Water demand management in Canada: a state of the art review" Social Science Series, No. 23, (Ottawa: Environment Canada, Inland Waters Directorate).

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