Great Lakes Diversions and Consumptive Uses

Annex F
Consumptive Water Use

Report to the International Joint Commission

by the
International Great Lakes Diversions and Consumptive Uses Study Board
(Under the Reference of February 21, 1977)

September 1981

CONVERSION FACTORS

(ENGLISH TO METRIC UNITS)

1 cubic foot per second (cfs) = 0.028317 cubic metres per second (cms)

1 cfs-month = 0.028317 cms-month

1 foot = 0.30480 metres

1 inch = 2.54 centimetres

1 mile (statute) = 1.6093 kilometres

1 ton (short) = 907.18 kilograms

1 ton (long) = 1016.40 kilograms

1 square mile = 2.5900 square kilometres

1 acre - foot = 1233.5 cubic metres

1 gallon (U.S.) = 3.7853 litres

1 gallon (Imperial) = 4.5459 litres

1 acre = 4047 square metres

Great Lakes
Diversions and Consumptive Uses

Annex F
Consumptive Water Use

Report to the
International Joint Commission
by the

International Great Lakes Diversions and
Consumptive Uses Study Board

(Under the Reference of Feburary 21, 1977)

September 1981

SYNOPSIS

On May 3, 1977, the International Joint Commission (IJC), at the request of the governments of the United States and Canada, established the International Great Lakes Diversions and Consumptive Uses Study Board to investigate the effect on the water levels and outflows of the Great Lakes of: existing and proposed new or changed diversions into, out of and within the Great Lakes basin; and existing and reasonably foreseeable patterns of consumptive water uses.

The purpose of this Annex is to document in detail the approach and methodology used to project consumptive water use in both the United States and Canadian portions of the Great Lakes and their basins from a base year 1975 to the year 2035. Projections are an integration of consumption in seven water use sectors from lake and nonlake sources within each of the five Great Lakes and their drainage basins. The United States projections are based on data and analyses available from the U.S. Departments of Commerce, Agriculture, Interior and Energy, the Federal Energy Regulatory Commission, and the U.S. Water Resources Council. In Canada a comprehensive historical data base was not available so more fundamental data analysis and model development was required. Overall, however, the approaches to determine the projections used in the two countries are compatible.

Findings and conclusions based on the data, assumptions and methodologies described in this Annex along with the hydrologic and economic impacts of projected consumptive water use on levels of the Great Lakes are summarized in the main report.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF ANNEXES TO MAIN REPORT

ANNEX A

Text of February 21, 1977 Reference from the Governments of the United States and Canada

ANNEX B

Text of the International Joint Commission Directive of May 10, 1977 to the International Great Lakes Diversions and Consumptive Uses Study Board.

ANNEX C

Series of Newsletters "Diversions" and Report on Public Workshops.

ANNEX D

Prior Reports that were Pertinent or of Special Interest to this Study.

ANNEX E

State, Provincial and Federal Agencies that Participated in this Study, Including a Listing of Participants.

ANNEX F

(bound separately)

Consumptive Water Use - A Documentation of the Methodology used in Consumptive Uses Projections.

ANNEX G

(bound separately)

Evaluation of Diversion Management Scenarios and Consumptive Water Use Projections - A Documentation of the Detailed Hydrologic, Economic and Environmental Evaluation of Selected Diversion Management Scenarios and the Hydrologic Evaluations of Consumptive Water Use Projections.

LIST OF APPENDICES TO MAIN REPORT

(bound separately)

APPENDIX A - COORDINATED BASIC DATA

A documentation of the coordinated basic data developed and employed in this study. It describes the methods and techniques employed in obtaining the water supply data and development of the basis-of-comparison. It also contains tabulations of the final basis-of-comparison data and tabulations of the basic data employed in their derivation.

APPENDIX B - COMPUTER MODELS -GREAT LAKES

A documentation of computer "software" containing a complete program listing of one program developed uniquely for this study as well as a tabulation of two standard programs used. The programs themselves are stored in the United States at the offices of the Detroit District, Corps of Engineers, Detroit, Michigan, and in Canada at the offices of the Inland Waters Directorate, Federal Department of the Environment, Ottawa, Ontario.

APPENDIX C - DIVERSION MANAGEMENT SCENARIOS

A documentation of the monthly mean levels and flows data of 13 diversion management scenarios selected for detailed hydrologic evaluation.

ANNEX F

CONSUMPTIVE WATER USE

1.1 Introduction

This annex describes in detail the methodology that was used to develop the projections for the Consumptive Uses section of the International Great Lakes Diversions and Consumptive Uses Study which has been conducted in response to a 21 February 1977 reference to the International Joint Commission (26). Projections extend from 1975 to 2035. The discussion encompasses each of the seven water use sectors that were addressed in the study from both the Canadian and United States perspectives. These sectors include municipal, rural-domestic, manufacturing, mining, rural-stock, irrigation and thermal power generation water uses.

Multiple alternative projections based on variations of the most sensitive assumptions were developed to establish a range of projections that envelop the most likely projection (MLP). The sources of these alternative scenarios or the specific assumptions which were varied are also included in this annex.

The Consumptive Uses Data Set (page F-130) tabulates MLP water withdrawals and consumptive uses in various combinations by country, by individual lake basin, by the total basin, and by water use sector in five year increments to 2035.

In 1969, the Regulation Subcommittee of the International Great Lakes Levels Board issued A Survey of Consumptive Use of Water in the Great Lakes Basin (27). That report helped to elicit some of the concerns that led to preparation of the present report. A detailed analysis and intercomparison of the two reports is also included in this annex (Section 9).

This annex is a mosaic of detailed explanations of methodologies used by the U.S. and Canada in developing the water use projections. These explanations are derived from a number of sources, basically documentation prepared as background to the preparation of initial drafts of the main report (Section 6).

1.2 Perspective: United States

The primary objectives of this effort were to 1) obtain all available regional water use data, 2) compare the data, 3) review assumptions and methodologies and 4) develop a set of projections for each water use sector. Primary sources of information included the 1972 OBERS Projections of Regional Economic Activity in the United States, the U.S. Geological Survey (USGS) reports "Estimated Use of Water in the United States" for 1970 and 1975, the U.S. Water Resources Council 1975 National Water Assessment (NAS), the reports by the Regional Reliability Councils, and the Great Lakes Basin Commission (GLBC) Framework study (base year 1970). The 1976 Canada Water Yearbook and the 1969 study by the Regulation Subcommittee of the

International Great Lakes Levels Board were also examined. These reports provided base year water withdrawal and consumptive use by sector and geographic divisions for the U.S. portion of the Great Lakes. Significantly different water use projections in each of these reports directed the study effort to comparison and verification. These differences were found to result from variations in 1) organization and duration of collection efforts, 2) designation of regional and sub-basin boundaries, 3) definition of categories of water use activities, 4) water use projection methodologies, 5) assumptions and 6) data bases. The accuracy of various assumptions used in previous studies was investigated by review of available data on urban and rural population statistics, industrial earnings, irrigated acreage, and water use rates for the various use sectors, and interactions with people who had participated in the previous studies.

Study efforts focused on the development of the selected sets of most likely projections for each water use sector. After consideration of all available information, the National Assessment Study figures were adopted as reliable estimates of water use for the rural-domestic, mining, rural-stock, and crop irrigation sectors. This decision was made in view of the minor significance of these sectors, the comprehensiveness of the NAS effort, and the lack of additional information. MLP's and alternative projections of water withdrawal and consumptive use were generated for the three major water use sectors, municipal, manufacturing, and thermal electric power generation.

The U.S. Water Resources Council Second National Water Assessment (NAS), completed in 1978, served as a fundamental source of information. The water use study was conducted in three phases, 1) the nation-wide water use analysis was undertaken by the Council's member agencies to assess current and future water requirements, problems related to this water use and possible implications for the future, 2) a specific problem analysis was conducted by regional agencies to reflect state and regional viewpoints about management of their water resources, and 3) a national water and related land use problem analysis was developed from information collected in the previous phases. The NAS was organized in this manner to allow presentation of water supply data and problems analysis from state, regional, and federal perspectives. The portion of the assessment prepared by state and regional agencies, termed the State-Regional Futures, was completed in 1975. The National Programs and Assessment Task Force, aided by federal agencies, completed the National-Futures segment of the study in 1978 and participating state and regional agencies in the Great Lakes region adopted them. The Great Lakes basin was divided into 12 sub-basin areas to expedite data collection. These sub-basin areas approximate hydrologic drainage areas within the Great Lakes basin with boundaries along county lines in closest approximation to the physical drainage area. The Great Lakes states and agencies with responsibilities in the basin including the Federal Power Commission, Energy Research and Development Administration, Department of Interior, Department of Agriculture, and the Department of Commerce Office of Business Research and

Analysis (OBRA) were given responsibility for collecting and compiling data relevant to their particular water use concerns. These agencies relied upon local and regional planning agencies and municipalities for much of the required statistical information.

Municipal and manufacturing water use estimates were developed by modification of NAS figures. Assumptions concerning the nature of water use were applied in accordance with information available in various federal and state agencies about current usage trends.

Power figures had to be generated directly from available data and information obtained from state and federal agencies and reliability councils. However, many of the assumptions used to formulate NAS power water use projections were applied to these figures also.

Projections were formulated on the basis of assumptions about growth and usage trends which are likely to change over the projection period. The differences in projections formulated with varying assumptions provide an indication of the sensitivity of the estimates to changing trends. Detailed explanation and comparison of the methodologies and assumptions used to derive present and projected water use and the alternative scenarios are included in the specific water use sectors.

1.3 Perspective: Canada

In contrast to the U.S. portion of the study, no well-defined national assumptions apply to the Canadian study because no national water demand forecast has been carried out. Available techniques of water use and demand forecasting were used in the Canadian approach to this study (60). Generally, the research was done using computer simulation techniques, which, given certain basic data on the forecasting parameters, calculated the water use for any given category at any point in the time horizon. Factors underlying many of the forecasting variables were not evaluated in this study, but allowance was made for this deficiency by allowing the variables to assume a range of values.

In the investigative phase of the Canadian section of the study, two principal models were developed. The first is demographically based and forms the framework of estimated water uses for municipal and rural-domestic categories. A second model focuses on the industrial activity in the basin, and forms the basis for water use estimates in manufacturing and mining. Individual models were developed as the basis for forecasts in the power generation, irrigation and rural-stock water use sectors (58).

1.3.1 A Review of the Water Use Forecasting Problem

If one word could be said to capture the problems of forecasting, that word would be "uncertainty". Here, the concept involves three principal dimensions - economic uncertainty, technological uncertainty and the uncertainties inherent in water management policies.

Any economy is complex. Unlike physical systems, parts of which can be isolated, controlled and experimented with, a social system is less amenable to controlled observation. That is why prediction in the social sciences is not exact, and why equally able practitioners of a subject can have vastly different views. It is also why, despite the availability of advanced forecasting models, economic predictions often turn out to be wrong.

There are three fundamental time frames over which economic forecasts are conventionally carried out. At the most detailed level, forecasts have a one to two year time frame, and are usually done on a quarterly basis. Models by the Conference Board in Canada and the Bank of Canada are examples of the tools used at this level. Statistically qualified statements are given on many economic parameters (e.g. real domestic product, unemployment, inflation rates, etc.) in these forecasts. Even here though, precision can often be lost by policy shifts, embargoes, energy crises, and many other factors. At the next level, the time frame is about 10 years. Macro-economic tools such as the CANDIDE model by the Economic Council of Canada (54) are employed in this type of forecast. Here, despite the statistical base employed, projections are viewed, not as certainties, but rather as conditional responses to assumptions made to operate the models. At the third level of forecasting, only broad parameters, which have some degree of regularity, with normally many years of past observation, such as population, are projected, and then only on an "alternative futures" basis. Past 25 years, forecasting enters the realm of guesswork. If we go back 60 years to 1920, who would have predicted current standards of living? Who the state of transportation? Who the intervention of a World War, and many smaller ones? The same problems are involved in going ahead 60 years.

Technological forecasting is even more difficult than economic. The current problem in the developed world is energy use. The energy 'crisis' affects everyone economically, but some of the more interesting effects will be technological. These cannot be predicted, but will inevitably affect water use. Constant technological assumptions are built into the MLP. Methods of water use, products, processes and even new industries are certain to develop over 60 years. Because the basic economic structure has been held constant throughout this paper, the probabilities of wholly new developments have not been incorporated. Thus, technological uncertainty is a major source of error in the forecasts.

The third dimension of uncertainty relates to public policy which can have major effects on the use of water. Two examples will serve to demonstrate this point, one related to water quality, the other to water supply. Over the past 10 years, water quality deterioration has been a major source of concern. In the Great Lakes area, this has led to large public programs of research and management in an attempt to reverse the deterioration. These programs are proving to be successful.

In connection with water supply, figures on water use imply considerable new expenditures on new or expanded water supply systems. In many cases, public expenditures are involved. Water supply and treatment systems already comprise some of the more costly items of public expense in urban areas, and will be even more costly in the future. They will have increased in cost because of competing demands for capital. This situation makes it desirable from a policy viewpoint to attempt to limit water supply expenditure by curtailing demands. One such method of doing so is through the use of economically-based pricing systems (22). If this is done, and at this stage it is not being widely considered, the water use forecasts, particularly for the municipalities and some industries, would be high.

1.3.2 The Ontario Economy

The aim of this section is to take a very brief overview of the Ontario economy and its medium-term (i.e. to 1985) prospects. It is undertaken to provide a background against which to assess the water use forecasts. The statistical basis of the review is an unpublished paper by the Department of Regional Economic Expansion's (DREE) Ontario Region (10), forecasts prepared by the Ontario Economic Council (51) and several other published works.

1.3.2.1 Aggregate Review

The Province of Ontario, and the Great Lakes basin account for roughly 40 percent of Canada's national economic activity. Several indices of this domination are given in Table 1. The province is particularly strong in terms of manufacturing and tertiary sectors; and has a strong but less dominant position in agriculture, forestry, mining and construction.

TABLE 1 CANADA: THE ONTARIO ECONOMY IN A NATIONAL CONTEXT 1978

Parameter	% of National Total
Land Area	10.7
Population	36.0
Labour Force	38.1
Retail Sales	36.5
Export Trade	44.2
Personal Income	39.9
Real Domestic Product	41.0

Source: (10)

In the post-war period to 1973, Ontario had annual growth rates of real domestic product over five percent, well in excess of the national average. Since 1974, real domestic product growth has fallen to 2.9 percent, below the national average, and one of the slowest in Canada. In addition, Ontario has assumed a relatively low position with respect to several other economic indicators - percentage growth of gross provincial product; percentage growth of per capita personal disposable income; percentage growth of public and manufacturing investment; percentage growth of residential construction; and other factors (10). Several factors have combined to cause this relatively slow growth, including general recession in international markets (notably the U.S.), wage and price controls, inflationary conditions, and rising energy prices. With regard to energy availability and prices, Ontario has been very sensitive to the post-1973, OPEC-induced rise in petroleum prices. With practically no petroleum or natural gas resources, the Province's industries have experienced lower-than-potential growth. In fact, the decline of Ontario's relative position in the economic picture of Canada dates exactly from the period of upheaval in the world petroleum markets. In terms of specific industries, transportation and communications, and finance, insurance and real estate have been relatively high growth performers, while agriculture and mining have had retarding effects.

In spite of the relative decline in the Ontario economy, income performance has been above the national average throughout the 1970's and the Province still constitutes Canada's highest concentration of income, at about 40 percent of the national total. The population has grown at only 1.1 percent annually between 1977 and 1979, lower than the national average, in contrast to the traditional situation in which Ontario's population growth has been above average. A lowering birth rate and a slackening of immigration accounts for low growth rate. The labour force in 1978 has expanded at 3.8 percent annually, with employment increasing at 3.6 percent. The previous two years saw much the same growth, with increasing rates of unemployment being the result. This pattern is the result of the post-war baby boom and is expected to be replaced by possible labour shortages in the mid-eighties (10). The strongest labour growth was experienced in the transportation and communication and the finance, insurance and real estate sectors; the weakest in construction and non-agricultural primary industries. The service and manufacturing sectors are the largest employers in the Province.

1.3.2.2 Brief Reviews of Selected Sectors

This section augments the material given in Section 1.3.2.1 by reviewing recent performance in specific economic sectors. The sectors selected as being the most important in terms of water use are: primary industries; manufacturing; and transportation, communication and utilities.

The primary industry sector consists of agriculture, forestry and mining, which form many of the important resource underpinnings of the Ontario economy. In 1978, farm cash receipts witnessed a very rapid (real) growth of 17.5 percent over 1977. This followed three years of little or no growth, so when seen in a four-year perspective, the rate seems to be quite modest. Forestry also showed a very high 21 percent expansion in timber harvest in 1978, due to good performance in the forest-based industries. The mining industry experienced a decline in 1978, due to a major strike at International Nickel in Sudbury. This was the second year of decline (10).

Manufacturing in 1978 advanced six percent over 1977 in real domestic product. This was still lower than the national average growth, a situation consistently experienced during the 1970's. Favourable factors in this growth were capacity utilization increases, rising productivity rates and slower increases in unit labour costs. The lower exchange rate (vis-a-vis the United States), removal of wage and price controls and higher product prices also aided in this relatively high growth. Wood, primary metals, auto assembly and machinery were the best performers among the manufacturing sectors.

The transporation, communication and utilities sector is a high growth area in the Ontario economy. Real domestic growth for utilities was 6.4 percent (over 1977) and in transporation and communication 4.5 percent. These high growth rates are expected to continue for some considerable time period.

1.3.2.3 The Great Lakes Basin Implication

The Great Lakes basin (essentially Southern Ontario plus a considerable area of Northern Ontario's producing economy) constitutes the major share of the Ontario economy. A strong consumer demand plus the recent rise in exports have contributed to a good economic performance in 1978, particularly in transportation equipment, steel and machinery. In Southwestern Ontario, agriculture proved a source of strength, as did the service sector in Metropolitan Toronto. Prospects for continued growth are good, especially if exchange rates and unit labour costs continue to remain relatively low. Areas of particular strength will be the auto industry, aviation, chemicals at Sarnia, and steel production at Hamilton, Sault Ste. Marie and a new facility at Nanticoke.

1.3.2.4 The Role of Energy

In the industrial economy of Ontario, the role of energy, its supply and price is critical. While the industrial base of the Province was developing in the decades of the fifties and sixties, energy was relativey abundant and cheap, with the result that industry became energy-intensive, and Canadians became the highest per capita users of energy in the world (21). The importance of energy in Ontario is exemplified by the fact that the post-1973 era, a period of rapidly rising energy costs, has been one of slower growth, high inflation and generally sluggish economic performance. The period from 1978 has witnessed adjustment to these higher prices, with the consequence that growth rates have been re-established at moderately high levels.

Few studies have been made of the response of economic growth to higher energy prices. In a study of the U.S. economy, Hudson and Jorgenson (24) show that each percentage reduction in energy input (e.g. through higher energy prices) leads to a 0.2 percent decrease in real GNP. This indicates a relatively inelastic response of economic growth to energy inputs, and suggests that decreases in energy use have a less-than-proportional impact on economic performance. A federal Department of Energy, Mines and Resources (EMR) study indicates that the price elasticity of energy demand in Canada for the industrial sector is -0.298 (7). This indicates that a one percent increase in energy price will produce roughly a 0.3 percent fall in energy demand. If both of these coefficients are applied to Ontario, a 10 percent rise in energy price will produce a 0.6 percent fall in potential GNP. This suggests quantitatively that the price of energy could have effects upon the growth rate.

1.3.2.5 Comparative Advantage

Although the Ontario economy has demonstrated slower-than-average growth through most of the 1970's, the Province still has a number of comparative advantages vis-a-vis Canada as a whole. Ontario's location, central in Canada and in the midst of the U.S. market, offers unmatched marketing and transportation advantages. Nationally, the abundance of water has aided in the past, and will continue to aid in the location of heavy industry, which require large water supplies. Although the western part of Canada is currently undergoing rapid economic growth, this growth may not extend to a completely diversified economy because of water constraints. Other natural resources, such as minerals and particularly uranium are abundant in the Province, and will continue to provide raw material advantages for Ontario's industry. The future emphasis on nuclear energy by Ontario Hydro is founded upon the uranium resources of the Province. It has been assumed that safety and environmental constraints will be met effectively, and that the presently anticipated role of this energy source will materialize. Other comparative advantages of the Province include a diversified industrial structure, a pool of well educated, skilled labour, the presence of a well-developed tertiary economic sector, with a national market, and a large, concentrated and generally affluent market.

The primary comparative disadvantages of Ontario, vis-a-vis future development, centre around the almost complete absence of petroleum resources. The need to import these resources leaves the Province open to the pressures of rising prices, which have to be met in the short term because petroleum is one of Ontario's economic backbones. In the long term, energy alternatives, such as nuclear and perhaps hydro power are available. However, these alternative sources will probably be more costly than the energy available currently. Thus, the more costly energy would translate ultimately to lower growth than would be experienced under conditions of low-priced energy.

1.3.2.6 Economic Outlook

Several forecasts of the Canadian and Ontario economies have been carried out in the last five years. It is worthwhile reviewing the findings of these studies to provide an independent basis against which to view the economic forecasts developed in this annex.

The Ontario Economic Council (51, 14) produced two forecasts of output in Ontario for the period 1977-87. The first of these, published in 1977, forecasts a growth rate from 1975 to 1987, of 3.2 percent in manufacturing output, 3.3 percent in all goods producing industries and 4.2 percent in the provincial economy's real domestic product. The 1978 updating of this study has these growth rates at 4.8 percent, 4.4 percent and 4.6 percent respectively. In both studies, the rates are slighlty in excess of the corresponding rates for Canada as a whole.

The DREE report (10) forecasts a growth in Ontario's real domestic product of three to four percent, rising to between five and 5.5 percent in the early eighties. The rate is expected to moderate to between four percent and five percent in 1983 and 1984. These rates were presented with a large caution that they might be optimistic given the June, 1979 petroleum price increases by OPEC.

A background paper for the Ontario Royal Commission on Electric Power Planning (Porter Commission) (21) uses a forecasted provincial growth rate of 3.5 percent as developed by TEIGA. The forecasted energy demand to 2000, showed an increase between 3.4 percent and 3.7 percent annually, depending upon the energy conservation scenario used. The Commission itself in its publicaton A Race Against Time, employed a long-term industrial growth rate of four percent (50).

The federal EMR department, in its Energy Strategy for Canada, projects growth rates of 5.8 percent in GNP annually between 1975 and 1980, and 3.2 percent thereafter to 1990 (7). This translates to a 15-year growth rate of 4.1 percent. This rate, of course, is for the national economy, but, given the predominance of Ontario, the results are probably indicative of provincial growth. A second EMR report uses a GNP growth rate of 3.4 percent to 2000 and 1.6 percent thereafter to 2025 (17). The Economic Council of

Canada's CANDIDE model produced scenarios with growth rates between 3.6 and 4.3 percent for the 1981 to 1985 period (7). Finally, Brooks forecast an industrial growth rate of 1.7 percent through 2025 in a study of the impact of energy conservation (4).

The variability in the forecasted annual growth rates is notable (Table 2). The Brooks forecast is heavily attuned to energy conservation, and thus may be a shade to the low side of the range. The second EMR forecast was done on the premise that government policy could cut in half the annual growth of energy use by 2025, and indicate the growth rates required to achieve this objective. The industrial growth rate which emerges for the long-term is between three and four percent. It should be noted that all studies used a population growth rate for Ontario of 1.5 percent annually.

TABLE 2 CANADA: A SURVEY OF ONTARIO AND CANADIAN ECONOMIC GROWTH RATES

Agency	Forecasting Parameter	Area Covered	Period	Growth Rate % (Compounded Annually)
Ontario Economic Council	real domestic product	Ontario	1977-87	3.4 (manufacturing) 3.3 (all goods production) 4.2 (total activity)
Ontario Economic Council	real domestic product	Ontario	1978-87	4.8 (manufacturing) 4.4 (all goods production) 4.6 (total activity)
DREE	real domestic product	Ontario	1979 1980-82 1983-84	3 - 4 5 - 5.5 4 - 5
Porter Commission	real domestic product	Ontario	1976-2000 1976-2000	3.5 (background study) 4 (interim report)
EMR	industrial output	Canada	1975-80 1980-90 1975-90	5.9 3.7 4.1
EMR	gross national product ($1975)	Canada	1975-2000 2000-25	3.4 1.6
Brooks	manufacturing output ($1961)	Canada	1975-2025	1.7
Economic Council of Canada	gross national product (real)	Canada	1981-85	3.6 (low) 4.3 (high)

In this study, the principal growth rates developed were: population - 1.6 percent; manufacturing output - 3.7 percent; power production - 4.6 percent; irrigation - 1.5 percent; and livestock - 1.6 percent. If these are placed into the context of the independent study results, they are very similar. The population growth rates, and the rates which depend upon them, are virtually identical. The industrial growth rate is shaded toward the upper end of the range which emerges from Table 2. The power production growth rate may be somewhat on the high side, but it is maintained because it accords with the official forecast of Ontario Hydro.

2.1 Municipal Water Use: United States

Municipal water withdrawals for domestic purposes are broken down into the following approximate percentages of total withdrawals:

Flushing toilets	41%
Washing and Bathing	37%
Kitchen Use	6%
Drinking Water	5%
Washing Clothes	4%
General Household Cleaning	3%
Lawns and Gardens	3%
Washing Cars	1%

Municipalities also provide water for fire protection, street cleaning, public swimming, heating and air conditioning, and most commercial needs. Commercial establishments, requiring widely variable quantities of water (Table 3), constitute a significant portion of central system water requirements. These requirements are included in the municipal supply category.

TABLE 3 U.S. PERCENTAGES OF TOTAL MUNICIPAL WITHDRAWALS AND CONSUMPTIVE USE FOR COMMERCIAL PURPOSES

LAKE BASIN	1975		1985		2000	
	W	C	W	C	W	C
Superior	33%	25%	32%	25%	31%	25%
Michigan	28	54	28	53	27	52
Huron	34	29	33	33	31	22
Erie	22	19	22	19	21	20
Ontario	26	11	26	26	25	26

W (Withdrawals)
C (Consumptive Use)

Municipal water supplies are obtained directly from the Great Lakes and from three inland sources in the drainage basins including ground water, inland streams and reservoirs. Because a large portion of the basin population is concentrated in urban areas in close proximity to the Great Lakes, these lakes currently supply an average of about 80 percent of the region's municipal requirements. This concentration is expected to continue and contribute to increasing municipal water needs in metropolitan areas (66). Table 4 indicates the approximate percentage of total municipal withdrawals and consumption derived from the Great Lakes as estimated for the National Water Assessment, Great Lakes Region Summary (72).

TABLE 4 U.S.: PERCENTAGE OF TOTAL MUNICIPAL WITHDRAWALS AND CONSUMPTIVE USE DERIVED FROM THE GREAT LAKES
(CU is constant proportion of withdrawal)

LAKE	1970	2020
Superior	59%	71%
Michigan	80%	73%
Huron	71%	79%
Erie	85%	85%
Ontario	39%	52%

2.1.1 Most Likely U.S. Projection

A distinction in expected water use trends was made between the Great Lakes population served by lake and non-lake sources. In the case of the population served by lake sources, a conservative estimate of a 10 percent increase in per capita water withdrawals and consumption from 1975 to 2000 was assumed as contrasted with an expected nation-wide average increase of about 27 percent (65). No increases in commercial withdrawal and consumptive use rates were assumed for the MLP as per capita figures are not available for this portion of the municipal sector. The per capita rates of water withdrawal and consumptive use for the Great Lakes population served by non-lake sources were assumed to remain constant over the projection period in accordance with the NAS assumption that future increases would be equal to quantities conserved.

Leakage losses are assumed to be 100 percent. This relatively small volume is the net leakage as opposed to the high total leakage reported in municipal water systems. Some of the water may eventually be returned to the Great Lakes system via ground-water flow but it is not possible to accurately determine what proportion of this water might be returned or the duration of subsurface travel (62). A large portion of the total leakage will return directly to the system through sewer lines.

The MLP for municipal withdrawals (Table 13) was derived as follows:

1. Per capita withdrawal rates (Table 5) were modified from the NAS per capita figures by assuming a 10 percent increase in the 1975 rate to be attained by the year 2000.

TABLE 5 U.S.: MLP PER CAPITA WITHDRAWAL RATES
(gpcd)

LAKE BASIN	1975	1985	1995	2000
Superior	75.2	78.2	81.2	82.7
Michigan	110.0	114.4	118.8	121.0
Huron	76.8	79.9	82.9	84.5
Erie	133.1	138.4	143.7	146.4
Ontario	87.8	91.3	94.8	96.6

2. Estimates for population served by lake and non-lake sources were obtained by multiplying the NAS total municipal service population (Table 6) by the estimated percentages of municipal water supply from each type of source (Table 7).

TABLE 6 U.S.: MUNICIPAL SERVICE POPULATION PROJECTIONS - - NATIONAL ASSESSMENT STUDY

LAKE BASIN	1975	1985	2000
Superior	385,700	397,200	413,400
Michigan	11,679,400	12,933,600	14,746,000
Huron	770,500	918,200	1,135,800
Erie	10,565,200	11,646,100	13,165,300
Ontario	1,899,300	2,155,800	2,542,800
	25,300,100	28,050,900	32,003,300

TABLE 7 U.S.: ESTIMATED PERCENTAGE OF MUNICIPAL SUPPLY FROM THE GREAT LAKES

LAKE BASIN	1975	1985	2000
Superior	60%	63%	66%
Michigan	79	78	76
Huron	72	73	76
Erie	85	85	85
Ontario	40	43	47

3. Population figures were multipled by the appropriate per capita withdrawal rates to obtain municipal domestic withdrawals from the lake and non-lake sources for 1975, 1985, 2000.

4. The NAS figures for commercial withdrawals from lake and non-lake sources were added to the municipal domestic withdrawals to obtain total municipal withdrawals from the Great Lakes and non-lake sources for 1975, 1985, and 2000.

5. Total municipal withdrawals for the entire projection period were obtained by interpolation and extrapolation.

The MLP for municipal consumptive use (Table 13) was derived as follows:

1. Per capita consumptive use rates were modified from the NAS per capita figures with the assumption of a 10 percent increase in the 1975 rate to be attained by the year 2000.

2. Estimates of population served by lake sources in each basin were multiplied by per capita rates to obtain consumptive use figures without conservation.

3. Lake served population multiplied by two gpcd produced net leakage estimates for each lake basin (Table 8) which were added to the domestic consumptive use figures.

TABLE 8 U.S.: MUNICIPAL SYSTEM LEAKAGE ESTIMATES FOR THE GREAT LAKES (cfs)

LAKE BASIN	1975	1985	2000	2015	2035
Superior	.7	.8	.9	.9	1.0
Michigan	28.6	31.3	34.7	38.1	42.6
Huron	1.7	2.1	2.7	3.3	4.1
Erie	27.8	30.7	34.7	38.7	44.0
Ontario	2.4	2.9	3.7	4.5	5.6
	61.2	67.8	76.7	85.5	97.3

4. NAS figures for commercial consumptive water use from lake sources, the domestic municipal consumption and leakage estimates were summed to obtain total consumptive use from the lakes. Projections to 2035 were obtained by extrapolation.

5. Ratios of NAS consumptive use versus withdrawals in the non-lake served municipal sector were multiplied by the non-lake domestic withdrawal projections to obtain domestic consumptive use with assumed conservation.

6. NAS non-lake commercial consumptive use figures were added to these domestic use projections to obtain total non-lake municipal consumptive water use. Projections to 2035 were obtained by extrapolation.

2.1.2. U.S. Alternative Projections

2.1.2.1 Projection 2

This projection (Table 13) was extracted from the Great Lakes Basin Framework Study.

1. Per capita usage rates were obtained from regional planning studies and municipality records. OBERS SERIES C population projections were used in the water use formulations. Broad variations in per capita usage exist throughout the basin,

however an average rate of change was applied to develop the projections. The gallons per capita daily (gpcd) domestic and commercial water usage was assumed to change at the rate of one percent per year to 108 gpcd. A rate of increase of 0.25 percent per year was applied above 108 gpcd to a maximum of 130 gpcd. The proportion of municipally supplied water for industrial use in 1970 was determined and this proportion was added to each of the target year projections of domestic and commerical water usage. The per capita rates for municipal withdrawals (Table 9) thus represent the average usage rates for combined domestic, commercial, and centrally supplied industrial withdrawals as reported by the planning subareas comprising each of the major lake basins (66). These per capita use rates are higher than those in the MLP because centrally supplied industrial water is transferred to the manufacturing sector in the MLP.

TABLE 9 U.S.: ESTIMATED PER CAPITA MUNICIPAL WITHDRAWAL RATES-PROJECTION 2 (gpcd)

LAKE BASIN	1970	1980	2000	2020
Superior	127	140	151	159
Michigan	196	194	192	192
Huron	173	183	193	203
Erie	177	180	187	192
Ontario	181	187	193	197

2. Estimates of future water usage in the lake basins are based on the relationship (66).

$$N = \frac{(gpcd) \quad (f) \quad (P)}{10^6}$$

where, N = water needs in the target year (mgd)
gpcd = daily per capita water use for each lake basin

f = water use coefficient given by the product a x b, where

$$a = \frac{\text{maximum monthly daily use (gal.)}}{\text{average daily use (gal.)}}$$

$$b = \frac{\text{total municipal use (gal.)}}{\text{domestic-commercial use (gal.)}}$$

P = population projected to be served by municipal sytems in the target year.

This calculation was applied to lake and non-lake municipal water sources.

3. Municipal consumptive water use increases from nine percent to 12.4 percent of water withdrawals through the projection period (66). The domestic and commercial portion was assumed to average 10 percent through the projection period. Projections of water use from 2020 to 2035 were obtained by extrapolation.

2.1.2.2 Projection 3

This projection (Table 13) constitutes the NAS municipal withdrawal and consumptive use estimates (67).

Water Withdrawal

1) Estimates of total domestic central system water use for the Region were obtained from the original data used to compile the USGS. Circular 765, "Estimated Use of Water in the United States in 1975" (43). The original data was compiled by aggregated subareas (ASA) for the NAS so no direct comparison can be made with the subtotals in the published report. The 1975 central system water withdrawals for the region were obtained directly as the residual of total public systems withdrawal minus industrial and commercial withdrawal.

2) 1975 USGS estimates of population served by central systems were divided into the total withdrawal figures for each A.S.A. to obtain a per capita withdrawal rate (Table 10). It was assumed that increased water use for water-using appliances would be counteracted by future water conservation measures and therefore these usage rates would remain constant over the projection period.

3) Estimates of population served by central systems for 1985 and 2000 were obtained from the U.S. Department of Agriculture (USDA) report to the NAS on domestic water use. Projections of the population served by central systems were based on the OBERS SERIES E projections and rates of transition from self-supplied to centrally supplied systems as determined from the 1950, 1960, and 1970 U.S. Censuses.

4) The USDA estimates of population served by central systems for 1985 and 2000 were multiplied by the 1975 per capita use rates to derive projections of domestic municipal withdrawals and the projections were extrapolated to 2035 based on extension of population trends.

Consumptive Use

1) 1975 estimates of consumptive use of domestic central supplies in the NAS were derived from the ratio of total water consumption to total withdrawals from public supply systems as indicated in the USGS data. This method assumes that the ratio between industrial, commercial and domestic central system users is relatively constant. The withdrawal figures obtained for each of these central system users were multiplied by the standard ratio to derive consumptive use estimates for commercial and domestic segments.

2) 1975 USGS estimates of population served by central systems were divided into the domestic consumptive use figures for each ASA to obtain a per capita consumptive use rate for each area (Table 10).

3) User population estimates for 1985 and 2000 were obtained from the USDA projections based on the OBERS SERIES E projections and historical rates of transition from self-supplied to central supplied systems. These population estimates were multiplied by the constant per capita consumptive use rates to derive total consumptive use for the projected years.

4) The NAS projected consumptive use figures were extrapolated to 2035.

TABLE 10 U.S.: ESTIMATED PER CAPITA WITHDRAWAL AND CONSUMPTIVE USE RATES - PROJECTION 3 (gpcd)

LAKE BASIN	Withdrawals	Consumptive Use
Lake Superior	75.2	7.5
Lake Michigan	110.0	4.0
Lake Huron	76.8	6.4
Lake Erie	133.1	18.6
Lake Ontario	87.8	14.8

2.1.2.3 Projection 4

This set of water use estimates (Table 13) utilized a set of population projections obtained from State Census reports (Table 11) rather than the OBERS SERIES E projections to determine if projections based on the different population estimates are significant.

The population estimates were generated by agencies within the states during various years from 1975 to 1978. Table 12 indicates the percentage difference of the OBERS SERIES E estimates from the State Census projections. These percentages also represent the approximate difference between OBERS SERIES E projections and existing 208 population estimates, since there is no significant difference between State Census and available Section 208 figures (45).

TABLE 11 U.S.: STATE CENSUS POPULATION PROJECTIONS

LAKE BASIN	1975	1985	2000
Superior	522,100	543,622	575,906
Michigan	13,632,300	14,715,303	16,339,808
Huron	1,303,600	1,418,351	1,590,478
Erie	10,786,617	11,459,998	12,470,069
Ontario	2,234,000	2,410,200	2,674,500
Total	28,478,617	30,547,474	33,650,761

TABLE 12 U.S.: PERCENT DIFFERENCE OF OBERS E POPULATION PROJECTIONS FROM STATE CENSUS FIGURES

LAKE BASIN	1975	2000
Superior	+2.4%	-8.3%
Michigan	+4.0	+3.2
Huron	+0.9	+5.5
Erie	+11.1	+14.4
Ontario	+6.5	+12.9
Total	+6.7	+8.0

Differences in the population projections are a result of several factors including variation in census data boundaries, sampling techniques, and projection methods. Neither data set appears to contain sophisticated sampling or projection techniques that should make it superior to the other.

The following procedure was used to develop Projection 4 water use projections:

1. State Census population data for counties within the Great Lakes basin were aggregated by the same basin sub-areas used in the NAS.

2. The percentages of total population served by municipal systems in each lake basin were calculated as the ratio of municipal population determined in the NAS to total OBERS SERIES E projections for each lake basin. These percentages were applied to the State Census figures to determine the municipal population by lake basin.

3. The municipal population in each basin was multiplied by the NAS per capita withdrawal and consumptive use rates to derive the withdrawal and consumptive use projections.

2.1.2.4 Projection 5

The movement toward water conservation has become sufficiently active that a conservation scenario was thought to be a viable projection of future water-use trends. The GLBC Great Lakes Basin Plan Water Conservation Assessment in an analysis of municipal, industrial, and agricultural water use concludes that the greatest benefits from water conservation in the Great Lakes basin would result from efforts in the municipal sector. An estimate of 10 percent reduction in total water withdrawals for municipal use was chosen as a result of conversations with members of the Commission staff. This figure was thought to represent a realistic estimate of the average saving of water throughout the basin if a moderate effort was successfully implemented (44).

The following procedure was used to derive Projection 5 (Table 13):

TABLE 13 U.S.: MUNICIPAL WATER USE PROJECTIONS (CFS)

	MLP		Projection 2 High		Projection 3		Projection 4		Projection 5 Low	
Year	W	C	W	C	W	C	W	C	W	C
1975	6120	670	6120	670	6120	610	5800	610	6120	670
1980	6510	710	6700	680	6430	640	6070	640	6300	690
1985	6900	750	7260	880	6740	670	6340	670	6470	700
1990	7290	790	7820	990	7030	700	6620	690	6600	720
1995	7690	830	8360	1100	7310	730	6890	720	6730	740
2000	8070	880	8920	1210	7620	760	7160	750	6860	750
2005	8460	920	9640	1340	7930	790	7430	780	7140	780
2010	8850	960	10370	1480	8200	820	7710	800	7380	810
2015	9240	1000	11090	1610	8490	850	7980	830	7650	840
2020	9630	1040	11810	1750	8800	880	8250	860	7920	870
2025	10020	1090	12710	1880	9090	910	8520	890	8180	910
2030	10410	1130	13600	2020	9400	940	8800	910	8460	940
2035	10800	1170	14500	2160	9710	980	9070	940	8740	970
BASIS	Modified NAS, Usage Increase, Leakage		Framework Study		NAS Figures		State Census Populations		Modified MLP, Conservation	

W (Withdrawals)
C (Consumption)

1. The NAS municipal withdrawal and consumptive use figures were adjusted by including the Lake Huron diversion, deleting the diversion out of Lake Michigan and adding leakage estimates that were used in the MLP. The figures for 1975 to 2000 were then multiplied by the fraction corresponding to attainment of a 10 percent decrease in water use over this period.

2. Per capita water use was assumed to remain constant at the rates for 2000. NAS water use figures for years 2005 to 2035 were multiplied by 0.90 to obtain conservation estimates throughout the projection period.

2.2 Municipal Water Use: Canada

The Great Lakes basin is one of Canada's most urbanized regions, with about 85 percent of the population in the basin served through centralized water distribution systems. The estimation of current and future municipal water use is therefore an important component of the overall project. The municipal water uses included here are residential, commercial, institutional and system losses. Manufacturing withdrawals from municipal systems are considered in Section 4.2.

2.2.1 Detailed Methodology for Municipal and Rural Domestic Sectors

2.2.1.1 County Population Forecasts

Two sets of population forecasts formed the basis of projecting municipal water use. These forecasts, prepared by Ontario's Ministry of Treasury, Economics and Intergovernmental Affairs (TEIGA) (13), reflect alternative assumptions as to fertility, with net migration held constant at 50,000 persons per year. The two levels of fertility are termed low and medium by TEIGA. The high-fertility-based forecast was not used because recent demographic trends indicate a trend to smaller families, and consequently lower population growth. The forecasts used were available by county, covering a period from 1971 to 2001. Linear regression equations using an exponential form were derived to describe the population growth for each county and for each forecast set. These were used to extend the available forecasts to 2035. In mathematical terms:

$$P_{i,t} = P_i \cdot e^{rt} \qquad (i = 1...42,\; t = t, t+5, t+10, ..., t+60)$$

where $P_{i,t}$ = the present population in the county i in period t, where t represents the base year 1975 and t = 60 is the last forecast year 2035.

e = 2.71828...
r = annual average growth rate (as calculated from the 1971-2001 population forecast).

For each reporting year of the forecast period, a diagonal matrix of county populations was formed, wherein the population figures comprise the principal diagonal of the matrix, and all off-diagonal elements are equal to zero. The notation $P_{i,t}$ is used to symbolize this matrix in time t.

2.2.1.2 Basin Disaggregation

Since many of the counties fall into two or even three basins, the proportion of the total county population falling into each basin had to be calculated. An analysis done at the Canada Centre for Inland Waters (CCIW) gives population by lake basin from 1901 to 1971 (2), but, for the current research only the period 1951 to 1971 was used. Total county populations for the same period were obtained from Statistics Canada. For each five-year interval, the proportion of county population falling into each basin was calculated, following which the time trend of the proportions was analyzed. In most cases, the proportions were remarkably stable and thus were left constant over the forecast period. Where a time trend did exist, the method of three-period rolling averages was used to project the proportions. Mathematically, this method is summarized as follows:

Calculation of proportions

$$D_{i,t,j} = \frac{P_{i,t,j}}{P_{i,t}} \qquad \begin{aligned}(i &= 1...42 \\ t &= t-24,\ t-19,\ t-4 \\ j &= 1...5\end{aligned}$$

where $D_{i,t,j}$ = the proportion of county i's population in time t residing in basin j
$P_{i,t,j}$ = the number of persons in county i in time period t also residing in basin j
$P_{i,t}$ = as defined above

Calculation of three-period rolling averages: The model is calibrated for the period 1951-1971.

$$\overline{D}_{i,t,j} = \frac{D_{i,t-5,j} + D_{i,t,j} + D_{i,t+5}}{3} \qquad \begin{aligned}(i &= 1...42 \\ t &= t-19,\ t-14, \\ & t-9)\end{aligned}$$

where $D_{i,t,j}$ = the three-period average proportion of the number of county i's population in time t residing in basin j.

Iterations of this model past t-9 (i.e. 1966) entail calculating a value for D in years after 1971. To do this, an average annual rate of change M_i (i = 1...42) in the proportion of county population residing within each basin was calculated for the period 1951 to 1971. Then:

$$\overline{D}_{i,t,j} = D_{i,t-b,j} \cdot M_i^{\,b} \qquad \begin{array}{l}(i = 1...42)\\ t = t-4,\ t+5,\ t+10,\ ...,\ t+65\\ j = 1...5\end{array}$$

where b = the number of years over which M_i is compounded. In this case b = 5 in all cases.

After $\overline{D}_{i,t,j}$'s are calculated, diagonal matricies $\overline{D}_{i,t,j}$ one for each reporting period, are composed by allocating each $\overline{D}_{i,t,j}$ to a position on the principal diagonal of a matrix, with all off-diagonal elements equal to zero.

2.2.1.3 Municipal Population Forecasts

The total county population forecasts must be split into municipal and rural components. This involved analyzing the municipal/rural split of population in each of the counties since 1951 and projecting it to 2035. The rolling average method was used in projecting the municipal/urban split. Because of rapid urbanization, use of the rolling average method often resulted in forecasts which classified the entire population of a county as municipal. When this occurred, a ceiling was placed on the municipal proportion of the population, beyond which the municipal/rural proportion for the county was held constant. This ceiling was somewhat artificial, but was based upon the judgement of the authors, taking account of overall population trends, locational factors, etc.

In mathematical terms, the first step was to calculate the municipal proportion of total population from 1951 to 1971, as follows:

$$E_{i,t} = \frac{M_{i,t}}{P_{i,t}} \qquad (i = 1...42,\ t = t-24,\ t-19,\ t-4)$$

where $M_{i,t}$ = the municipal population of county i in year t.

Second, calculate a long-term average annual rate of change in $E_{i,t}$, based upon the 1951 to 1971 period. Using this rate of change calculate the projected municipal proportion of country population for the reporting periods to 2035.

$$E_{i,t} = E_{i,t-b} \cdot L_i^b \qquad (i = 1 \ldots 42;\ t = t,\ t + 5 \ldots t + 60)$$

where L_i = the average annual rate of change in a county's population over the 1951 to 1971 period.

b = the number of years over which the growth rate is compounded. For 1971 to 1975, b = 4; for forecasts after 1975, b = 5.

Third, for all reporting periods in the time frame, calculate an average value of $E_{i,t}$, based on the rolling average method. These values are designated $E_{i,t}$, and represent the municipal proportions of county populations for future reporting periods. These proportions were adjusted, as outlined earlier, in cases where they approached or exceeded one. Following this adjustment process, a diagonal matrix $E_{i,t}$ was formulated for each reporting period, wherein the individual $E_{i,t}$'s form the principal diagonal and all off-diagonal elements are zero.

2.2.1.4 Municipal Water Use Analysis

Two major municipal water uses are considered in this section: domestic and commercial-institutional. The only reliable Canadian source which provides data on these uses is the 1975 National Inventory of Municipal Waterworks and Waste Treatment Systems (9). The individual municipal responses to this inventory were used to develop per capita water use coefficients. These raw coefficients show considerable variation among municipalities, as a result of inconsistencies in measurements, misclassification of water use by some municipalities, uncertainty, etc. To allow for these errors, the following analysis technique was adopted:

a. Eleven groups of counties comprising the Great Lakes region were chosen. This was done because each county by itself has insufficient useable data to permit statistical analysis. The eleven groups are:
   - I: Lambton, Kent, Essex
   - II: Perth, Huron, Wellington
   - III: Bruce, Grey Dufferin
   - IV: Elgin, Middlesex, Oxford
   - V: Brant, Haldimand-Norfolk, Waterloo
   - VI: Hamilton-Wentworth, Niagara, Halton, Peel
   - VII: Simcoe, York, Metropolitan Toronto, Ontario
   - VIII: Durham, Victoria, Peterborough, Haliburton, Hastings, Northumberland
   - IX: Frontenac, Leeds, Grenville, Lennox and Addington
   - X: Algoma, Manitoulin, Muskoka, Nippissing, Parry Sound, Sudbury
   - XI: Thunder Bay

   The groupings were arbitrarily made but the objective was to obtain contiguous groups of counties with at least 15 municipalities in each.

b. The coefficients of domestic and commercial-institutional water use per capita for each of the eleven groups were ordered from low to high.

c. To eliminate extreme values, the data falling below the tenth percentile and above the ninetieth percentile were eliminated from each group.

d. The mean, median and standard error of the mean of each group were calculated, following a logarithmic transformation of the data.

e. The mean and median coefficients were selected as two of the values to be included in the forecasting model. To account for the variation in the means of each group, coefficient values two standard errors above and below the mean values were also selected for inclusion in the model. The coefficients thus derived were assumed to apply to each county in the respective groupings.

f. System losses were assumed to be 10 percent of the sum of the domestic plus commercial-institutional coefficients.

g. The result of this analysis was four sets of water withdrawal coefficients (i.e. mean, median, mean $\pm$ two standard errors of the mean) for each use category (i.e. domestic and commercial-institutional) for each group of counties.

h. Four coefficient matrices were formed for the water use coefficients. The rows of these matrices are the individual counties and the columns are the three water uses. The matrices are noted as:
W_1 = average water withdrawals per capita
W_2 = median water withdrawals per capita
W_3 = low water withdrawals per capita (i.e. mean - 2 standard errors)
W_4 = high water withdrawals per capita (i.e. mean + 2 standard errors)

These coefficients are shown in Table 14 by the eleven county groupings used in the analysis. They show considerable, and as yet unexplained, variation. The mean residential water use coefficient, for example, varies from a low of 53.7 gpcd to a high of 100.4 gpcd. Generally, southern and southwestern parts of the basin experience lower per capita usage rates, while the high values occur in the northern and eastern areas. In all cases, the coefficient distribution was found to be skewed, either to the left or right of the mean, with no consistency in the direction of skew. On the average the coefficients for residential use fall within $\pm$18 percent of the mean.

TABLE 14 CANADA: MUNICIPAL WATER USE COEFFICIENTS BY COUNTY GROUPING

(gallons per capita per day except where indicated)

County Grouping	Residential Water Use High	Residential Water Use Mean	Residential Water Use Low	Commercial Water Use High	Commercial Water Use Mean	Commercial Water Use Low	Losses[1] (%)	Consumption[2] Rate (%)
1. Lambton, Kent, Essex	66.8	55.6	46.3	16.8	11.2	7.5	10	15
2. Perth, Huron, Wellington	74.0	62.7	53.7	13.5	10.0	7.4	10	15
3. Bruce, Grey, Dufferin	83.5	73.5	64.7	16.7	12.7	9.7	10	15
4. Elgin, Oxford, Middlesex	63.1	53.7	45.7	17.6	10.2	5.6	10	15
5. Brant, Haldimand-Norfolk, Waterloo	66.7	54.4	44.4	21.3	15.2	10.9	10	15
6. Niagara, Wentworth, Halton, Peel	64.0	54.8	47.0	22.1	17.3	13.5	10	15
7. Simcoe, York-Metro Toronto, Ontario	58.8	51.4	45.0	23.4	18.3	14.4	10	15
8. Victoria, Peterborough, Hastings, Northumberland	84.7	75.5	67.3	19.5	15.0	11.6	10	15
9. Eastern Ontario (Frontenac, Leeds, Lennox & Addington, Grenville)	88.5	72.5	59.3	24.5	16.9	11.7	10	15
10. Haliburton, Nippissing, Muskoka, Parry Sound, Sudbury, Algoma	97.5	83.2	71.1	14.8	10.2	7.1	10	15
11. Thunder Bay	124.8	100.4	80.7	39.1	28.0	20.0	10	15

1. Defined as a percentage of residential plus commercial water uses.
2. Defined as a percentage of residential plus commercial water uses plus estimated losses.

The mean commercial water use coefficients vary between 10.0 gpcd and 28.0 gpcd, with an areal variation similar to that outlined for the residential coefficients. The band of variation is quite broad, with the coefficients falling within ± 40 percent of the mean. Again an unexplained skewness is apparent. Sources of variation in the two sets of coefficients rest mainly with estimation problems and different classification methods used by the respondents to the original survey.

2.2.1.5 Calculation of the Municipal Water Demands

i. To calculate the total county population in reporting period t residing in each basin $(C_{i,t,j})$:

$$(C_{i,t,j}) = (P_{i,t}) \cdot (D_{i,t,j}) \qquad \begin{pmatrix} i = 1 \ldots 42 \\ t = t, t+5, t+10, \ldots, t+60 \\ j = 1 \ldots 5 \end{pmatrix}$$

ii. To calculate the municipal population of each county residing in each basin $F_{i,t,j}$:

$$(F_{i,t,j}) = (E_{i,t}) \cdot (C_{i,t,j}) \qquad \begin{pmatrix} i = 1 \ldots 42 \\ t = t, t+5, t+10, \ldots, t+60 \\ j = 1 \ldots 5 \end{pmatrix}$$

iii. To calculate municipal water intake in three use categories by basin:

$$(MWI^n_{t,j}) = (F_{i,t,j}) \cdot T(W_n) \qquad \begin{pmatrix} i = 1 \ldots 42 \\ t = t, t+5, t+10, \ldots, t+60 \\ j = 1 \ldots 5 \\ n = 1 \ldots 4 \end{pmatrix}$$

where $MWI^n_{t,j}$ = total municipal water use in category in time t and basin j, for each of the n sets of coefficients, where n = 4

$F_{i,t,j}{}^T$ = the transpose of $F_{i,t,j}$

iv. Municipal water consumption is assumed to be 20 percent of total withdrawal (61). Thus total water consumption by category and by basin, $MC^n_{t,j}$ is:

$$MC^n_{t,j} = .20(MWI^n_{t,j}) \qquad \begin{pmatrix} t = t, t+5, t+10, \ldots, t+60 \\ j = 1 \ldots 5 \\ n = 1 \ldots 4 \end{pmatrix}$$

v. Rural residential water intake (RWI) is assumed to be 35 gallons per capita-day; 60 percent of which is consumed. Thus:

$$RWI_{t,j} = 35(C_{Ltj} - F_{Ltj})$$

$$RC_{t,j} = 0.6(RWI_{t/j}) \qquad (t = t, t + 5, t + 10, \ldots, t + 60; \; j = 1 \ldots 5)$$

2.2.2 Assumptions

Two types of assumptions are built into the methodology. The first type relates to demographic assumptions underlying the population projections. The two alternatives selected employ the same assumption about migration into the province at a level of 50,000 persons per year. They differ only in their fertility assumption, one being designated a low fertility projection, the other a medium fertility projection. The second type of assumption relates to the reliability of the coefficients to reflect the underlying variables of municipal water use. This assumption is open to criticism (58) centering upon the inability of coefficients to account for variables such as water availability, water pricing structures, and several other sources of structural variation. However, the coefficients approach is a standard one, and two features of the present study permit its use. First, the level of disaggregation is only to the lake basin level, a fairly broad one in spatial terms. Thus, errors which might occur at the individual municipal level are assumed to be compensating ones at the broader level. The caveat mentioned above follows from this, namely that the forecasts presented here cannot be disaggregated without introducing undefined, but possibly critical errors. The second mitigating factor is that the coefficients have been allowed to assume four different values. Most of the variations in municipal water use will be captured in this way.

2.2.3 Discussion of Results

2.2.3.1 Demographic Levels and Trends

Population in the Canadian section of the basin in 1975 totalled just over 7.1 million persons. Erie and Ontario basins accounted for 82 percent of this total. The Canadian part of the basin is heavily urbanized, with about 85 percent of the total population residing in communities of 1,000 or more persons. This population, about six million persons, is the population considered to be served from central water supply systems (Table 15).

By 2035, Canada's population in the basin will have grown to 18.1 million persons under the medium growth assumption and 16.8 million under the low growth assumption. These represent annual increases of 1.6 percent and 1.4 percent respectively over the 60-year projection period. According to an independent study done

TABLE 15 CANADA: MUNICIPAL POPULATION BY LAKE BASIN AND SELECTED YEAR
(thousands of persons)

Lake Basin	Year	Population Medium	Population Low
Superior	1975	128	128
	1985	137	135
	2000	144	139
	2015	157	149
	2035	173	161
Huron	1975	611	611
	1985	752	745
	2000	928	897
	2015	1,184	1,127
	2035	1,588	1,476
Erie	1975	1,253	1,253
	1985	1,529	1,516
	2000	1,930	1,864
	2015	2,498	2,376
	2035	3,447	3,197
Ontario	1975	3,909	3,909
	1985	4,657	4,618
	2000	5,690	5,510
	2015	7,450	7,113
	2035	10,665	9,945
St. Lawrence	1975	153	153
	1985	165	164
	2000	176	170
	2015	193	183
	2035	211	196
Great Lakes Total	1975	6,054	6,054
	1985	7,240	7,178
	2000	8,868	8,580
	2015	11,482	10,948
	2035	16,084	14,975

by TEIGA (11), the long term population growth rate will be 1.4 percent annually, consistent with the low growth scenario. The proportion of total population resident in the two dominant lake basins will remain at 82 percent in 2035, denoting practically no intra-basin net migration over the forecast period. The highest rates of growth will be experienced in the Lake Ontario basin and the lowest in the Lake Superior basin, but these differences are quite small and have practically no impact upon overall population distribution. Slightly higher than average growth rates will be experienced in all sub-basins in the periods 1975 to 1985 and 2000 to 2015.

By 2035, municipal population is projected at between 15.0 million and 16.1 million persons depending upon the growth assumptions used. These represent 89 percent both of the total low and medium population forecasts, an increase from the current 85 percent. The Lake Ontario basin is the most heavily urbanized sub-region of the Canadian Great Lakes basin with 93 percent of its total population residing in communities of over 1,000 persons. The Erie sub-basin, in contrast, has the lowest percentage of urban dwellers, 77 percent in 1975, increasing to about 85 percent in 2035.

Rural population (i.e. farm plus communities under 1,000) totalled 1.1 million persons in 1975. This is projected to grow at between 0.9 percent and 1.1 percent per annum to between 1.9 and 2.1 million persons in 2035. The Lakes Huron and Erie basins dominate the current rural population distribution, accounting for 67 percent of the total. By 2035, the Lake Ontario basin will replace Erie as one of the dominant rural basins. A relatively rapid rate of urbanization in the Lake Erie basin will account for this displacement.

2.2.3.2 Projected Municipal Water Use for Canada

With four coefficient sets and two sets of population estimates, eight complete projections of municipal water use were calculated. Three of these, tabulated for the purposes of discussion here are termed high, medium and low; the high projection was derived using the high coefficients of Table 14 with the medium population forecasts; the medium using the mean coefficients with the medium population forecasts; and the low using the low coefficients with the low population forecast. The medium projection was employed as the MLP. The three projections of municipal water use are shown in Table 16.

3.1 Rural-Domestic Water Use: United States

The methodology used to obtain these current and projected water use figures consisted of three main steps (69):

TABLE 16 CANADA: MUNICIPAL WATER USE FORECASTS (cfs)

Lake Basin	Year	High Forecast Withdrawal	High Forecast Consumption	MLP Withdrawal	MLP Consumption	Low Forecast Withdrawal	Low Forecast Consumption
Superior	1975	-	-	30	10	-	-
	1985	50	10	40	10	30	10
	2000	50	10	40	10	30	10
	2015	50	10	40	10	30	10
	2035	60	10	40	10	30	10
Huron	1975	-	-	110	20	-	-
	1985	150	20	130	20	110	20
	2000	190	30	160	20	130	20
	2015	240	40	200	30	160	20
	2035	330	50	270	40	210	30
Erie	1975	-	-	170	30	-	-
	1985	260	40	210	30	170	30
	2000	330	50	270	40	210	30
	2015	430	60	350	50	260	40
	2035	600	90	480	70	360	50
Ontario/St. Lawrence	1975	-	-	600	90	-	-
	1985	840	130	710	110	600	90
	2000	1030	150	870	130	710	110
	2015	1330	200	1130	170	910	140
	2035	1900	280	1600	240	1260	190
Cdn. Great Lakes Total	1975	-	-	910	140	-	-
	1985	1310	200	1090	160	900	140
	2000	1600	240	1330	200	1070	160
	2015	2060	310	1720	260	1370	210
	2035	2880	430	2400	360	1870	280

Municipal Withdrawals

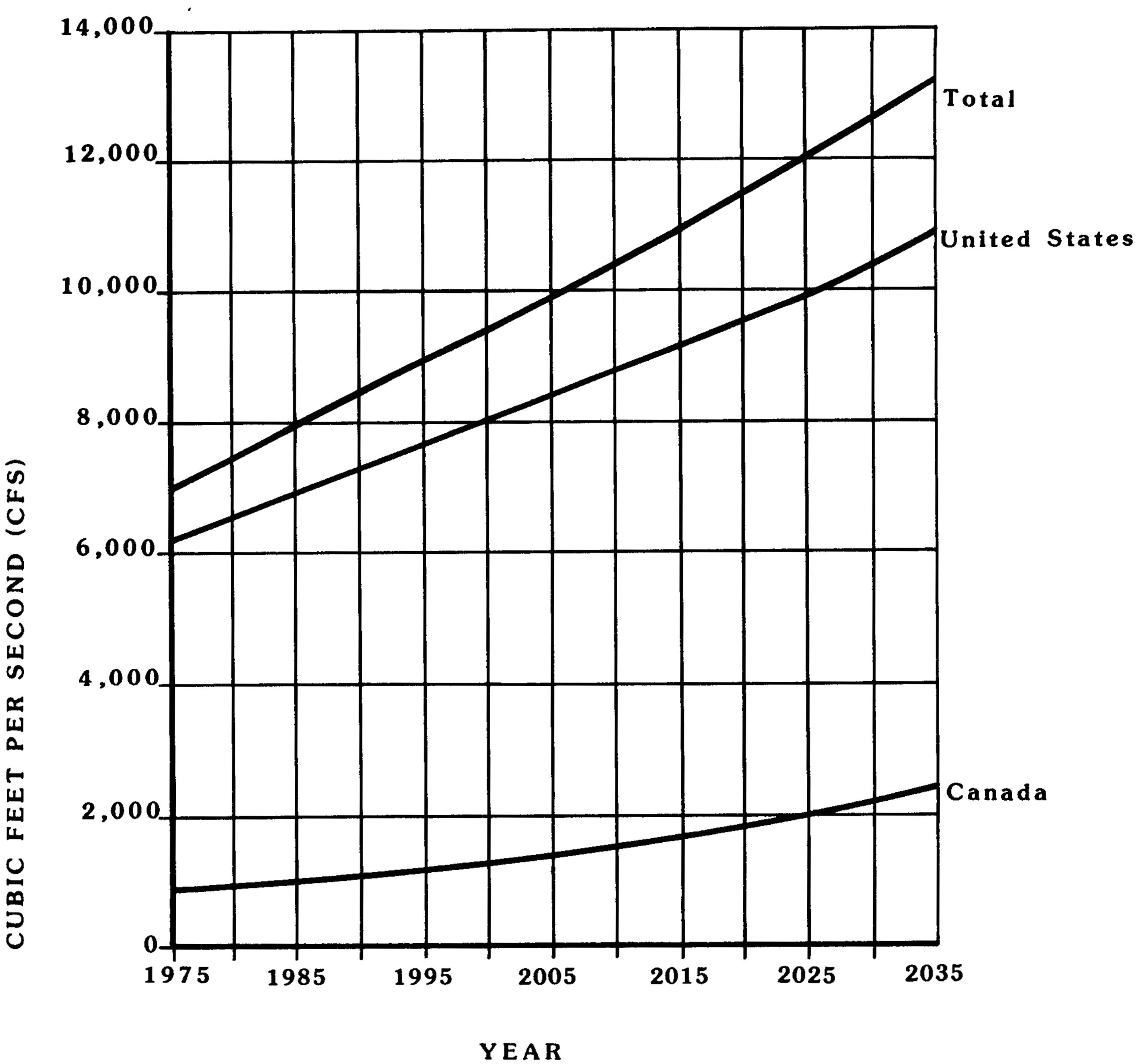


Figure F-1

Municipal Consumption

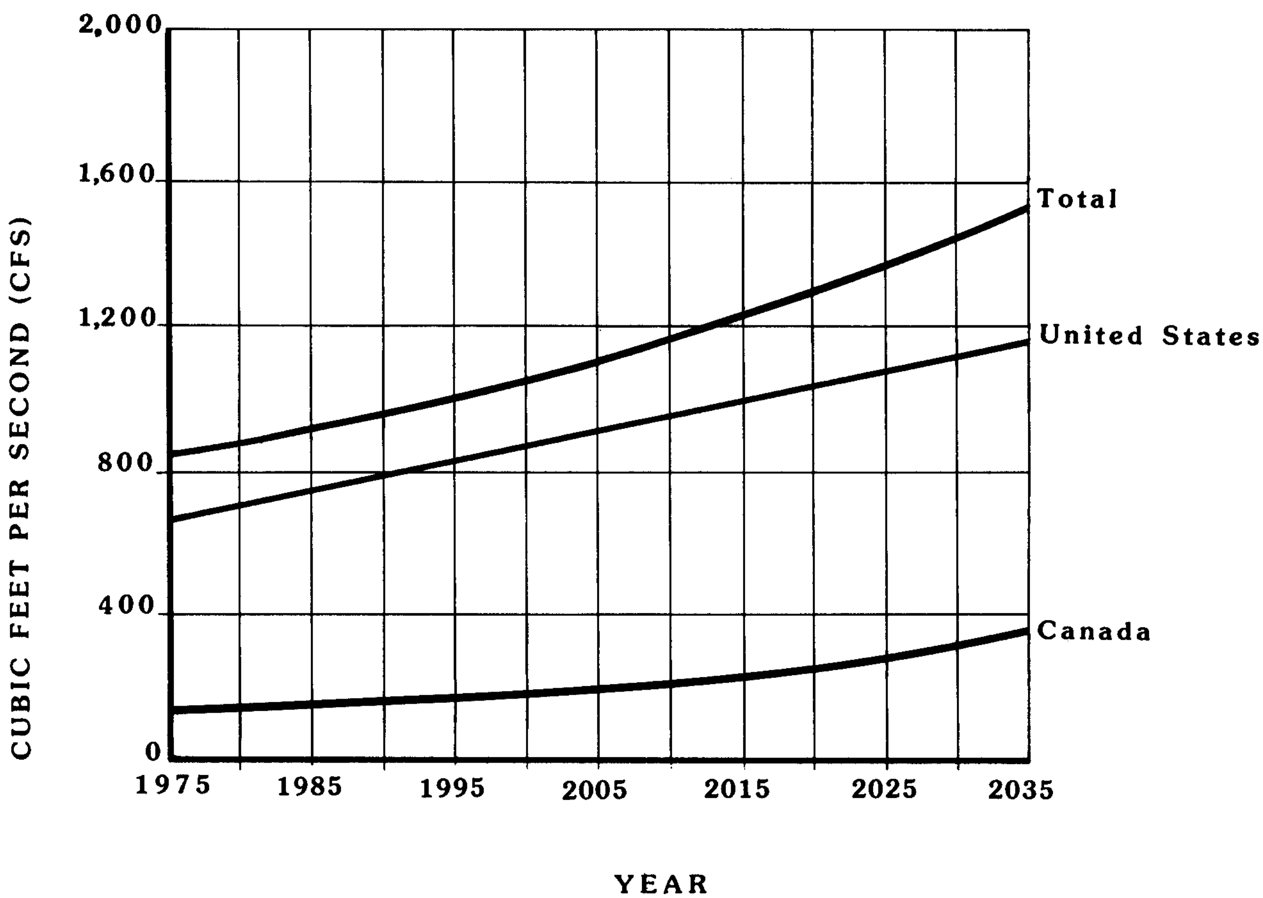


Figure F-2

1. An estimate of the number of people served by self-supplied systems in 1970 was determined with 1970 Census of Housing data. Tabulations were made of population, total housing units and units without plumbing for counties in each ASA. Data were also compiled for housing units with an individual well water source and those with other water sources. The individual well category describes a source which serves five or fewer houses. Other water sources include springs, creeks, rivers, lakes and ponds.

The number of self-supplied systems was calculated by summing the number of units with individual well and other water sources. The percentage of total housing units with self-supplied systems was obtained by dividing the number of self-supplied systems by the total number of housing units. Total population served by self-supplied systems in 1970 was calculated by multiplying the percent of units with self-supplied systems by the OBERS SERIES E 1970 population.

2. Projections of the population served by self-supplied systems were made according to the following method: tabulations for the number of housing units supplied by public systems, private companies, individual wells, and other water sources were made for 1960 and 1970 with Census of Housing Data. The standard rate of decline in numbers of self-supplied systems from 1970 was calculated from this information and assigned to each ASA on the basis of specific sub-basin characteristics (76). The population served by self-supplied systems for the years 1975, 1985, and 2000 were calculated by multiplying an appropriate rate of decline times the percentage of units with self-supplied systems in 1970 times the OBERS SERIES E population projections for 1975, 1985 and 2000 for each ASA.

The 1970 population without water under pressure was determined by using the 1970 Census of Housing tabulation and the procedure outlined for calculation of total population with self-supplied systems. 1970 population with water under pressure was obtained as the residual of the self-supplied systems population minus those without pressure systems.

3. Distinct per capita rates of rural-domestic water use were estimated for housing units with running water under pressure and without water under pressure. Since self-supplied systems are rarely metered, no specific data was available for these use rates. Per capita use estimates were based upon information supplied by the EPA, USGS Circulars and completed river basin studies (49). Average per capita use estimates are 40 gallons with and 10 gallons without pressure.

4. The population projections for pressure and non-pressure systems for 1975, 1985 and 2000 were multiplied by the corresponding per capita withdrawal and consumptive use rates and summed to obtain total withdrawals and consumptive use during the forecast period. Projections of rural-domestic water use for the period from 2005 to 2035 were derived by extrapolation.

3.2 Rural-Domestic Water Use: Canada

The current and projected water use figures for rural residential purposes are given in Table 17. Two forecasts of rural population described in Section 2.2 were used to project the water use. All withdrawals for rural-domestic purposes are from non-lake sources.

4.1 Manufacturing Water Use: United States

4.1.1 U.S. Concepts and Approach

Approximately 90 percent of U.S. manufacturing water withdrawals are made by five industry groups: food and kindred products, paper and allied products, petroleum and coal products, chemical and allied products, and primary metals processing (49). Currently, the greatest consumer of manufacturing water is primary metals processing and it is expected to maintain this ranking to 2035. The greatest rate increase in consumption within the manufacturing sector is projected for chemical and allied products where water consumption is expected to quadruple between 1975 and 2000 (19).

Most of the manufacturing industries requiring large quantities of water are located in the shoreline counties of the Basin and the lakes serve as the source of water supply for over 90 percent of current manufacturing needs. This proportion is expected to remain relatively constant to 2035 as the lakes continue to serve as a source of abundant water (23). Thus, the majority of the projected increases in consumptive use will be taken directly from the lakes. A study undertaken by the Bureau of Economic Analysis indicates that the least-cost method of meeting Clean Water Act goals for most large manufacturing water users involves a high degree of within-plant reuse of treated and untreated wastewater instead of using water on a once-through basis. The cost savings calculated by the Bureau of Domestic Commerce in new plant construction are so substantial as to induce water reuse to the optimum level. The water costs and savings may not be the same for existing manufacturing operations as the difficulties encountered in retrofitting and spacing of equipment and piping would greatly increase capital costs (49). This information influenced the development of the most likely projections for manufacturing water use. The figures were calculated on the basis of the assumption that currently existing industry would continue to recyle water at a relatively low rate while all new industry would institute recycling at relatively high rates. The low rate was assumed to represent best practicable technology (BPT) for wastewater pollution control while the high rate represents the best available technology (BAT) mandated by P. L. 95-217. Rates were originally selected for the NAS as a result of a survey of water use by 10,000 large manufacturing plants (5).

TABLE 17 CANADA: RURAL POPULATION AND WATER USE BY LAKE BASIN AND SELECTED YEAR

LAKE BASIN		POPULATION FORECASTS (thousands of persons)		WATER USE (cfs)			
				Medium Forecast		Low Forecast	
		Medium	Low	Withdrawal	Consumption	Withdrawal	Consumption
Superior	1975	20	20	0	0	0	0
	1985	22	22	0	0	0	0
	2000	24	23	0	0	0	0
	2015	27	26	0	0	0	0
	2035	31	29	0	0	0	0
Huron	1975	353	353	20	10	20	10
	1985	370	367	20	10	20	10
	2000	415	401	30	20	30	20
	2015	489	466	30	20	30	20
	2035	531	587	40	20	40	20
Erie	1975	375	375	20	10	20	10
	1985	386	383	30	20	20	10
	2000	401	387	30	20	30	20
	2015	465	442	30	20	30	20
	2035	587	554	40	20	40	20
Ontario/St. Lawrence	1975	345	345	20	10	20	10
	1985	390	416	20	10	20	10
	2000	452	437	30	20	30	20
	2015	572	544	40	20	30	20
	2035	800	744	50	30	50	30
TOTAL	1975	1093	1093	60	30	60	30
	1985	1168	1187	70	40	60	30
	2000	1292	1248	90	60	90	60
	2015	1553	1478	100	60	90	60
	2035	2049	1904	130	70	130	70

Rural - Domestic Withdrawals

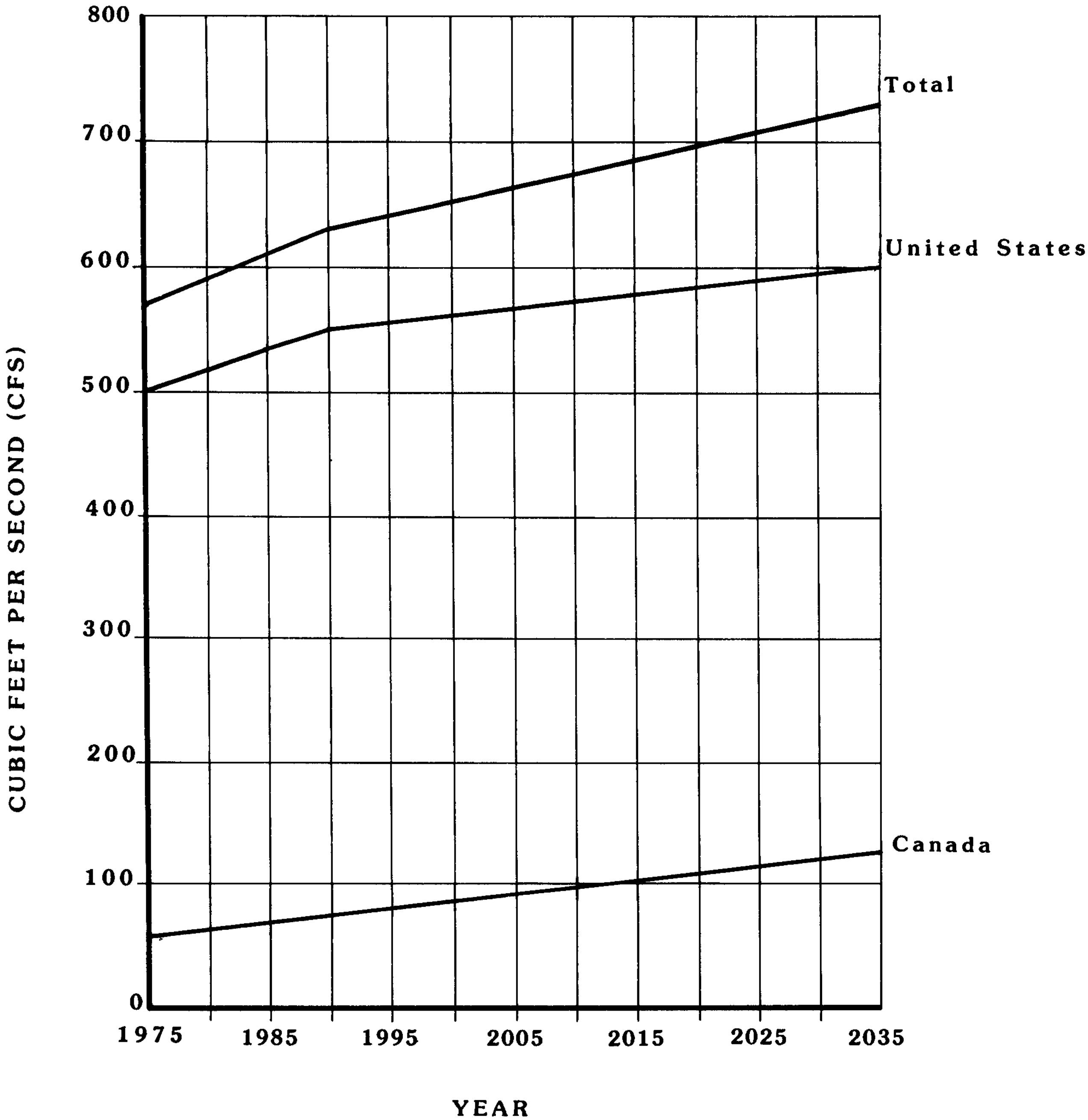


Figure F-3

Rural - Domestic Consumption

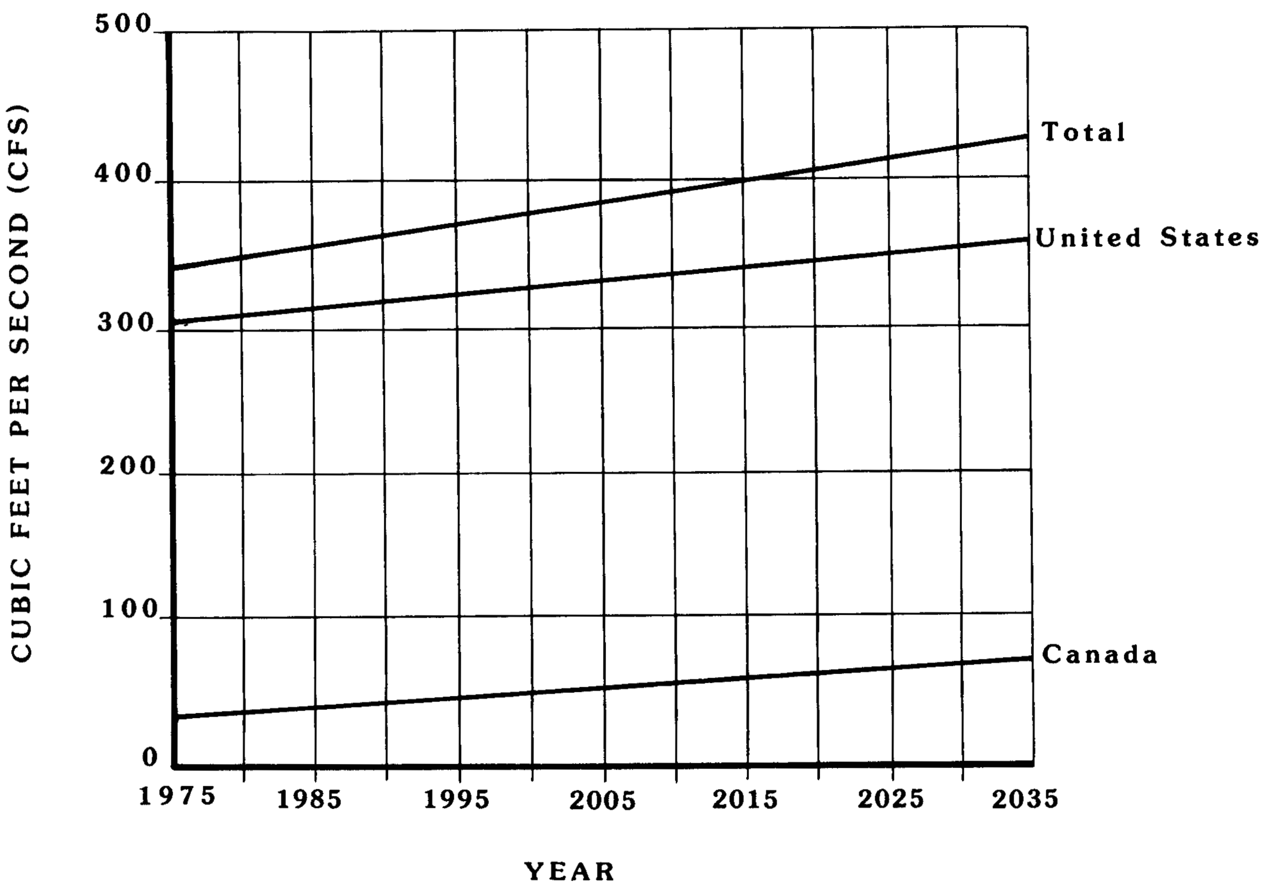


Figure F-4

Experience in Detroit with industrial water recyling indicates that for economic reasons some existing industries are converting to closed systems as means of recovering material products and byproducts in addition to the apparent water quality benefits derived from recycling (49). Effective cycling of industrial waste-water could also promote compliance with federal drinking water standards thus assuring state and federal efforts toward state control over water treatment works and distribution systems. Thus, additional incentives may be provided to industry in the future to encourage conformance with such policies.

4.1.2 Most Likely U.S. Projection

The primary asumptions used to formulate the MLP (Table 18) are:

1) economic growth according to OBERS SERIES E projections.

2) institution of best available technology (high recycle rate) in manufacturing water use systems coming on line after 1975.

3) the best practicable technology in 1975 within a major industry group (low recycle rate) will be uniformly adopted by existing industry within each group.

4) water withdrawals for new industry will decrease in direct proportion to increases in consumptive use.

5) the relationship between water withdrawals and consumptive use for industry existing in 1975 will remain constant throughout the projection period.

The MLP water use estimates were derived from Projection 3 with modification of the P.L. 95-217 compliance compliance assumption as interpreted in the NAS. The NAS presumes that all industries will incorporate the maximum attainable recirculation. The MLP was formulated on the assumption that new industry, coming on line after 1975, will utilize best available technology with associated high recirculation rates while industry existing in 1975 will continue to use low recirculation rates. The high recirculation rate used for new industry reflects the best available technology for pollution control according to a 1975 Department of Commerce survey of 10,000 manufacturing plants. The low recirculation rates represent the mean rate for each major manufacturing category which were assumed to represent best practicable technology for the existing segment of the manufacturing sector. Total manufacturing water use projections are the sum of the increment of new manufacturing water use estimates plus the existing 1975 water use. The procedure used to derive the withdrawal and consumptive use projections is outlined below.

1. Manufacturing earnings projections for the major industry groups in each lake basin were obtained for 1975 to 2035 from OBERS SERIES E projections and extrapolation of trends.

2. The increase in earnings from 1975 to 1985, 2000, 2015, and 2035 were calculated as a fraction of the total earnings for each industry group in each lake basin.

3. The Projection 3 consumptive use was multiplied by the fractional increase to determine the portion of water usage attributable to new industry using best available technology for wastewater treatment. Projection 3 figures were calculated on the basis of the assumption that all industry would use BAT by 2000. Therefore, multiplying these figures by the new earnings fractions provided the required data. New manufacturing water use figures were calculatd for 1980 to 2000 by interpolation.

4. Consumptive use totals for each industry group were calculated for 1985, 2000, 2015 and 2035 by summing new manufacturing consumptive water use figures and the 1975 consumptive use figures for each industry group within each lake basin.

5. Industry group totals were aggregated to obtain consumptive use projections for each lake basin for 1985, 2000, 2015, and 2035. Totals for the intervening years were obtained by interpolation.

6. The relationship between withdrawals and consumptive use for manufacturing using BPT and BAT was assumed to be constant over time. Ratios between Projection 3 manufacturing withdrawal and consumptive use for 2000 in each lake basin were calculated as representative of the relationship between withdrawals and consumptive use for BAT manufacturing. These ratios are:

Lake Basin	Withdrawals (cfs)/Consumptive Use (cfs)
Superior	1.26
Michigan	1.38
Huron	1.37
Erie	1.35
Ontario	1.55

Figures for the best available technology in each lake basin during the period 1980 to 2035 were calculated for Step 3. These figures were multiplied by the ratios of withdrawals to consumptive use for each lake basin to determine the withdrawal figures for new manufacturing. The withdrawal projections for new manufacturing were added to the 1975 withdrawal figures to determine total withdrawals throughout the projection period.

4.1.3 U.S. Alternative Projections

4.1.3.1 Projection 2

Projection 2 (Table 18) is the 1978 NAS projection and represents the low scenario for manufacturing withdrawal and consumptive use. Projections of consumptive use of water to 2035 were obtained by extrapolation. Projections of industrial

TABLE 18 U.S.: MANUFACTURING WATER USE FORECASTS

	MLP		Projection 2		Projection 3		Projection 4	
	W	C	W	C	W	C	W	C
1975	20450	2280	20450	2280	20450	2280	20450	2280
1980	20800	2530	13350	2480	14490	2800	22200	2500
1985	21150	2790	6350	2660	8570	3300	24000	2700
1990	21720	3200	5500	2830	7620	3910	27000	2960
1995	22300	3620	4650	3010	6670	4520	30000	3230
2000	22800	4040	4360	3180	5740	5120	33000	3530
2005	23520	4500	4020	3360	6350	5730	36000	3800
2010	24160	4970	4200	3530	6960	6340	40000	4100
2015	24810	5440	4360	3710	7970	6950	43000	4400
2020	25500	5940	4530	3890	8580	7550	48500	4640
2025	26200	6450	4720	4060	9190	8160	54000	4900
2030	26900	6950	4890	4240	9790	8770	59500	5160
2035	27600	7460	5080	4430	10410	9380	65000	5400

W (Withdrawals)

C (Consumptive Use)

U.S.: Manufacturing Water Use Ranges - Withdrawals

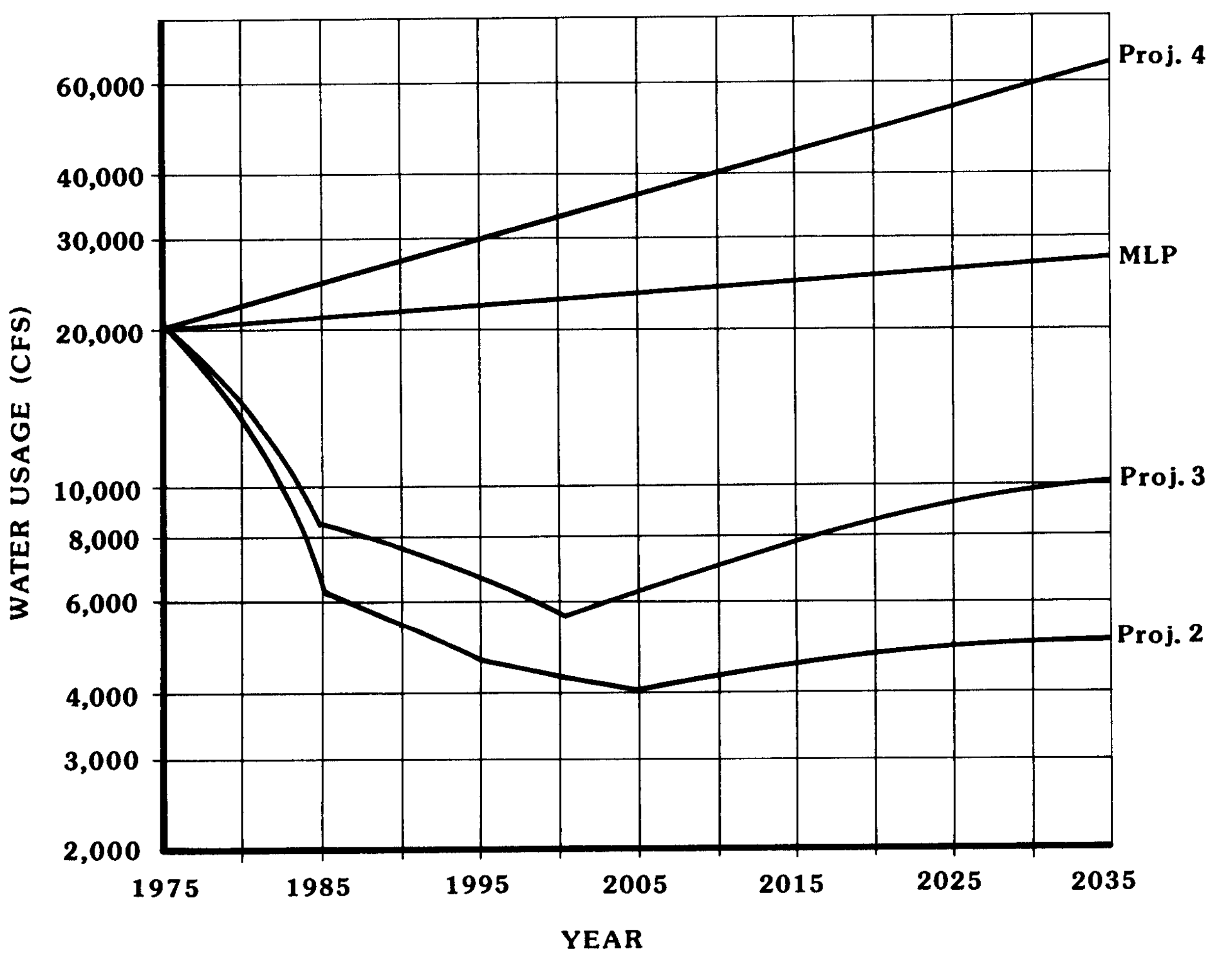


Figure F-5

U.S. :
Manufacturing Water Use Ranges - Consumption

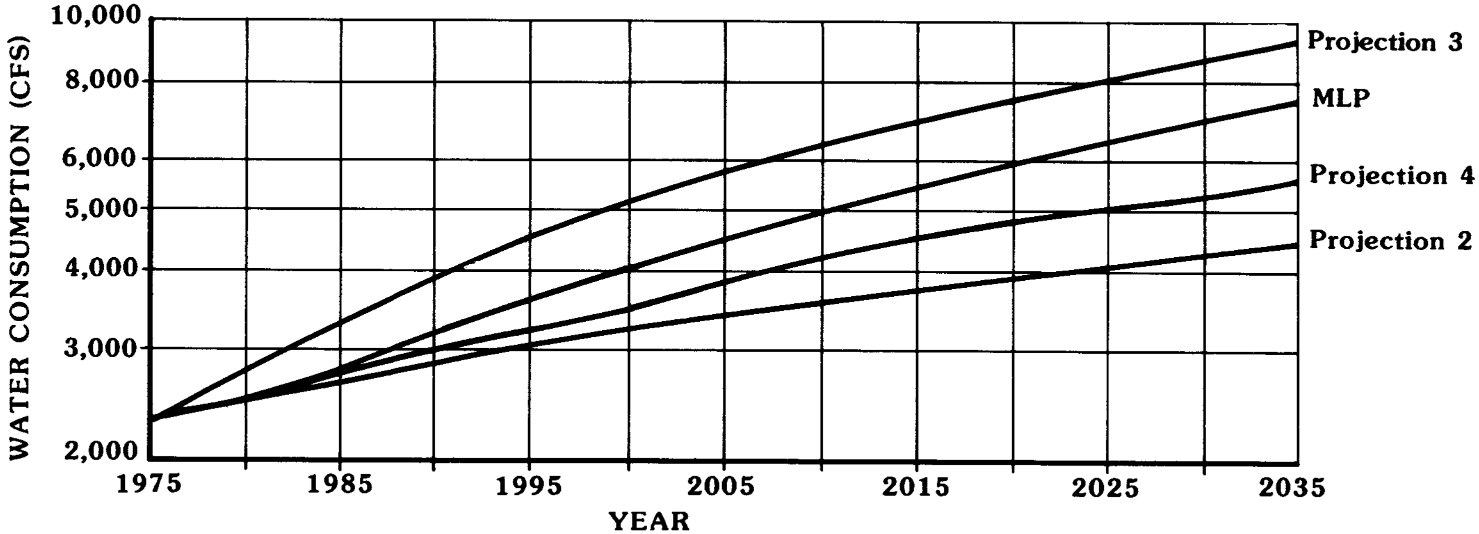


Figure F-6

water withdrawals were made by transposing the slope of the projected consumptive use curve to extend the withdrawal curve beyond 2000. This methodology was used in accordance with the assumption that withdrawals would be proportional to consumptive use after the system had reached a steady state condition by 2000.

4.1.3.2 Projection 3

This set of figures (Table 18) represents the NAS projections (Projection 2) with corrections to the NAS Lake Erie water use data. An apparent error in these figures was detected during the data analysis. The time curves for each of the lake basins, with the exception of Lake Erie, show a trend toward increased consumptive use and decreased withdrawals as a result of assumed compliance with PL95-217; however, the NAS Lake Erie data trends toward decreased consumptive use and withdrawals. Examination of consumptive water use figures for each industry group in Lake Erie indicated that consumptive use increased for all groups except the primary metals sector (49); however, the OBERS SERIES E projections of manufacturing earnings for the primary metals sector show an expected increase of about 28 percent from 1975 to 2000. Therefore, an adjustment in the consumptive use and withdrawal figures was made to coincide with the earnings projections for Lake Erie. The procedure used to obtain the revised Lake Erie water use figures is outlined by Pinsak et al (49).

4.1.3.3 Projection 4

These projections (Table 18) represent estimated manufacturing water withdrawals and consumptive use without the assumption of increased recycling for compliance with goals of P. L. 95-217. The result of non-compliance is increased rates of withdrawals and decreased rates of consumptive use relative to the other projections. These data were generated by the Canadians utilizing OBRA information on rates of gross water withdrawal, recirculation, and consumptive use. Recirculation rates for each industry category were held constant from 1975 to 2035. Increases in total withdrawals and consumptive use over the projection period reflect expected industrial growth according to the OBERS SERIES E earnings projections. The water use estimates were generated through an iterative process based on the correlation of production earnings and water use rates for each major industry group.

The U.S. manufacturing water use forecasts are summarized in Table 18.

4.2 Manufacturing Water Use: Canada

4.2.1 Detailed Methodology for Manufacturing and Mining Sectors

4.2.1.1 The Input-Output Model

The econometric model of Canadian water use is based upon the Ontario input-output (I-O) table for 1965. The input-output methodology applied to water demand forecasting has been described by several researchers (37). Thus, only a brief outline of the model will be given. The manufacturing sectors used in the analysis were based upon the 2-digit Standard Industrial Classification of Statistics Canada (57).

The concept of an economic multiplier is a well-known one. According to this concept any given expenditure on the products of an industry will not only affect that industry, but also the output of many other industries. This effect occurs because industries are interconnected - for example automobiles with steel, plastics, textiles and ultimately to seemingly unrelated industries like food and beverages, paper, etc. The multiplier is a measure of how a given expenditure (e.g. $1 million) will affect the total output of industry after all interactions have worked through the system.

Input-output analysis is designed to examine these interactions, as well as to examine the underlying structure of an economy. The basic tool of I-O analysis is an I-O table, of which there can be several types. Table 19 is a "square" table, with 25 rows and 25 columns in the intermediate demand section of the table, one column for final demand and one row for value added. The intermediate demand sector of the table shows, reading across the rows, how the produce of each industry is distributed to every other industry in the system. Reading down the columns, it shows how the inputs used by each industry is derived from the industries in the system. The final demand column shows how much of each industry's output is used by ultimate points of consumption, and is calculated by aggregating private (household) expenditures, government expenditures and several other types of expenditures. The value added or primary input sector, row 26, shows the amount of primary input (e.g. labour, imports, etc.) which is used by each industry. It should be noted that the I-O table used includes all economic sectors, not just manufacturing and mining. This enables the use of the industrial model for those sectors as well. The I-O results were not used as extensively in agriculture and power generation as they were in manufacturing and mining.

To illustrate Table 19, consider the agriculture sector, row 1, column 1. The total output of this industry in the base year, 1965 was $1,706.8 million (row 1, column 27). Of this total, $604 million went to satisfy final demands as indicated in row 1, column 26. The remaining $1,102.8 million constituted inputs both to agriculture itself and to other industries. For example, $113.6 million was used by the industry itself (i.e. intra-industry demand), none by mining, $781 million by food and beverages (row 1, column 3), and so on across row 1 of the table.

The total value of inputs to the industry equals the total value of outputs, and reading down the first column, one can see how the inputs to agriculture were derived: $113.6 million from the industry itself, $2.2 million from mining, $162.4 million from food

TABLE 19 CANADA: ONTARIO INPUT-OUTPUT TABLE 1965

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Agriculture, etc.	113606	0	781290	69994	0	0	8191	3906	456	0	0	0	0
2. Mines	2217	44924	9514	43	1011	476	1302	701	16904	135	118022	20262	7271
3. Food & Beverages	162376	4	739491	6	2081	27075	513	0	4839	0	30	0	837
4. Tobacco	0	0	0	24968	0	0	0	0	0	0	0	0	0
5. Rubber & Plastic	3269	14	11540	885	108591	3699	7426	8910	17121	1055	0	238	1066
6. Leather	0	0	0	0	1066	34731	899	198	0	3	0	0	0
7. Textiles, etc.	10492	868	5986	2	43347	5305	377396	24522	5103	407	5	9	1554
8. Wood, etc.	3448	92	2038	766	345	220	2938	112426	12941	6	291	1236	9659
9. Paper & Allied	1477	737	81094	6686	3993	2817	14285	8174	315173	39497	565	10133	16216
10. Printing, etc.	0	4	17103	769	318	132	463	124	8191	20123	151	22	1107
11. Iron & Steel	0	1556	842	0	0	0	99	373	1576	0	194655	35024	497072
12. Other Primary Metals	0	12054	9	2063	0	0	1274	1159	5940	267	20102	244322	238522
13. Metal Fabricating	5322	24412	57801	7	5014	2663	1157	36552	691	1912	3324	32486	189972
14. Machinery	20955	652	0	0	0	0	51	0	0	0	0	295	7702
15. Transportation Equipment	859	1104	0	0	70	0	0	265	0	0	0	5236	53265
16. Electrical Products	135	0	233	0	477	0	40	1506	0	0	2336	2400	13857
17. Non Metal Mineral Prod.	143	3116	20014	0	1792	82	1176	3554	6437	1	16682	6802	798
18. Petroleum & Coal	84943	10187	9723	134	1811	549	2632	1884	6957	520	1590	11206	4917
19. Chemicals	48338	38430	34749	60	136256	3257	57437	5689	31915	6648	7157	5988	14841
20. Misc. Manufacturing	273	72	5385	37	20421	5407	10801	2025	1603	128	0	3	2674
21. Construction, etc.	41015	18011	7573	533	1651	357	2944	2066	4452	3972	5565	8511	8559
22. Transportation	121991	34868	142307	6688	13560	10673	38058	43397	55870	7842	26538	37948	83193
23. Utilities	13763	28862	14561	236	4060	819	5018	3609	22051	5885	25527	17450	13905
24. Communications	88668	45333	61215	2911	12853	5434	25741	15753	27724	82606	15131	16003	72947
25. Others	85811	88833	178753	9984	29224	12319	46628	25406	55486	94805	89729	28788	139970
26. Primary Input	897649	476247	772073	45690	174472	62048	392989	217311	422453	318385	523844	260767	878091
27. Total	1706750	830380	2953294	172462	562413	178063	999458	519510	1023883	584007	1051243	745129	2257995

	14	15	16	17	18	19	20	21	22	23	24	25	Final Demand	Total Output
1. Agriculture, etc.	0	4	0	85	0	928	2436	11318	75308	0	29182	6088	603958	1706750
2. Mines	2458	10712	3549	27741	327337	24380	1099	29482	2734	2857	1320	34	173895	830380
3. Food & Beverages	0	0	0	286	0	54042	270000	113	8476	0	204360	54414	1694081	2953294
4. Tobacco	0	0	0	0	0	0	0	0	0	0	0	0	147494	172462
5. Rubber & Plastic	98	75800	28807	5649	0	23076	69379	10408	10943	0	1115	42430	130894	562413
6. Leather	0	739	2918	816	97	872	4375	112	91	0	823	2294	128029	178063
7. Textiles, etc.	149	62088	510	428	0	1480	10523	20562	21154	0	17237	9627	380704	999458
8. Wood, etc.	2596	8194	2748	1569	216	940	13105	178691	3381	788	6583	449	153844	519510
9. Paper & Allied	10047	11650	28177	13829	998	41554	15620	27803	30038	0	10037	28495	304788	1023883
10. Printing, etc.	58	212	993	140	34	5945	2807	0	3914	149	6289	315001	200048	584097
11. Iron & Steel	97842	252825	151849	3817	9331	3559	6124	48025	1930	0	74	1067	-256396	1051243
12. Other Primary Metals	43982	176766	220587	541	0	4388	16588	99608	966	0	902	2655	-347565	745129
13. Metal Fabricating	12672	103655	11033	5334	7386	30047	22405	359448	12537	0	2205	207366	1122624	2257995
14. Machinery	6233	14431	0	6	0	0	438	8498	2905	813	5610	5901	414376	488866
15. Transportation Equipment	890	1042754	1564	0	0	116	464	3568	23034	0	0	53100	2464305	3650594
16. Electrical Products	1627	62720	162247	1768	0	10572	12233	115110	1556	0	338	43805	987431	1420441
17. Non Metal Mineral Prod.	381	42815	17178	93102	96	16292	5478	199204	1130	0	1956	7701	85203	531133
18. Petroleum & Coal	2394	5184	4438	7027	44639	50797	1239	39293	86910	2649	17552	2100	166181	567456
19. Chemicals	3388	31863	13976	5360	25138	230047	6166	26796	1648	130	30595	81708	392459	1240039
20. Misc. Manufacturing	221	21244	7118	290	304	12651	44552	22191	5169	0	11480	56564	311232	541845
21. Construction, etc.	1641	17426	3561	3480	8800	8745	1939	1811	76749	25831	398060	0	2523466	3176718
22. Transportation	23700	176280	59095	40835	51512	69339	20043	343183	272076	6426	91040	511495	1860360	4148317
23. Utilities	1846	13803	7076	12711	2551	27134	3014	2758	30484	88461	18895	0	120271	484700
24. Communications	25072	71092	56225	19968	5217	49582	23897	146413	323966	21175	605626	464296	4558462	6843310
25. Others	21091	167032	82625	54215	6469	132480	59023	23572	312504	13626	348082	0	-206949	1899505
26. Primary Input	230480	1281305	554198	332136	77331	439565	200136	1458754	2838714	321795	5033899	2915	1269295	19382418
27. Total	488866	3650594	1420441	531133	567456	1240039	541845	3176718	4148317	484700	6843310	1899505	19382418	

Source (58)

and beverages, and so on. Primary inputs (e.g. labour) were valued at \$897.6 million, as indicated in row 26, column 1. The table is really a balance sheet, in which the total value of inputs in each industry equals its total value of outputs.

The basic I-O algorithm states that total demand (X) for the goods produced in an economy is the sum of intermediate demand (AX) plus final demand (F), where A is a 25 x 25 matrix of proportions (called technological coefficients) showing how much of each industry's production is used per dollar of output by each industry in the intermediate demand sector of Table 20. In mathematical terms:

(1) $X = AX + F$ (X and F are 25 x 1 column vectors)

The object of this analysis is to show how a given change in expenditure in any or all categories of final demand will affect the output levels in all component sectors of the economy. Once this has been done, the analysis proceeds to examine the effects of these changed production levels on water use. To fulfill the first objective requires mathematical steps which, although conceptually simple, require the use of a computer when working with a table the size of the one used here. Conceptually, these steps follow from the first equation.

(2) $X - AX = F$
$X(I - A) = F$ (where I is a 25 x 25 identity matrix)

(3) $X = (I - A)^{-1} \cdot F$ (where $(I - A)^{-1}$ is the inverse of $(I - A)$)

The process of matrix inversion is a common mathematical tool, and in this case, shows how a unit increase (i.e. \$1) in expenditure in all sectors will ultimately change the production levels in all sectors. After calculation of the inverse, this algorithm allows calculations of the set of industrial outputs required to satisfy a set of final demands.

The technical coefficients matrix, A, is derived from Table 19, by dividing each entry in the intermediate demand sector of the table by its respective column total, the result being shown in Table 20. Each entry in Table 20 shows the amount spent on the products of each industry per dollar of total input or output. This matrix is then subtracted from an identity matrix of the same order (i.e. 25 x 25) to give the (I - A) matrix of Equation 3 above. The latter is then inverted mathematically to give the inverse $(I - A)^{-1}$, the transposed form of which is shown in Table 21.

Table 21 is the key one for the purposes of this study, for it shows the total impact of unit expenditures in each industry (via final demand) on all industrial sectors in the system. Specifically, it shows the amount of production from each industry at the top of the table required to deliver one dollar's worth of final demand from each industry at the left. For example, agriculture, industry 1, must produce \$1.120 worth of output to

F-47

TABLE 20   CANADA: MATRIX OF TECHNOLOGICAL COEFFICIENTS FOR ONTARIO

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Agriculture, etc.	0.066563	0.000000	0.264549	0.405852	0.000000	0.000000	0.008195	0.007519	0.000445	0.000000	0.000000	0.000000	0.000000
2. Mines, etc.	0.001299	0.054101	0.003221	0.000249	0.001798	0.002673	0.001303	0.001349	0.016510	0.000231	0.112269	0.027193	0.003220
3. Food & Beverages	0.095138	0.000005	0.250395	0.000035	0.003700	0.152053	0.000513	0.000000	0.004726	0.000000	0.000029	0.000000	0.000371
4. Tobacco	0.000000	0.000000	0.000000	0.144774	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5. Rubber & Plastic	0.001915	0.000017	0.003908	0.005132	0.193081	0.020774	0.007430	0.017151	0.016722	0.001806	0.000000	0.000319	0.000472
6. Leather	0.000000	0.000000	0.000000	0.000000	0.001895	0.195049	0.000899	0.000381	0.000000	0.000005	0.000000	0.000000	0.000000
7. Textiles, etc.	0.006147	0.001045	0.002027	0.000012	0.077073	0.029793	0.377601	0.047202	0.004984	0.000697	0.000005	0.000012	0.000688
8. Wood, etc.	0.002020	0.000111	0.000690	0.004442	0.000613	0.001236	0.002940	0.216408	0.012639	0.000010	0.000277	0.001659	0.004278
9. Paper & Allied	0.000865	0.000888	0.027459	0.038768	0.007100	0.015820	0.014293	0.015734	0.307821	0.067621	0.000537	0.013599	0.007182
10. Printing, etc.	0.000000	0.000005	0.005791	0.004459	0.000565	0.000741	0.000463	0.000239	0.008000	0.034451	0.000144	0.000030	0.000490
11. Iron & Steel	0.000000	0.001874	0.000285	0.000000	0.000000	0.000000	0.000099	0.000718	0.001539	0.000000	0.185167	0.047004	0.220139
12. Other Primary Metals	0.000000	0.014516	0.000003	0.011962	0.000000	0.000000	0.001275	0.002231	0.005801	0.000457	0.019122	0.327892	0.105634
13. Metal Fabricating	0.003118	0.029399	0.019572	0.000041	0.008915	0.014955	0.001158	0.070359	0.000675	0.003273	0.003162	0.043598	0.084133
14. Machinery	0.012278	0.000785	0.000000	0.000000	0.000000	0.000000	0.000051	0.000000	0.000000	0.000000	0.000000	0.000396	0.003411
15. Transportation Equipment	0.000503	0.001330	0.000000	0.000000	0.000124	0.000000	0.000000	0.000510	0.000000	0.000000	0.000000	0.007027	0.023590
16. Electrical Products	0.000000	0.000000	0.000079	0.000000	0.000000	0.000000	0.000005	0.001551	0.000000	0.000000	0.002222	0.002647	0.004489
17. Non Metal Mineral Products	0.000084	0.003752	0.006777	0.000000	0.003186	0.000461	0.001177	0.006841	0.006287	0.000002	0.015869	0.009129	0.000353
18. Petroleum & Coal	0.049769	0.012268	0.003292	0.000777	0.003220	0.003083	0.002633	0.003626	0.006795	0.000890	0.001512	0.015039	0.002178
19. Chemicals	0.028322	0.046280	0.011766	0.000348	0.242270	0.018291	0.057468	0.010951	0.031171	0.011382	0.006808	0.008036	0.006573
20. Misc. Manufacturing	0.000160	0.000087	0.001823	0.000215	0.036310	0.030366	0.010807	0.003898	0.001566	0.000219	0.000000	0.000004	0.001184
21. Construction, etc.	0.024031	0.021690	0.002564	0.003091	0.002936	0.002005	0.002946	0.003977	0.004348	0.006800	0.005294	0.011422	0.003791
22. Transportation, etc.	0.071476	0.041990	0.048186	0.038780	0.024110	0.059939	0.038079	0.083534	0.054567	0.013426	0.025244	0.050928	0.036844
23. Utilities	0.008064	0.034758	0.004930	0.001368	0.007219	0.004599	0.005021	0.006947	0.021537	0.009990	0.024283	0.023419	0.006158
24. Communications	0.051951	0.054593	0.020728	0.016879	0.022853	0.030517	0.025755	0.030323	0.027077	0.141425	0.014393	0.021477	0.032306
25. Others	0.050277	0.106979	0.261418	0.057891	0.310220	0.069183	0.393202	0.418300	0.412599	0.162310	0.085355	0.038635	0.388881

	14	15	16	17	18	19	20	21	22	23	24	25
1. Agriculture, etc.	0.000000	0.000001	0.000000	0.000160	0.000000	0.001964	0.001713	0.003563	0.018154	0.000000	0.004264	0.003205
2. Mines, etc.	0.005028	0.002934	0.000000	0.052230	0.576850	0.019661	0.002028	0.009281	0.000659	0.005894	0.000193	0.000018
3. Food & Beverages	0.000000	0.000000	0.000000	0.000538	0.000000	0.043581	0.000498	0.000036	0.002043	0.000000	0.029863	0.028646
4. Tobacco	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
5. Rubber & Plastic	0.000200	0.020764	0.000000	0.010636	0.000000	0.018609	0.128042	0.003276	0.002638	0.000000	0.000163	0.022337
6. Leather	0.000000	0.000202	0.000000	0.001536	0.000171	0.000703	0.008074	0.000035	0.000022	0.000000	0.000120	0.001208
7. Textiles, etc.	0.000305	0.017008	0.000000	0.000806	0.000000	0.001194	0.019421	0.006473	0.005099	0.000000	0.002519	0.005068
8. Wood, etc.	0.005310	0.002245	0.000000	0.002954	0.000381	0.000758	0.024186	0.056250	0.000815	0.001626	0.000962	0.000236
9. Paper & Allied	0.020552	0.003191	0.000000	0.026037	0.001759	0.033510	0.028827	0.008752	0.007241	0.000000	0.001467	0.015001
10. Printing, etc.	0.000119	0.000058	0.000000	0.000264	0.000060	0.004794	0.005180	0.000000	0.000944	0.000307	0.000919	0.165833
11. Iron & Steel	0.200141	0.069256	0.000001	0.007187	0.016444	0.002870	0.011302	0.015118	0.000465	0.000000	0.000011	0.000562
12. Other Primary Metals	0.089967	0.048421	0.000001	0.001019	0.000000	0.003539	0.030614	0.031356	0.000233	0.000000	0.000132	0.001398
13. Metal Fabricating	0.025921	0.028394	0.000000	0.010043	0.013016	0.024231	0.041349	0.113151	0.003022	0.000000	0.000322	0.109168
14. Machinery	0.012750	0.003953	0.000000	0.000011	0.000000	0.000000	0.000808	0.002675	0.000700	0.001677	0.000820	0.003107
15. Transportation Equipment	0.001821	0.285640	0.000000	0.000000	0.000000	0.000094	0.000856	0.001123	0.005553	0.000000	0.000000	0.027955
16. Electrical Products	0.003323	0.009480	0.000000	0.003329	0.000000	0.001534	0.015619	0.013193	0.000291	0.000000	0.000002	0.014390
17. Non Metal Mineral Products	0.000779	0.011728	0.000000	0.175289	0.000169	0.013138	0.010110	0.062707	0.000272	0.000000	0.000286	0.004054
18. Petroleum & Coal	0.004897	0.001420	0.000000	0.013230	0.078665	0.040964	0.002287	0.012369	0.020951	0.005465	0.002565	0.001106
19. Chemicals	0.006930	0.008728	0.000000	0.010092	0.044299	0.185516	0.011380	0.008435	0.000397	0.000268	0.004471	0.040043
20. Misc. Manufacturing	0.000452	0.005819	0.000000	0.000546	0.000536	0.010202	0.082223	0.006986	0.001246	0.000000	0.001678	0.029778
21. Construction, etc.	0.003357	0.004773	0.000000	0.006552	0.015508	0.007052	0.003579	0.000570	0.018501	0.053293	0.058168	0.000000
22. Transportation, etc.	0.048480	0.048288	0.000000	0.076883	0.090777	0.055917	0.036990	0.108031	0.065587	0.013258	0.013304	0.269278
23. Utilities	0.003776	0.003781	0.000000	0.023932	0.004496	0.021882	0.005562	0.000868	0.007349	0.182507	0.002761	0.000000
24. Communications	0.051286	0.019474	0.000000	0.037595	0.009194	0.039984	0.044103	0.046089	0.078096	0.043687	0.088499	0.244430
25. Others	0.043143	0.350985	0.000003	0.437058	0.011400	0.316021	0.108930	0.007420	0.075333	0.028112	0.050865	0.000000

Source (58)

TABLE 21 CANADA: DIRECT PLUS INDIRECT REQUIREMENTS PER DOLLAR OF FINAL DEMAND

($)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Agriculture, etc.	1.119935	0.050290	0.155778	0.000000	0.010896	0.000405	0.017482	0.007531	0.020127	0.020770	0.017765	0.013891	0.032947
2. Mines, etc.	0.009131	1.080071	0.018114	0.000000	0.009572	0.000499	0.007794	0.004677	0.017375	0.028789	0.027077	0.040603	0.065680
3. Food & Beverages	0.402198	0.035279	1.401164	0.000000	0.018541	0.000552	0.016474	0.006963	0.071899	0.037060	0.023472	0.017518	0.060763
4. Tobacco	0.536553	0.031656	0.082617	1.169282	0.018859	0.000468	0.013672	0.012814	0.083281	0.032452	0.016333	0.033477	0.032357
5. Rubber & Plastic	0.019557	0.036042	0.046079	0.000000	1.268071	0.004519	0.165085	0.007446	0.052116	0.033176	0.022869	0.021305	0.054788
6. Leather	0.085182	0.023965	0.280342	0.000000	0.051582	1.243427	0.074507	0.007765	0.058578	0.032983	0.021522	0.018019	0.057913
7. Textiles, etc.	0.024689	0.019659	0.022938	0.000000	0.028391	0.002517	1.615955	0.009887	0.050851	0.024425	0.012487	0.014208	0.028621
8. Wood, etc.	0.020540	0.021149	0.016197	0.000000	0.037667	0.001268	0.106690	1.280617	0.045671	0.022607	0.040248	0.031340	0.122302
9. Paper & Allied	0.012675	0.044848	0.026080	0.000000	0.039768	0.000584	0.022745	0.026500	1.461944	0.035747	0.015498	0.023227	0.029326
10. Printing, etc.	0.010858	0.011971	0.023201	0.000000	0.014780	0.000593	0.009230	0.005121	0.116730	1.074880	0.014878	0.013733	0.038011
11. Iron & Steel	0.007075	0.159370	0.013395	0.000000	0.008154	0.000463	0.005202	0.003438	0.014507	0.027933	1.243970	0.049687	0.036563
12. Other Primary Metals	0.007793	0.082778	0.012824	0.000000	0.008918	0.000416	0.006418	0.007857	0.042429	0.021632	0.120345	1.516161	0.098263
13. Metal Fabricating	0.007923	0.059305	0.014440	0.000000	0.010154	0.000470	0.008286	0.009731	0.027937	0.026512	0.325200	0.197939	1.129487
14. Machinery	0.007217	0.055213	0.012652	0.000000	0.007649	0.000362	0.006118	0.010527	0.043876	0.020633	0.277762	0.159337	0.058651
15. Transportation Equipment	0.008656	0.039019	0.014438	0.000000	0.047140	0.001109	0.049221	0.008241	0.025063	0.024057	0.155676	0.130425	0.075596
16. Electrical Products	0.008577	0.047461	0.015874	0.000000	0.038688	0.003481	0.010782	0.007260	0.051845	0.026049	0.181740	0.280438	0.049274
17. Non Metal Mineral Products	0.010847	0.091577	0.019144	0.000000	0.026889	0.002884	0.011124	0.008849	0.061265	0.033086	0.029317	0.018770	0.047177
18. Petroleum & Coal	0.011332	0.687206	0.019832	0.000000	0.010464	0.000747	0.008121	0.006021	0.021817	0.026103	0.048746	0.033892	0.068664
19. Chemicals	0.034618	0.076864	0.094115	0.000000	0.043518	0.001938	0.015238	0.006965	0.081934	0.043493	0.033267	0.030522	0.072843
20. Misc. Manufacturing	0.015143	0.027363	0.026723	0.000000	0.189391	0.012210	0.066919	0.038927	0.071864	0.042401	0.053360	0.080003	0.092120
21. Construction, etc.	0.012710	0.043822	0.012387	0.000000	0.015138	0.000731	0.022504	0.076035	0.031369	0.014800	0.075086	0.088353	0.151747
22. Transportation, etc.	0.028208	0.022446	0.017722	0.000000	0.009785	0.000375	0.013803	0.004678	0.020252	0.020643	0.011941	0.010090	0.024964
23. Utilities	0.003842	0.017206	0.006712	0.000000	0.003306	0.000178	0.003370	0.008342	0.005734	0.009802	0.008832	0.009005	0.018172
24. Communications	0.021934	0.008968	0.052470	0.000000	0.005453	0.000427	0.008590	0.007227	0.011707	0.015276	0.010065	0.010067	0.022444
25. Others	0.034067	0.027312	0.071316	0.000000	0.047114	0.002569	0.025472	0.008032	0.064318	0.197693	0.058682	0.047100	0.155305

	14	15	16	17	18	19	20	21	22	23	24	25
1. Agriculture, etc.	0.014837	0.007765	0.006146	0.007555	0.069985	0.061587	0.006447	0.042240	0.153350	0.020649	0.128241	0.110624
2. Mines, etc.	0.002178	0.011959	0.007816	0.011796	0.023989	0.079228	0.007752	0.039214	0.121437	0.053933	0.138574	0.161676
3. Food & Beverages	0.006152	0.010229	0.007282	0.017507	0.036469	0.059278	0.010709	0.028815	0.176682	0.022814	0.134353	0.159131
4. Tobacco	0.007664	0.008964	0.006540	0.006645	0.039072	0.044704	0.007786	0.031138	0.162867	0.017435	0.126739	0.147111
5. Rubber & Plastic	0.001426	0.010194	0.012956	0.017099	0.030455	0.408712	0.063339	0.022457	0.139381	0.031683	0.133341	0.168556
6. Leather	0.002230	0.010274	0.008189	0.009137	0.019998	0.072598	0.051872	0.020661	0.177662	0.019925	0.136791	0.167691
7. Textiles, etc.	0.001234	0.007264	0.006732	0.008385	0.017271	0.136943	0.026751	0.018157	0.130369	0.019962	0.112439	0.127975
8. Wood, etc.	0.001471	0.011597	0.010518	0.016194	0.015719	0.050739	0.013803	0.019947	0.180990	0.021744	0.114896	0.122497
9. Paper & Allied	0.001102	0.007714	0.006145	0.016605	0.021468	0.083812	0.010469	0.021824	0.149892	0.047961	0.114560	0.131964
10. Printing, etc.	0.001409	0.010840	0.008102	0.005991	0.008938	0.040712	0.009737	0.026947	0.103692	0.021606	0.247843	0.218045
11. Iron & Steel	0.001198	0.009053	0.009433	0.028953	0.011158	0.034906	0.006660	0.022165	0.105008	0.049721	0.096226	0.157687
12. Other Primary Metals	0.001972	0.024263	0.012184	0.024499	0.033889	0.037069	0.005930	0.033841	0.149162	0.056858	0.105868	0.119818
13. Metal Fabricating	0.005078	0.046152	0.015654	0.013650	0.013734	0.033235	0.008160	0.021834	0.126465	0.031119	0.117029	0.146024
14. Machinery	1.014010	0.011664	0.010086	0.011939	0.015409	0.029664	0.005829	0.020089	0.121824	0.024954	0.122599	0.113814
15. Transportation Equipment	0.006829	1.410235	0.034323	0.029274	0.013414	0.049711	0.017302	0.022094	0.148294	0.023367	0.105841	0.133513
16. Electrical Products	0.001240	0.012829	1.136578	0.027762	0.017192	0.046439	0.013950	0.021427	0.135099	0.029079	0.127435	0.139918
17. Non Metal Mineral Products	0.001417	0.010592	0.011941	1.218779	0.028016	0.046288	0.009584	0.026392	0.181587	0.047693	0.139615	0.183164
18. Petroleum & Coal	0.001908	0.011258	0.008180	0.011872	1.107860	0.115696	0.008413	0.048568	0.207956	0.045543	0.130551	0.143839
19. Chemicals	0.001893	0.012602	0.020643	0.027438	0.067283	1.270659	0.024250	0.029795	0.177455	0.047528	0.157744	0.205909
20. Misc. Manufacturing	0.002501	0.014445	0.037175	0.022712	0.016644	0.098756	1.107373	0.022491	0.148966	0.024070	0.156405	0.201787
21. Construction, etc.	0.004078	0.012290	0.046819	0.083134	0.025160	0.033180	0.013064	1.017006	0.183869	0.016935	0.116820	0.080031
22. Transportation, etc.	0.001894	0.014112	0.005584	0.004915	0.029867	0.017433	0.006640	0.032218	1.122313	0.014692	0.139634	0.110485
23. Utilities	0.002698	0.003323	0.004843	0.006659	0.010966	0.008506	0.002916	0.072534	0.049392	1.226486	0.086793	0.053053
24. Communications	0.001820	0.004561	0.005690	0.007548	0.008405	0.017322	0.006036	0.069351	0.058940	0.007609	1.136626	0.079033
25. Others	0.005561	0.053286	0.035880	0.015224	0.021067	0.092924	0.042772	0.037738	0.380400	0.019588	0.397657	1.136047

Source (58)

satisfy one dollar's worth of final demand for its own products (i.e. the original one dollar's worth of output plus 12 cents to satisfy indirect demand both from itself and from other industries). Similarly, it must produce 0.91 cents of output to satisfy one dollar's worth of final demand from the mining industry (industry 2), 40.22 cents to satisfy one dollar's worth of final demand from the food and beverage industry, and so on down column 1 of Table 21. Thus when the inverse of Table 21 is pre-multiplied by the transposed final demand vector of Table 19 (i.e. column 26), the total output vector (i.e. column 27, Table 19) can be derived. This is equivalent to the operation shown in Equation 3.

4.2.1.2 1975 Water Use by Industrial Sector

Water use statistics were collected from various provincial and federal water resource agencies (59).

For the manufacturing and mining industries in the I-O table, data were compiled on four basic water use parameters - total intake, recirculation, gross water use and total consumption (Table 22). Total intake consists of the total amount of new water taken into a plant, regardless of the purpose of intake. Recirculation is an estimate of the amount of water which would have been required had recycling not been practised. Water circulated many times within one system (e.g. blast furnace cooling) is not included in recirculation. Rather, only water which is used in one system, leaves the system, then enters another system (or the same system) is counted as recirculation. Gross water use is the sum of new water intake plus recirculation. Water consumption consists of the amount of water lost during production mainly through evaporation or incorporation into the product. For the purposes of this study, water intake was disaggregated into its sources of supply - public utilities, self-supplied surface and self-supplied ground water.

4.2.1.3 Water Use Applications of the Input-Output Model

To apply the I-O model of Equation 3 above to water demand forecasting, the water use data in Table 22 was converted to coefficients of water use per thousand dollars of total output, as given in column 27 of Table 19. The water use coefficients derived in this manner are given in Table 23. Each column of this table was then diagonalized to form a square matrix, in which the individual coefficients form the principal diagonal of the matrix and all off-diagonal elements are zero. The result of this step is a set of seven 25 x 25 diagonal matricies, one for each water use parameter. These are pre-multiplied, in turn, by the inverse matrix (Table 21) to give seven water use interactions matrices. In mathematical terms:

$$WI_k = (I - A)_T{}^{-1} \cdot W_k$$

TABLE 22 CANADA: WATER USE BY INDUSTRY FOR ONTARIO, 1971 (MILLION GALLONS PER DAY)

Industrial Group	Total Water Intake	Public	Company Water System Surface	Company Water System Ground	Gross Water Use	Recirculation	Consumption
Mines & Mineral Fuels	93.600	0	81%	19%	93.600	0.000	10.400
Food & Beverages	103.335	63.579	31.180	7.898	138.159	34.824	9.279
Tobacco	0.568	0.568	0.000	0.000	4.676	4.108	0.278
Rubber & Plastics	268.250	254.180	10.197	3.454	331.040	62.790	1.611
Leather	2.672	2.425	0.166	0.061	2.989	0.317	0.277
Textiles, Knitting Mills & Clothing	44.508	10.481	32.425	0.820	68.414	23.906	1.189
Wood, Furniture & Fixtures	5.276	2.242	2.915	0.117	5.828	0.552	0.476
Paper & Allied Products	463.053	37.132	425.002	0.296	1559.567	1096.514	20.978
Printing & Publishing	1.525	1.479	0.000	0.046	12.501	10.976	0.064
Iron & Steel	645.000	32.610	602.126	0.328	1051.000	406.000	14.819
Other Primary Metals	42.155	2.131	39.353	0.021	165.983	123.828	0.969
Metal Fabricating	13.543	11.691	1.402	0.450	25.287	11.744	0.737
Machinery	3.039	3.028	0.006	0.005	7.664	4.625	0.172
Transportation Equipment	103.979	32.859	71.083	0.036	176.201	72.222	3.222
Electrical Products	16.118	13.635	1.898	0.461	37.712	21.594	0.480
Non Metallic Mineral Products	27.611	4.815	16.248	3.056	50.291	22.680	3.610
Petroleum & Coal	187.173	0.809	186.364	0.000	284.679	97.506	8.558
Chemicals & Chemical Products	713.167	25.440	678.639	1.035	955.042	241.875	37.960
Misc. Manufacturing	5.230	4.432	0.484	0.074	15.146	9.916	0.216

Source (58)

TABLE 23 CANADA: VALUE OF OUTPUT AND WATER USE COEFFICIENTS BY INDUSTRY FOR ONTARIO, 1971 (MILLION GALLONS PER DAY/MILLION DOLLARS PER YEAR)

Industrial Group	Output Value $\$10^6$	Total Water Intake	Public	Company Water System Surface	Company Water System Ground	Gross Water Use	Recirculation	Consumption
Mines & Mineral Fuels	1020.7	.0916973	Unknown	Unknown	Unknown	.0916973	0.0000000	.0101891
Food & Beverages	3918.6	.0263702	.0162248	.0079569	.0020155	.0352569	.0088868	.0023679
Tobacco	280.9	.0020218	.0020218	0.0000000	0.0000000	.0166447	.0146228	.0009897
Rubber & Plastics	700.6	.3829123	.3628282	.0145557	.0049304	.4725417	.0896293	.0022995
Leather	206.2	.0129558	.0117582	.0008049	.0002958	.0144929	.0015370	.0011009
Textiles, Knitting Mills & Clothing	1257.0	.0354083	.0083381	.0257956	.0006523	.0544266	.0190184	.0009459
Wood, Furniture & Fixtures	787.9	.0066962	.0028455	.0036997	.0001485	.0073968	.0007006	.0006041
Paper & Allied Products	1453.8	.3185152	.0255416	.2923416	.0002035	1.0727623	.7542471	.0144298
Printing & Publishing	871.1	.0017507	.0016979	0.0000000	.0000528	.0143509	.0126002	.0000735
Iron & Steel	915.7	.7043497	.0356106	.6575307	.0003582	1.1477079	.4433581	.0161832
Other Primary Metals	2185.6	.0192880	.0009750	.0180060	.0000096	.0759455	.0566575	.0004434
Metal Fabricating	2028.4	.0066767	.0057636	.0006912	.0002218	.0124664	.0057898	.0003633
Machinery	1512.6	.0020092	.0020019	.0000040	.0000033	.0050669	.0030577	.0001137
Transportation Equipment	5651.2	.0183993	.0058145	.0125783	.0000064	.0311792	.0127799	.0005701
Electrical Products	2029.6	.0079416	.0067182	.0009352	.0002271	.0185812	.0106397	.0002365
Non Metallic Mineral Products	722.6	.0382101	.0066634	.0224852	.0042291	.0695964	.0313863	.0049958
Petroleum & Coal	783.5	.2389077	.0010326	.2378751	0.0000000	.3633644	.1244567	.0109228
Chemicals & Chemical Products	1787.4	.3989965	.0142330	.3796791	.0005791	.5343186	.1353221	.0212376
Misc. Manufacturing	800.1	.0065368	.0055394	.0006049	.0000925	.0189304	.0123936	.0002700

Source (58)

where $(I - A)_T^{-1}$ = the transposed form of the inverse (i.e. the matrix shown in Equation 3)

W_k = the matrix of water use coefficients for parameter k (k = 1,...,7)

WI_k = the water use interactions matrix for parameter k

The water use interactions matrices show the amount of water required (thousand gallons per day) by each industry from the source indicated at the top of the table to satisfy one million dollars worth of annual deliveries to final demand by each industry at the left.

The water use interactions matrices can be used to project water uses over a given period of time. The method used to project final demand has been outlined, and in terms of the model, a final demand vector for each point in the future can be derived in this manner. When the elements of these new final demand vectors are multiplied by their respective elements in any column of the water use interactions matricies and the products summed, the result will be a projection of water use in the column industry. In this way, water use for each industry in the system can be obtained. This is equivalent to transposing the water use interactions matrix and post-multiplying by the column vector of final demands, denoted mathematically as:

$$WU_k = (WI_k)_T \cdot F$$

where WU_k = the vector of water uses for parameter k at a given point in the future

$(WI_k)_T$ = the transpose of the water use interactions matrix for parameter k

The resulting interactions matrices, for each water use parameter given in Table 19, are shown in Tate (58; pp. 185-212):

Table 49 Total Water Intake Interactions Matrix
Table 50 Public Water Intake Interactions Matrix
Table 51 Company Surface Water System Intake Interactions Matrix
Table 52 Company Ground Water System Intake Interactions Matrix
Table 53 Gross Water Use Interactions Matrix
Table 54 Recirculation Water Use Interactions Matrix
Table 55 Consumptive Water Use Interactions Matrix

4.2.1.4 Advantages and Limitations of the Model

A major problem encountered in projecting water demands is that of uncertainty about future economic growth, trends in production and water use technology, and a host of other unforeseeable developments. Two ways around this difficulty are (i) to use a range of values in the underlying variables of the model (e.g. growth rates, water use coefficients) and (ii) to build a "reactive" type of model to test a series of "What would happen if..." type of questions.

The simple approach to this project, used to develop the MLP, was to assume a growth rate for each industry and apply this to current water use to project future water use. All variables of water use are assumed constant except production levels, which are projected with a constant rate of increase. This gives a base against which to evaluate other projections, even though it ignores virtually all principles of water demand forecasting.

The model developed here is a much more powerful tool, for it allows testing of a wide range of assumptions. The model is capable of generating water demand forecasts based on industry growth rates, both as sets (i.e. high, medium or low rates in all industries) or as selected combinations of high, medium or low rates for individual industries. In the section which follows a method is developed for altering the water use coefficients. The model is capable of handling these alterations fairly simply by adjusting the water use coefficient matrices. An additional advantage of the model relates to testing the impact on water use of changes in specific industries. In the same manner that changes in expenditure patterns (i.e. in final demand) will cause changes in employment, so will they cause changes in water use. The former changes are quantified by developing employment multipliers using an I-O table (34). In a similar manner, water use multipliers can be developed from the water use interactions tables.

One limitation of the model concerns the assumed constancy of the I-O technological coefficients (Table 20) throughout the forecasting period. Much criticism of I-O models has concentrated on this constancy assumption (29). Stated simply, the problem is that the constancy assumption makes no allowance for technological change, more efficient methods of production, economies of scale, etc. While this problem is no doubt a major one, some preliminary evidence for coefficient stability was derived by testing the Canadian I-O model over a 10-year period. Regression analysis of individual coefficients suggests no slope to the regression line, indicative of coefficient constancy. Since the Ontario economy forms a major part of the national economy, it is suggested that this preliminary evidence of constancy extends to the Ontario I-O table (15). Also, there is no reason that technological coefficients cannot be altered in future periods, based on trend line evidence, following methods suggested by Miernyk (37).

4.2.1.5 Current Water Use

The source of water use data for manufacturing was an Environment Canada water use survey for 1972 (59). A breakdown of water use by manufacturing sector is shown in Table 24. Seven parameters of water use were developed during the project although only two of these, total water withdrawal and total consumption, are highlighted. Table 24 gives both the Ontario and the Great Lakes water use statistics. Water withdrawal forecasts provide an estimator of the volume of daily water use and water consumption an estimator of instantaneous water loss.

Total water intake for the Ontario manufacturing industries in 1971 was 4,940 cfs, and had increased to 5,870 cfs by 1975. Firms in the Great Lakes basin accounted for 95 percent of total withdrawal, or 5,580 cfs. Gross water use in Ontario for 1975 totalled 10,880 cfs for Ontario, giving an overall use rate (i.e. gross use divided by intake) of 1.85. Water consumption for 1975 was 230 cfs, resulting in a consumption rate of four percent. The use and consumption rates for Ontario as a whole apply also to the Great Lakes basin, resulting in a gross water use in the basin of 10,310 cfs and a water consumption of 220 cfs. Five manufacturing sectors, chemicals, primary metals, paper and allied products, rubber and plastics, and petroleum and coal, accounted for 78 percent of the total water withdrawals and 79 percent of total consumption by manufacturing firms in the basin in 1975. The use rates for these five industries average 2.03, ranging between 1.23 for rubber and plastics, and 3.39 for paper and allied products. Consumption rates for these same industries average four percent, reflecting the basin average, varying from a low of two percent for pulp and paper to a high of five percent for both chemicals and petroleum and coal.

Having approached water demand forecasts from the "top down", it remains to break the forecasted basin totals into sub-basins and into lake versus non-lake sources. To do so implies a knowledge of future industrial location. This forced the simplest of disaggregation techniques, namely the assumption that future water use would be distributed among basins and sources as it is currently. This assumption is questionable, but seems reasonable for the purposes of the overall study.

Table 25 contains data on current manufacturing water use by lake basin. The Lake Ontario basin, with 36 percent of the water intake in 1975, dominates the current Great Lakes water use in manufacturing. Combined with Lake Erie and Lake Huron, these

TABLE 24 CANADA: MANUFACTURING WATER USE BY SECTOR, 1971 AND 1975
(cfs)

Sector	Year	Total Water Withdrawal Ontario	Total Water Withdrawal Great Lakes Basin	Total Consumption Ontario	Total Consumption Great Lakes Basin
Food and Bev.	1971	190	170	20	20
	1975	220	200	20	20
Tobacco	1971	10	10	0	0
	1975	10	10	0	0
Rubber and Plastics	1971	500	500	10	10
	1975	600	600	10	10
Leather	1971	10	10	0	0
	1975	10	10	0	0
Textiles, etc.	1971	80	80	0	0
	1975	100	90	0	0
Wood, etc.	1971	10	10	0	0
	1975	10	10	0	0
Paper and Allied	1971	860	650	40	30
	1975	1,000	750	50	40
Printing, etc.	1971	10	10	0	0
	1975	10	10	0	0
Iron and Steel	1971	1,200	1,200	30	30
	1975	1,430	1,430	30	30
Other Primary Metals	1971	80	80	0	0
	1975	90	90	0	0
Metal Fabricating	1971	30	20	0	0
	1975	30	30	0	0
Machinery	1971	10	10	0	0
	1975	10	10	0	0
Transportation Equipment	1971	190	190	10	10
	1975	230	230	10	10
Electrical Products	1971	30	30	0	0
	1975	40	30	0	0
Non-metallic Mineral Products	1971	50	50	10	10
	1975	60	60	10	10
Petroleum and Coal	1971	350	350	20	20
	1975	410	410	20	20
Chemicals	1971	1,320	1,320	70	70
	1975	1,600	1,600	80	80
Miscellaneous Mfg.	1971	10	10	0	0
	1975	10	10	0	0
TOTAL MANUFAC.	1971	4,940	4,700	210	200
	1975	5,870	5,580	230	220

TABLE 25 CANADA: MANUFACTURING WATER USE BY LAKE BASIN, 1975

	Total Water Withdrawal (cfs)	% Withdrawn from Lake	Total Consumption (cfs)
Lake Superior	700	99	20
Lake Huron	1100	70	60
Lake Erie	1520	88	60
Lake Ontario	1990	90	70
St. Lawrence	260	90	10
TOTALS	5570	87	220

three basins account for 83 percent of the total water withdrawal. Consumption rates vary amongst lake basins, from a low of 2.7 percent in Lake Superior to a high of 5.3 percent in Lake Huron. This variation reflects the industrial composition of the basins. The Lake Superior water use, for example, is dominated by the paper and allied products industry, and the figures accordingly mirror that industry's consumption rate of two percent.

On the basis of the 1971 water use information for Ontario as a whole, the vectors of water use coefficients were developed. The coefficient vectors for water withdrawal and consumption are shown in Table 26. The vectors were used in conjunction with the input-output model to generate estimates of future water uses in manufacturing.

4.2.1.6 MLP Water Use Projection for Manufacturing

For the MLP all parameters of water use except the economic production level are held constant. Specifically, the technology of water use, as reflected by the withdrawal and consumption rates, is assumed constant, as is the pattern of inter-industry production, as reflected by the technical coefficients of the I-O model.

The selection of economic growth rates for each manufacturing sector is critical in projecting MLP water use. The empirical basis for determining this set of growth rates was the real value of shipments (1971 dollars) data for Ontario since 1950 (56). It is important to put this period in perspective. While Ontario has always been the centre of the Canadian economy, it had until after World War II, a relatively small economic base in terms of industrial diversification. Since the war, it has matured into a relatively strong diversified economy with well developed primary metals, petroleum and petro-chemicals, pulp and paper, and food and

TABLE 26 CANADA: WATER USE COEFFICIENTS FOR MANUFACTURING, 1971

(mgd/$\$10^6$ of annual output)

	Industry	Total Withdrawal	Total Consumption
3	Food & Bev.	0.0279344	0.0025084
4	Tobacco	0.0026085	0.0012767
5	Rubber & Plastic	0.3599379	0.0021616
6	Leather	0.0122965	0.0010447
7	Textiles, etc.	0.0346011	0.0009243
8	Wood, etc.	0.0080522	0.0007265
9	Paper & Allied	0.3592791	0.0162767
10	Printing, etc.	0.0019667	0.0000825
11	Iron & Steel	0.4678517	0.0107490
12	Other primary metals	0.0431389	0.0009916
13	Metal Fab.	0.0045882	0.0002497
14	Machinery	0.0046163	0.0002613
15	Trans. Equipment	0.0217472	0.0006739
16	Electrical Products	0.0085573	0.0002548
17	Non Metal Min. Pr.	0.0405812	0.0053058
18	Petroleum & Coal	0.2539139	0.0116096
19	Chemicals	0.4340094	0.0231012
20	Misc. Manu.	0.0072706	0.0003003

beverage sectors. To base long term growth rates on this 25-year period would probably bias the results of the water use forecasting toward the high side. Nevertheless, the economic statistics from this period had to be used in formulating a future growth pattern for they are the best data available. The 25-year period was split into five-year segments. Compound annual growth rates for each period were then calculated, and three growth scenarios were formulated. The high scenario used the highest five-year growth rate, the low scenario the lowest rate and the medium scenario the median rate. These rates are shown in Table 27. For the MLP it was assumed that growth in each industry would reflect the medium rate of growth to 1985, the low rate of growth past 2000 and the average of these two rates between 1985 and 2000. The forecasted economic output resulting from this growth pattern is shown by industrial sector in Table 28. Using the final demand projections as the "driver" of the water use model results in the MLP projections of water withdrawal Table 29 and consumption Table 30.

4.2.1.7 Alternative Projections for Manufacturing Water Use

In order to demonstrate the alteration to the Canadian MLP of manufacturing water use as a result of varying the underlying assumptions of the model, five cases will be presented. The first alters the growth rate for each sector from the MLP to the high, medium and low rates shown in Table 27. These high, medium and low scenarios set upper and lower limits on the MLP projection. The second alteration uses a set of constant growth rates based on the last 25 years. The third alteration of the MLP simulates changes in the technological assumptions about water use by altering the withdrawal and consumption rates. The fourth simulation shows what would happen to water withdrawal and consumption in the Canadian section of the basin if the withdrawal and consumption rates for Canada took on the zero pollutant discharge values assumed in the United States. The last case combines the growth rate alternatives with the medium technological change alternative to simulate water use under a complex set of future assumptions.

4.2.1.8 Changing Growth Rates - Scenario I

The result of substituting different manufacturing growth rates into the water use model is shown in Table 31. The high set of growth rates from Table 27 yields average water use increases of 5.9 percent per annum. Under the medium set of growth rates, withdrawal and consumption increase an average annual 4.4 percent for both parameters. The average annual increase for both withdrawal and consumption under the low set of growth rates is 3.3 percent.

TABLE 27 CANADA: ALTERNATIVE MANUFACTURING GROWTH RATES FOR ONTARIO, 1975-2035

(%)

Sector	High	Medium	Low
Food & Beverage	5	3	2
Tobacco	4	2 1/2	1
Rubber & Plastics	6	4 1/2	2
Leather	3	2	1
Textiles, etc.	3	2	1
Wood, etc.	6	4	2
Paper & Allied	5	4	3
Printing, etc.	5	3 1/2	2 1/2
Iron & Steel	5 1/2	4 1/2	3 1/2
Other Primary Metals	5 1/2	4 1/2	3 1/2
Metals Fabricating	5 1/2	4 1/2	3 1/2
Machinery	7	5	3
Transportation Equipment	7	4 1/2	3
Electrical Products	7	5	3 1/2
Non-Metallic Mineral Products	6	4 1/2	3
Petroleum & Coal	6	4 1/2	3 1/2
Chemicals, etc.	6	4 3/4	4
Miscellaneous	5	4 1/2	4
Electrical Power	5	4 1/2	3 1/2
Agriculture	4 1/2	3 1/2	2 1/2
Mining	5	4 1/2	3 1/2

TABLE 28 CANADA: PROJECTED FINAL DEMANDS AND TOTAL OUTPUTS BY INDUSTRY FOR SELECTED YEARS

($ million, 1971)

Industry	Final Demand					Total Output				
	1975	1985	2000	2015	2035	1975	1985	2000	2015	2035
Agriculture, etc.	855	1,206	2,020	3,385	6,735	2,442	3,445	5,772	9,670	19,241
Mines & Minerals Fuels	292	453	877	1,697	4,093	1,309	2,032	3,933	7,612	19,358
Food & Beverages	2,389	3,211	4,628	6,229	9,256	4,163	5,595	8,064	10,853	16,128
Tobacco	206	263	339	393	480	240	308	396	460	561
Rubber & Plastics	219	340	562	756	1,124	889	1,380	2,279	3,067	4,557
Leather	168	205	254	295	360	235	287	357	414	505
Textiles, etc.	531	647	805	935	1,141	1,392	1,697	2,112	2,451	2,991
Wood, etc.	229	340	524	705	1,048	767	1,135	1,751	2,356	3,501
Paper & Allied	436	646	1,077	1,677	3,029	1,508	2,232	3,721	5,797	10,471
Printing, etc.	343	484	750	1,086	1,780	890	1,255	1,946	2,818	4,618
Iron & Steel	-400	-498	-1,113	-1,865	-3,711	1,644	2,553	4,576	7,666	15,255
Other Primary Metals	-538	-836	-1,499	-2,511	-4,996	1,165	1,810	3,244	5,434	10,813
Metal Fab.	1,803	2,800	4,829	7,524	13,589	3,520	5,466	9,427	14,687	26,526
Machinery	685	1,116	1,990	3,100	5,599	800	1,303	2,325	3,622	6,542
Transportation Equipment	3,855	5,987	10,325	16,086	29,053	5,702	8,855	15,270	23,790	42,968
Electrical Products	1,611	2,624	4,864	8,149	16,215	2,289	3,729	6,912	11,581	23,043
Non-Metallic Mineral Prod.	137	213	368	573	1,035	811	1,260	2,173	3,385	6,114
Petroleum & Coal	268	416	754	1,249	2,485	879	1,365	2,447	4,099	8,157
Chemicals, etc.	657	1,045	2,014	3,626	7,946	1,978	3,147	6,061	10,915	23,915
Misc. Manufacturing	506	786	1,463	2,634	5,773	858	1,332	2,481	4,468	9,791
Construction, etc.	3,673	5,383	9,695	17,459	38,256	4,598	6,806	12,257	22,074	48,368
Transportation, etc.	2,818	4,171	7,512	13,529	29,645	6,206	9,186	16,543	29,793	65,281
Utilities	179	278	538	1,041	2,510	739	1,148	2,221	4,299	10,368
Communication, etc.	6,557	9,706	17,480	31,480	68,976	9,932	14,701	26,476	47,682	104,477
Others	-432	-640	-1,152	-2,075	-4,548	2,735	4,408	7,291	13,130	28,770
	27,011	40,346	69,904	117,157	198,617	57,691	86,075	150,035	252,123	511,319

The medium set of rates from Table 27 produces water use estimates which are very close to those for the MLP. The overall growth in water use for the latter was 4.5 percent. For individual lake basins, variances between the base case and the medium growth rate scenarios may be up to 15 percent. The range of water use estimates produced by the alternative growth rate scenario is wide, although it does bracket the MLP, which lies in the bottom part of the range.

4.2.1.9 Changing Growth Rates - Scenario II

The second simulation of future water use was based on output from the CANDIDE model of the Canadian economy, regionalized for the Great Lakes basin in a study for the Canada Centre for Inland Waters (54). The results of this simulation are also shown in Table 31, under the columns labelled "historic". This particular label is used because the CANDIDE model employs econometric equations based upon historic data. As outlined earlier, this growth scenario is probably too high to be considered an accurate forecast.

4.2.1.10 Water Use and Technological Change

One of the most important factors affecting industrial water use is the technology used in circulating water through plants. Changes designed to recirculate more water will lead to reductions in water demand. They may or may not affect water consumption. Thus, it is important in making defensible water demand forecasts that technology be taken into account explicitly (3).

One way of approaching the technological change problem is empirically, through examining changes over time in the use rate and the consumption rate. The use rate is the ratio of gross water use to water intake. The consumption rate is the ratio of water consumption to gross water use. The difficulty in using this approach is the non-existence of an appropriate time series of water use data in Canada. However, water use surveys have been conducted in the U.S. by the Department of Commerce every four or five years (5), and the published results of these surveys are an appropriate place to begin an analysis of technological change as it affects water use.

For each major industry, except agriculture and thermal power generation for which no data could be found, the published U.S. data were used to develop use rates and consumption rates for 1954, 1959, 1964, 1968, and 1973. It was assumed that trends in these rates reflect the evolving state of water use technology. Since the U.S. has a somewhat more water-intensive industry (with higher use and consumption rates generally), technological impacts on water use can be examined by allowing Canadian water use patterns to assume the parameteric values associated with the U.S. data. Specifically, for each industry, the method allowed the Ontario use and consumption rates to assume the high, medium and low U.S. values over the time frame of the study in gradual and equal increments.

TABLE 29 CANADA: PROJECTED MANUFACTURING WATER WITHDRAWALS BY LAKE BASIN AND SELECTED YEAR

(cfs)

Basin	Industry	1975	1985	2000	2015	2035
Lake Superior	Chemical & Allied Products	10	10	30	50	120
	Primary Metals	390	610	1,100	1,840	3,660
	Paper & Allied Products	290	430	710	1,100	1,990
	Petroleum & Coal Products	0	-	-	-	-
	Rubber & Plastic Products	0	-	-	-	-
	Others	10	10	10	20	30
	TOTAL	700	1,060	1,850	3,010	5,800
Lake Huron	Chemical & Allied Products	330	520	1,000	1,800	3,930
	Primary Metals	50	80	140	230	460
	Paper & Allied Products	290	430	720	1,120	2,020
	Petroleum & Coal Products	0	-	-	-	-
	Rubber & Plastic Products	410	630	1,040	1,400	2,080
	Others	30	40	60	90	150
	TOTAL	1,110	1,690	2,950	4,630	8,640
Lake Erie	Chemical & Allied Products	1,020	1,620	3,120	5,620	12,300
	Primary Metals	60	10	10	20	50
	Paper & Allied Products	10	10	10	10	10
	Petroleum & Coal Products	250	390	710	1,180	2,350
	Rubber & Plastic Products	20	30	50	60	100
	Others	220	330	540	830	1,460
	TOTAL	1,520	2,380	4,440	7,720	16,270
Lake Ontario	Chemical & Allied Products	150	240	460	820	1,810
	Primary Metals	1,070	1,670	2,990	5,000	9,950
	Paper & Allied Products	80	120	190	300	550
	Petroleum & Coal Products	160	250	450	750	1,490
	Rubber & Plastics Products	170	260	420	570	840
	Others	360	500	800	1,180	2,030
	TOTAL	1,990	3,030	5,300	8,630	16,670
St. Lawrence River	Chemical & Allied Products	90	140	280	510	1,110
	Primary Metals	-	-	-	10	10
	Paper & Allied Products	100	150	250	380	690
	Petroleum & Coal Products	-	-	-	-	-
	Rubber & Plastic Products	10	10	10	20	30
	Others	60	80	110	150	220
	TOTAL	260	380	650	1,050	2,050
Great Lakes	Chemical & Allied Products	1,600	2,530	4,880	8,790	19,270
	Primary Metals	1,520	2,360	4,240	7,100	14,120
	Paper & Allied Products	760	1,120	1,870	2,910	5,260
	Petroleum & Coal Products	420	640	1,150	1,930	3,850
	Rubber & Plastic Products	600	920	1,520	2,050	3,050
	Others	680	960	1,530	2,270	3,890
	TOTAL	5,570	8,550	15,200	25,050	49,430

Figures may not add due to rounding

TABLE 30 CANADA: PROJECTED MANUFACTURING WATER CONSUMPTION BY LAKE BASIN AND SELECTED YEAR

(cfs)

Basin	Industry	1975	1985	2000	2015	2035
Lake Superior	Chemical & Allied Products	-	-	10	10	10
	Primary Metals	10	10	10	20	30
	Paper & Allied Products	10	20	40	60	100
	Petroleum & Coal Products	-	-	-	-	-
	Rubber & Plastic Products	-	-	-	-	-
	Others	-	10	10	10	10
	TOTAL	20	30	50	80	140
Lake Huron	Chemical & Allied Products	40	60	120	220	470
	Primary Metals	-	-	-	-	10
	Paper & Allied Products	10	20	40	60	100
	Petroleum & Coal Products	-	-	-	-	-
	Rubber & Plastic Products	10	10	10	10	10
	Others	10	10	10	10	10
	TOTAL	60	90	170	290	600
Lake Erie	Chemical & Allied Products	30	50	90	170	380
	Primary Metals	-	-	10	10	10
	Paper & Allied Products	-	-	-	-	-
	Petroleum & Coal Products	20	30	50	80	150
	Rubber & Plastic Products	-	-	-	10	10
	Others	10	20	30	40	70
	TOTAL	60	90	170	300	610
Lake Ontario	Chemical & Allied Products	10	20	40	70	160
	Primary Metals	30	50	90	140	290
	Paper & Allied Products	10	10	10	10	30
	Petroleum & Coal Products	10	10	10	10	20
	Rubber & Plastics Products	-	-	10	10	10
	Others	20	30	50	70	120
	TOTAL	70	110	190	320	620
St. Lawrence River	Chemical & Allied Products	-	10	10	10	10
	Primary Metals	-	-	-	-	-
	Paper & Allied Products	10	10	10	20	40
	Petroleum & Coal Products	-	-	-	-	-
	Rubber & Plastic Products	-	-	-	-	-
	Others	10	10	10	10	10
	TOTAL	10	10	20	30	60
Great Lakes	Chemical & Allied Products	90	130	260	470	1,030
	Primary Metals	40	50	100	160	320
	Paper & Allied Products	40	60	90	140	260
	Petroleum & Coal Products	20	30	50	90	180
	Rubber & Plastic Products	10	10	10	10	20
	Others	40	60	90	130	220
	TOTAL	220	340	600	1,010	2,030

Figures may not add due to rounding

TABLE 31 CANADA: MANUFACTURING WATER USE PROJECTIONS UNDER VARYING ECOMOMIC GROWTH ASSUMPTIONS BY LAKE BASIN AND SELECTED YEAR

(cfs)

Basin	Year	Water Withdrawal				Consumption			
		High	Medium	Low	Historic	High	Medium	Low	Historic
Lake Superior	1975	-	700	-	-	0	20	-	-
	1985	1,210	1,060	930	1,070	40	40	30	30
	2000	2,640	1,990	1,510	2,020	90	60	50	50
	2015	5,750	3,750	2,460	3,840	190	120	80	90
	2035	16,280	8,740	4,740	9,050	520	270	150	210
Lake Huron	1975	-	1,100	-	-	-	60	-	-
	1985	2,010	1,680	1,390	1,720	60	70	50	90
	2000	4,640	3,180	2,190	3,370	150	100	80	180
	2015	10,750	6,040	3,500	6,610	340	190	140	350
	2035	33,200	14,220	6,670	16,280	1,020	450	270	870
Lake Erie	1975	-	1,520	-	-	-	60	-	-
	1985	2,880	2,330	2,110	2,400	150	120	110	100
	2000	6,980	4,480	3,670	4,780	350	230	190	190
	2015	16,960	8,630	6,400	9,520	850	440	330	370
	2035	55,700	20,720	13,530	23,890	2,750	1,050	700	910
Lake Ontario	1975	-	1,990	-	-	-	70	-	-
	1985	3,580	3,020	2,600	3,070	120	100	90	110
	2000	8,190	5,740	4,220	6,050	280	190	140	220
	2015	18,840	10,960	6,900	11,820	640	350	230	420
	2035	57,760	26,050	13,410	28,900	1,950	830	450	130
St. Lawrence	1975	-	260	-	-	-	10	-	-
River	1985	450	380	330	400	20	20	20	10
	2000	970	670	530	750	50	30	30	20
	2015	2,130	1,220	870	1,430	110	60	40	40
	2035	6,240	2,740	1,700	3,380	310	130	90	90
TOTALS	1975	-	5,570	-	-	-	220	-	-
	1985	10,130	8,460	7,360	8,660	400	350	290	340
	2000	23,420	16,070	12,120	16,970	910	620	490	660
	2015	54,440	30,600	20,130	33,210	2,110	1,160	820	1,280
	2035	169,170	72,480	40,040	81,500	6,550	2,730	1,650	3,100

This set of simulations allows conclusions to be drawn on what will happen to water demands if water use patterns change in intensity during the forecast period.

Data on the parametric values used are shown in Table 33, based upon the five annual surveys conducted in the U.S. between 1954 and 1973. The use and consumptive rates are shown because they are the parameters of water use thought to be important in analyzing future water use. The gross use per employee parameter is used to relate economic output to water use. According to the methodology, the various Canadian parameters were allowed to assume, in turn, the high and the low U.S. values over the 60-year life of the forecast in linear increments. Then a medium scenario was calculated by averaging, for each forecast year, the high and low values. The gross use per employee figure was used, after conversion to gross use per million dollars of output, to calculate new coefficients for the water use model, which, when applied to the MLP forecasts of output, enabled the computation of new gross water use amounts for each forecasting year.

An example of the method for projecting parametric values is given in Table 32. Working with the set of data on use rates from Table 33, the figure for 1975 is the most current Canadian measure of this parameter. The figures for this parameter for 2035 are the highest and lowest values from the corresponding array in Table 33, for the high and low respectively and the average of these two figures.

TABLE 32 CANADA: USE RATE MANIPULATIONS, FOOD AND BEVERAGE INDUSTRY

	Use Rate		
Year	High	Medium	Low
1975	-	1.330	-
1980	1.465	1.418	1.370
2000	1.668	1.549	1.430
2015	1.870	1.680	1.490
2035	2.140	1.855	1.570

To obtain the intervening figures, simple linear interpolation was used. In a similar manner, the current Canadian consumption rates were altered to assume the U.S. high, average, low values of Table 33 by 2035, and the adjustments made for intervening years. These parameters were then used to calculate water withdrawal and consumption forecasts. The parameter forecasts were then arranged to simulate extensive, medium and intensive water-using technologies.

Scenario	Use Rate	Consumption Rate
extensive	low	low
medium	medium	medium
intensive	high	high

TABLE 33 CANADA: PARAMETRIC VALUES USED IN TECHNOLOGICAL CHANGE SCENARIOS[1]

Industry	Year	Use Rate[2]	Consumption Rate[3]
Food & Beverage	1954	2.14	.0501
	1959	2.08	.0408
	1964	1.57	.0605
	1968	1.66	.0431
	1973	1.96 (1.33)[4]	.0373 (.0883)
Tobacco	1954	3.67	.0909
	1959	14.67	.0227
	1964	21.33	.0156
	1968	12.83	.0130
	1973	20.00 (8.23)	.0100 (.0468)
Textiles	1954	1.15	.1754
	1959	1.35	.0824
	1964	1.82	.0483
	1968	2.13	.0549
	1973	2.39 (1.53)	.0423 (.0278)
Lumber & Wood	1954	1.20	.1580
	1959	1.31	.0761
	1964	1.44	.1290
	1968	2.03	.0390
	1973	1.66 (1.10)	.1396 (.0231)
Furniture & Fixtures	1954	1.14	.3750
	1959	1.33	.2500
	1964	1.33	-
	1968	1.50	-
	1973	1.50 (1.10)	- (.0599)
Paper & Allied Industries	1954	2.37	.0391
	1959	3.12	.0187
	1964	1.41	.0222
	1968	2.90	.0267
	1973	3.37 (2.42)	.0140 (.0129)
Chemical & Allied Industries	1954	1.60	.0314
	1959	1.61	.0343
	1964	1.98	.0273
	1968	2.10	.0320
	1973	2.66 (1.34)	.0167 (.0293)
Petroleum & Coal	1954	3.33	.0214
	1959	4.45	.0199
	1964	4.41	.0131
	1968	5.08	.0299
	1973	9.13 (1.52)	.0106 (.0242)

Leather & Leather Products	1954	1.10	.0909
	1959	1.16	-
	1964	1.00	.1429
	1968	1.25	.0500
	1973	1.25 (1.11)	- (.0687)
Non-Metallic Minerals	1954	2.23	.0435
	1959	1.64	-
	1964	1.56	.0797
	1968	1.65	.0799
	1973	2.17 (1.82)	.0568 (.1383)
Primary Metals	1954	1.28	.0323
	1959	1.53	.0266
	1964	1.46	.0430
	1968	1.55	.0397
	1973	1.79 (1.77)	.0208 (.0154)
Machinery	1954	1.34	-
	1959	1.46	.0239
	1964	1.73	.0292
	1968	1.79	.0237
	1973	2.56 (2.52)	.0137 (.0400)
Electrical Equipment	1954	1.14	.1846
	1959	1.71	.0314
	1964	2.69	.0511
	1968	2.91	.0243
	1973	10.02 (2.34)	.1160 (.0103)
Transportation Equipment	1954	1.41	.0492
	1959	2.01	.0594
	1964	2.49	.0150
	1968	2.91	.0220
	1973	8.12 (1.71)	.0076 (.0296)
Miscellaneous	1954	1.14	-
	1959	1.43	.0500
	1964	1.69	.0455
	1968	1.71	.0417
	1973	2.17 (2.90)	- (.0507)

---

[1] Source (5)
[2] Use Rate - ratio of gross water use (intake plus recirculation) to water withdrawal (intake).
[3] Consumption Rate - ratio of water consumption to gross water use.
[4] ( ) Bracketed values indicate the most current (1975) Canadian measure.
All values are based on U.S. water use surveys from 1954 to 1973.

Under the extensive water use future, water intake will be relatively large because recirculation, as reflected by the use rate, will be relatively low. It follows that consumption will be relatively low in the face of low recirculation. The reverse reasoning can be applied to selection of use and consumption rates for the intensive water use future. Both rates will be high for this alternative. Since the subject of interest here is the technology of water use within plants, gross use is held constant at the MLP rates.

The simulation results are shown in Table 34 in aggregated form for all manufacturing sectors. For the extensive water use scenario, water withdrawal increases at an average annual rate of 4.0 percent. Consumption, on the other hand, will increase by a slower rate of 3.3 percent. This scenario represents what would happen if Canadian water use patterns reflected the most extensive patterns experienced in the U.S.

Under the medium set of assumptions, the average annual growth rate for water withdrawal decreases to 3.4 percent, while that for consumption increases to 4.2 percent. This scenario produces results relatively close to the MLP.

The set of assumptions denoting the most intensive water use results in average annual growth of 3.0 percent and 4.9 percent respectively over the current figures, and will be the result if the intensity of water use in Canada approaches the maximum intensity yet experienced in the United States.

4.2.1.11 Simulation Using U.S. MLP Parameters

Previously, the impact was shown of trends toward more intensive water use in the U.S. For forecasting purposes, these trends are reflected in the substantial changes in withdrawal and consumption rates. In order to examine the impact that similar assumptions would have on Canada, the use and consumption rates inherent in the U.S. Projection 2 (NAS) were applied to Canadian gross use estimates as developed in the MLP. Since the parametric rates for the U.S. were available only to 2000, the assumption was made that the 2000 rates would apply to all subsequent years. This simulation for Canada is the exact analogy to the U.S. Projection 2, the only difference being in the underlying economic growth rate and the gross water use figures.

The results of this simulation are shown in Table 35. This table is somewhat different in its format than comparable ones for other simulations because it is necessary to show gross water use and the two parametric rates, in addition to projected withdrawal and consumption. For 1975, the withdrawal and consumption rates shown in the table should be compared to the corresponding rates in Table 32 to show base year differences in Canadian and U.S. water use patterns. The overall results of these base year differences is a slight (25 cfs) overestimate of Canadian withdrawals and a 100 percent larger estimate of consumption.

TABLE 34 CANADA: MANUFACTURING WATER USE UNDER VARYING TECHNOLOGICAL ASSUMPTIONS

(cfs)

Basin	Year	Water Withdrawal			Consumption		
		Extensive	Medium	Intensive	Extensive	Medium	Intensive
Lake Superior	1975	-	700	-	-	20	-
	1985	1,200	1,110	1,050	40	40	40
	2000	2,400	2,040	1,820	60	90	180
	2015	4,510	3,510	2,960	110	170	220
	2035	10,480	7,280	5,700	240	420	610
Lake Huron	1975	-	1,070	-	-	60	-
	1985	1,740	1,590	1,490	50	60	60
	2000	3,160	2,620	2,290	90	110	130
	2015	5,270	3,930	3,220	140	200	260
	2035	10,880	7,040	5,250	280	460	660
Lake Erie	1975	-	1,520	-	-	60	-
	1985	2,260	2,040	1,920	100	110	120
	2000	4,000	3,280	2,890	150	190	230
	2015	6,620	4,960	4,120	210	310	400
	2035	13,130	8,770	6,760	330	590	860
Lake Ontario	1975	-	1,990	-	-	70	-
	1985	3,130	2,910	2,770	100	110	120
	2000	5,750	4,970	4,500	170	220	260
	2015	9,940	8,020	6,950	280	410	530
	2035	21,180	15,730	12,890	590	1,020	1,470
St. Lawrence River	1975	-	260	-	-	10	-
	1985	410	370	350	20	20	20
	2000	770	620	540	30	40	40
	2015	1,870	990	800	40	60	80
	2035	3,030	1,860	1,360	70	140	210
TOTALS	1975	-	5,570	-	-	220	-
	1985	8,750	8,030	7,580	300	340	370
	2000	16,090	13,520	12,050	500	650	760
	2015	27,710	21,410	18,050	790	1,160	1,490
	2035	58,700	40,690	31,960	1,520	2,640	3,800

Columns may not add due to conversion and rounding.

TABLE 35 CANADA: MANUFACTURING WATER USE SIMULATION - ZERO DISCHARGE OF POLLUTANTS

Industry	Year	Gross Use	U.R.	Water Withdrawal	C.R.	Consum.
Food and Beverage	1975	260	1.37	190	.1039	20
Textile		120	1.43	80	.1439	10
Paper and Allied Products		2,570	2.24	1,150	.0224	30
Chemicals and Chemical Products		2,130	1.51	1,410	.032	40
Petroleum and Coal Products		620	2.51	250	.0742	20
Primary Metals		2,860	1.37	2,090	.1343	280
Transportation Equip.		380	2.2	170	.1209	20
Others		910	1.93	470	.0558	30
Total		9,870		5,820		450
Food and Beverage	1985	350	3.77	90	.3097	30
Textile		150	11.0	10	.3333	10
Paper and Allied Products		3,800	6.02	630	.2518	160
Chemicals and Chemical Products		3,390	11.52	300	.2831	80
Petroleum and Coal Products		980	14.67	70	.3957	30
Primary Metals		4,180	5.58	750	.4775	360
Transportation Equip.		600	9.3	60	.4478	30
Others		1,670	7.19	230	.2359	50
Total		15,130		2,150		740
Food and Beverage	2000	510	6.5	80	.5913	50
Textile		180	13.0	10	.5	10
Paper and Allied Products		6,340	11.61	550	.7844	430
Chemicals and Chemical Products		6,540	25.78	250	.761	190
Petroleum and Coal Products		1,750	32.27	50	.802	40
Primary Metals		7,500	11.85	630	.7934	500
Transportation Equip.		1,030	19.23	50	.7425	40
Others		2,800	11.89	240	.4599	110
Total		26,650		1,870		1,370
Food and Beverage	2015	680	6.5	110	.5913	60
Textile		210	13	20	.50	10
Paper and Allied Products		9,880	11.61	850	.7844	670
Chemicals and Chemical Products		11,780	25.78	460	.761	350
Petroleum and Coal Products		2,940	32.27	90	.8021	70
Primary Metals		12,590	11.85	1,060	.7934	840
Transportation Equip.		1,600	19.23	80	.7425	60
Others		3,990	18.89	210	.4599	100
Total		43,650		2,880		2,150
Food and Beverage	2035	1,020	6.5	160	.5913	90
Textile		260	13.0	20	.50	10
Paper and Allied Products		17,840	11.61	1,540	.7844	1,210
Chemicals and Chemical Products		35,800	25.78	1,000	.7608	760
Petroleum and Coal Products		5,850	32.27	180	.8021	140
Primary Metals		25,000	11.85	2,110	.7934	1,680
Transportation Equip.		2,890	19.23	150	.7425	110
Others		6,500	11.89	550	.4599	250
Total		85,170		5,700		4,250

Columns may not add due to rounding

The same U-shaped configuration as noted for the U.S. Projection 2 occurs for Canadian water withdrawal under this simulation. It is extremely unlikly that this simulation will occur in the absence of regulatory and economic instruments to promote such an outcome in Canada. The result of this simulation is reported solely for illustrative purposes and comparison with the U.S. National Assessment Study.

4.2.1.12 Water Use Ranges Based on Simulation Runs

Because water use data collection in Canada is relatively recent, insufficient measurements exist to allow a statistical approach to this forecasting exercise. The simulation approach taken here is an alternative and allows the selection of a range of water use estimates around the MLP (Figures 7 and 8). A wide range of alternatives have been covered in these forecasts, and it is improbable that future manufacturing water use will fall outside of the indicated band, excluding the lowest curve. Trends in environmental control, even in Canada, will induce more recirculation (i.e. higher use rates) in the future than experienced currently with attendant increases in water consumption. The high growth rate future can probably be dismissed because the growth rates are thought too high to be experienced in a mature industrial economy such as Ontario's. Eliminating this scenario, Table 36 gives the MLP water use projection together with the best estimate of its upper and lower limits.

5.1 Mining Water Use: United States Most Likely Projection

Estimates of mining industry water requirements in the Great Lakes region, based on the standard water withdrawal rates and consumption percentages (Table 37) as applied to the OBERS SERIES E mineral earnings were developed by the U.S. Bureau of Mines (USBM) in a three step procedure (77):

1. Rates of incremental change in OBERS SERIES E mineral earning projections between 1975, 1985 and 2000 were determined through a two stage process. A curve connecting earnings for the period 1975 to 2000 was developed and projected back to 1972, the most recent USBM mineral production base year. The rates of change for time intervals, 1975/1972, 1985/1975, and 2000/1985, were then calculated for each mineral group.

2. The mineral industry average water withdrawals for 1972 were calculated by multiplying USBM estimates of national water withdrawal averages in gallons per production dollar by the 1972 production totals for each mineral group.

TABLE 36 CANADA: MANUFACTURING WATER USE RANGES FOR THE GREAT LAKES BY SELECTED YEARS
(cfs)

	Water Withdrawal			Water Consumption		
Year	MLP	High	Low	MLP	High	Low
1975	5,570	—	--	220	—	--
1985	8,550	8,750	7,580	340	360	300
2000	15,200	16,090	12,050	600	790	500
2015	25,050	30,600	18,050	1,010	1,700	790
2035	49,430	72,500	31,960	2,030	4,800	1,520

NOTE: High water consumption estimate represents a combination of high growth and intensive technology assumptions.

Canada: Manufacturing Water Use Ranges - Withdrawals

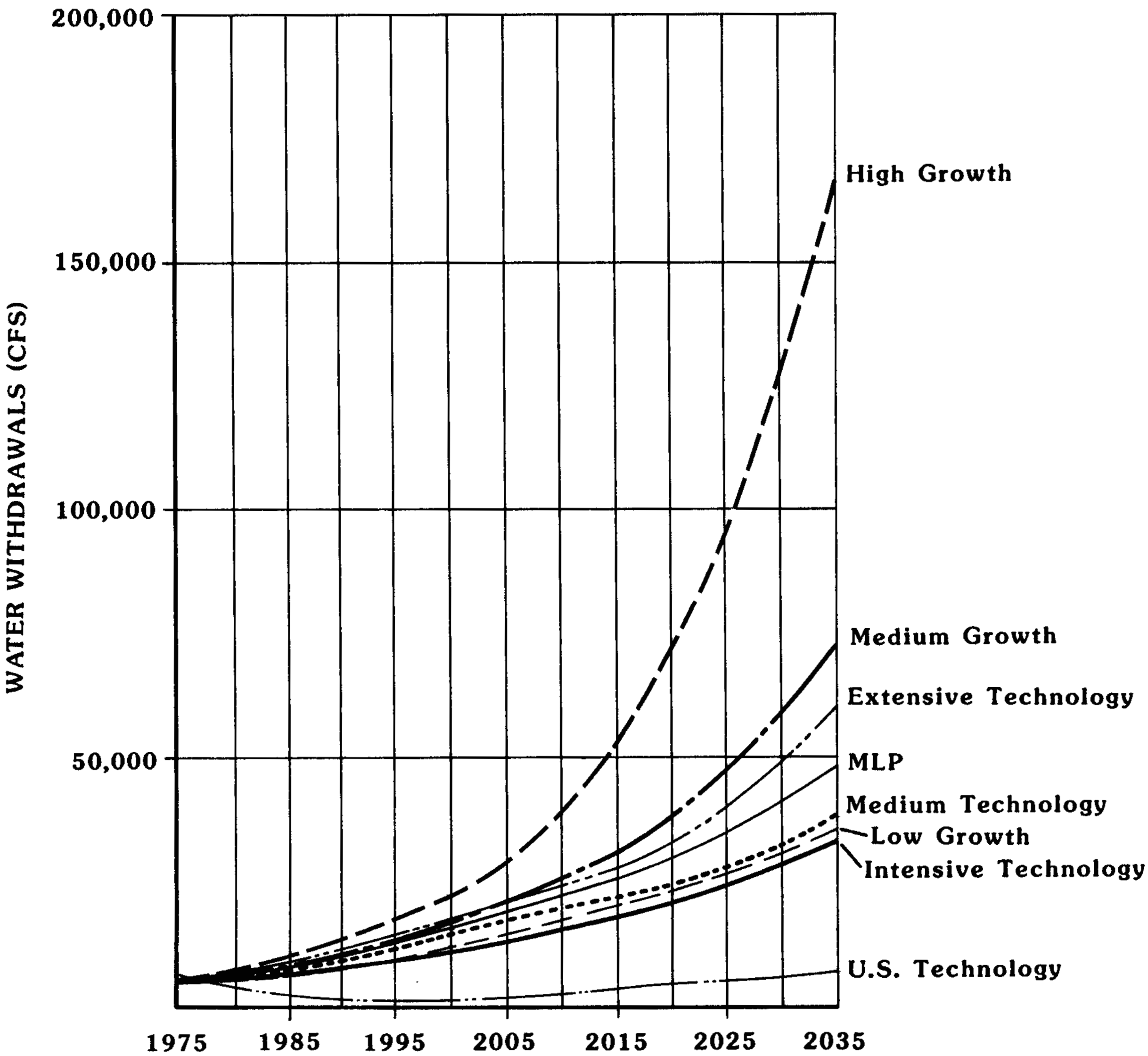


Figure F-7

Canada: Manufacturing Water Use Ranges - Consumption

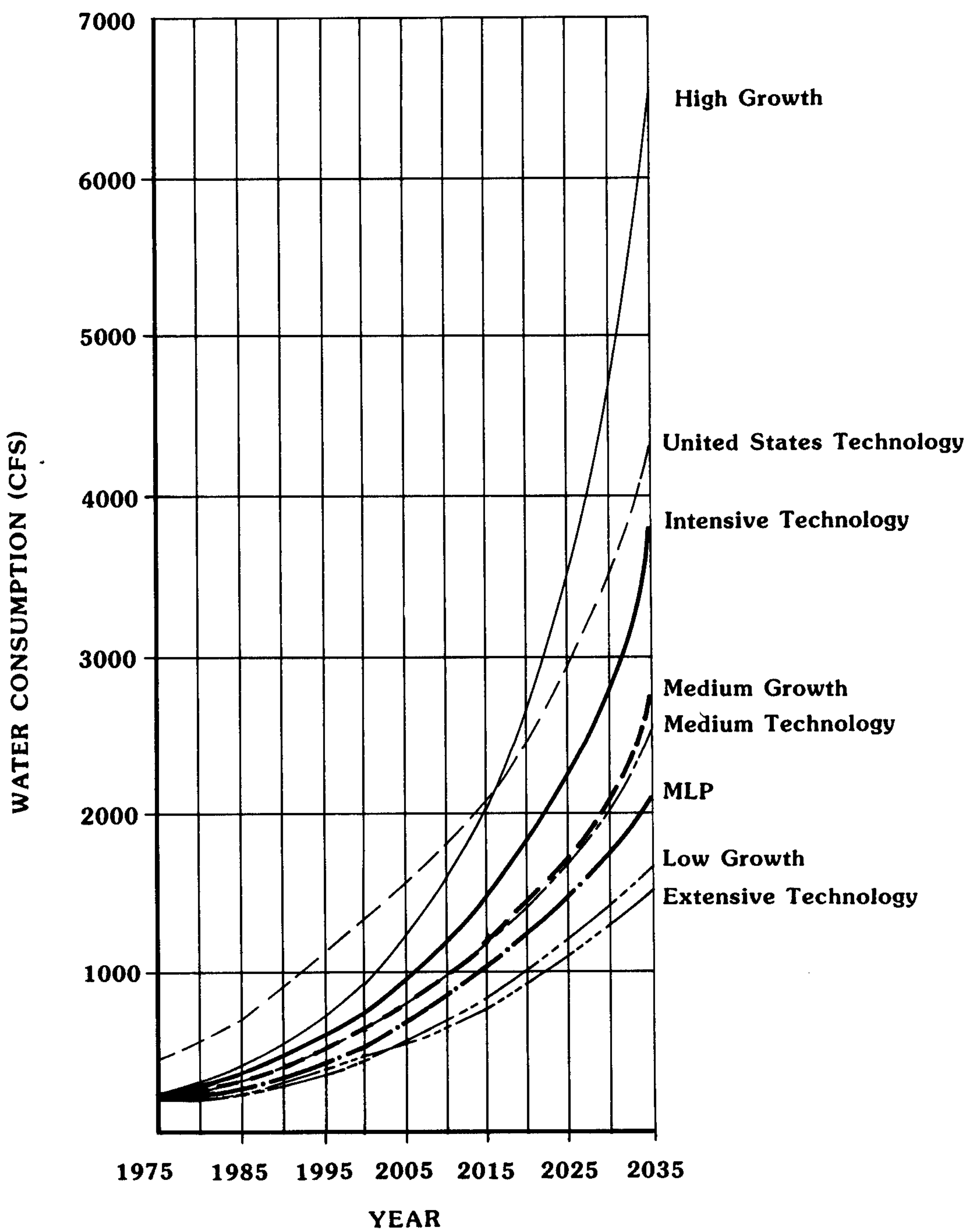


Figure F-8

Manufacturing Withdrawals

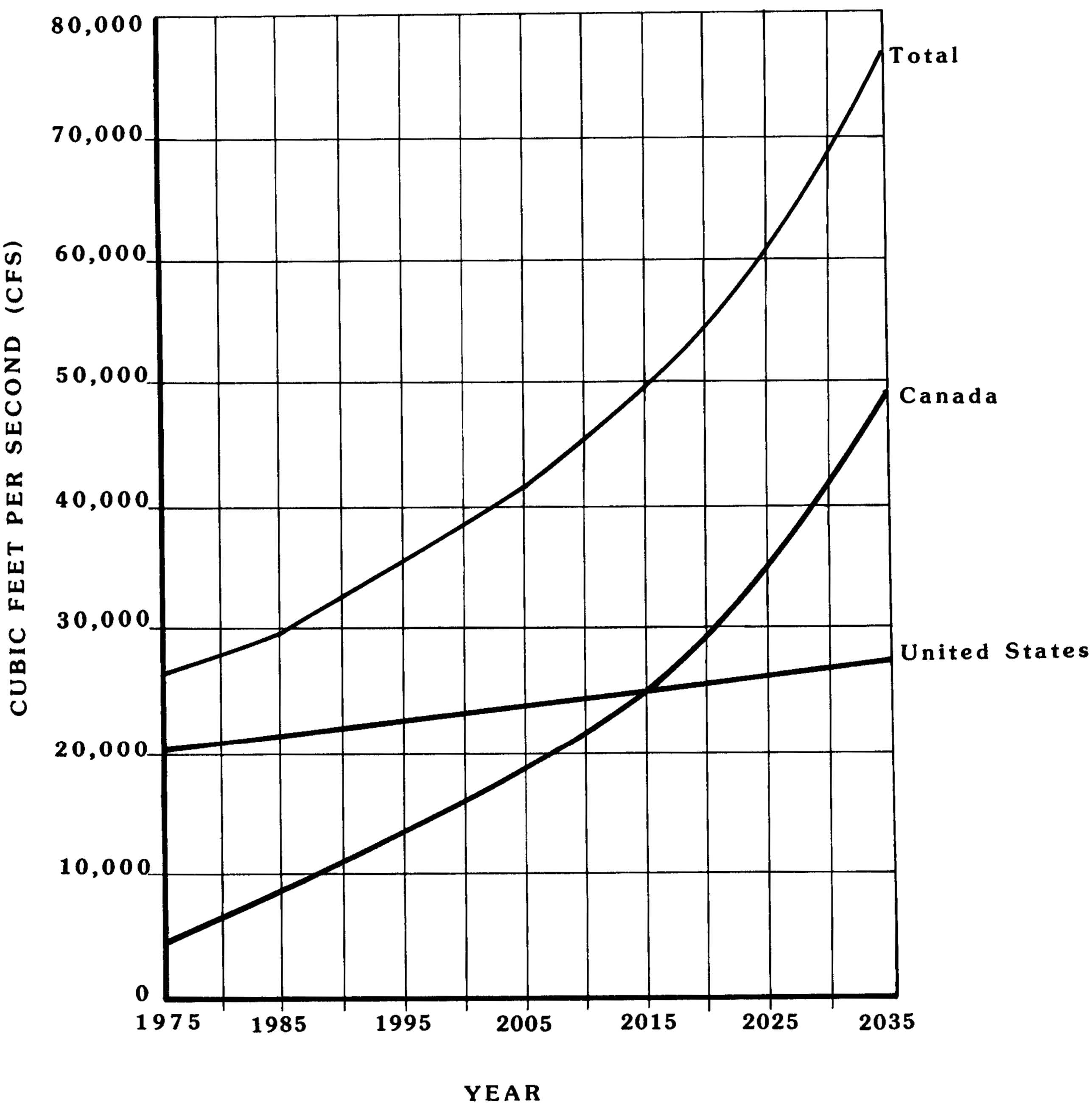


Figure F-9

Manufacturing Consumption

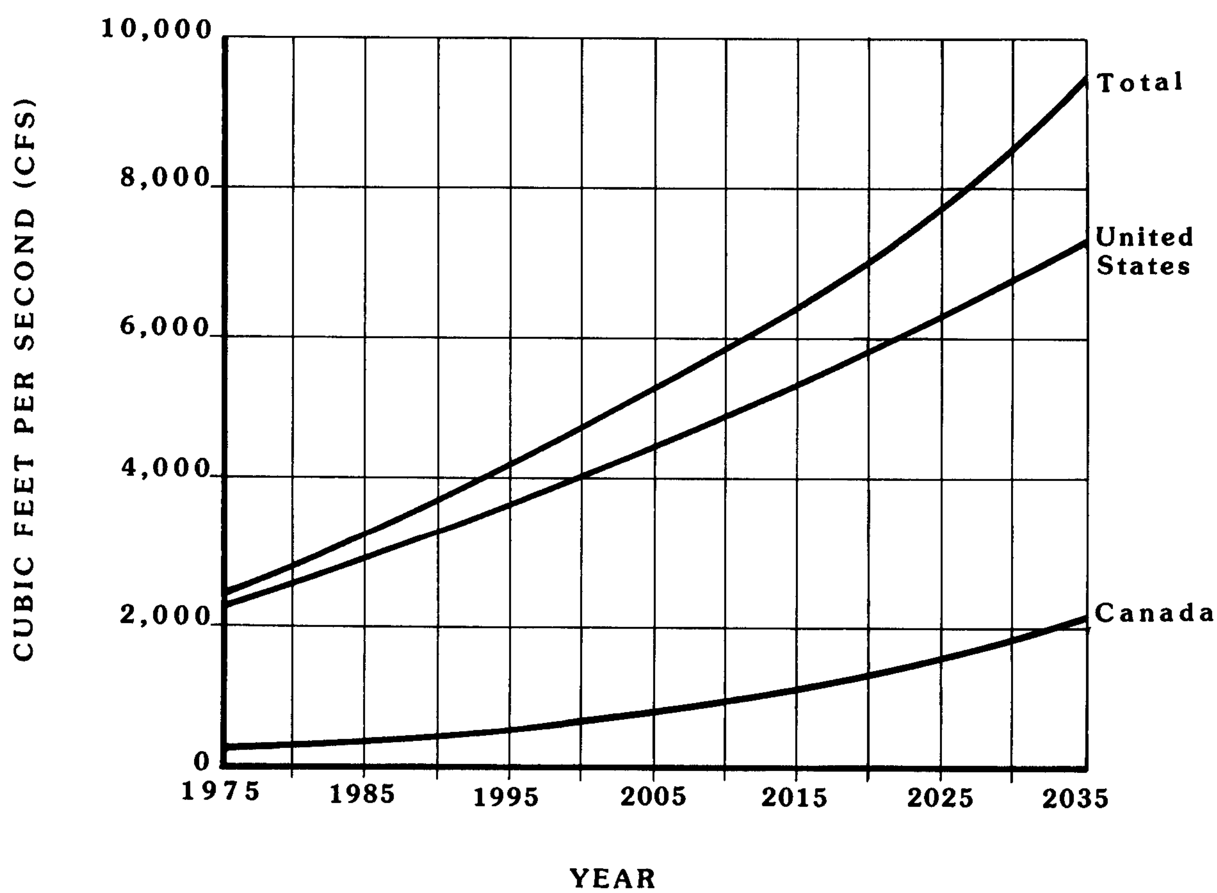


Figure F-10

3. Estimates of water withdrawals and consumptive use for 1975, 1985 and 2000 were made by; a) multiplying 1972 water withdrawals by the earnings change rates for each mineral group and, b) determining average consumption percentages of water withdrawals for each mineral group.

TABLE 37 U.S.: WATER USE RATES & PERCENTAGES FOR THE MINERAL INDUSTRY

Industry Category	Withdrawals (Gal/1972 production dollar)	% Consumed	% Recirculation
Metals	92	14.5	88.2
Nonmetals	163	13.3	94.4
Fuels	52	55.2	60.0

4. Projections of mineral industry water withdrawals and consumption were obtained by extrapolating the USBM data to 2035.

5.2 Mining Water Use: Canada

High, MLP, and low forecasts for mining water withdrawals and consumption were prepared using the respective growth rates from Table 27 in the Canadian manufacturing discussion (Table 38). Under the high growth scenario, water withdrawal increases at a compound rate of five percent per year; the corresponding figure for the low growth scenario is 3.5 percent or 1,040 cfs per annum. The consumptive use projections for the high and low scenarios are 70 cfs and 30 cfs respectively by 2035. No technological change alternatives have been computed for the mining sector.

6.1 Rural-Stock Water Use: United States Most Likely Projection

The following procedure was used in the NAS to generate the U.S. rural-stock use data.

1. Livestock water use estimates were calculated as a function of stock water use rates and projected livestock production figures. Stock water use rates were obtained from several sources. Drinking water use rates, classified according to animal type and weight categories, were taken from J.F. Sykes "Animals and Fowl and Water". Water use rates for other than drinking purposes were estimated from river basin reports and special area studies. Drinking and non-drinking water use rates were finally summed to obtain total stock water use rates.

TABLE 38 CANADA: MINING WATER USE PROJECTIONS
(cfs)

Basin	Year	Withdrawal High	Withdrawal MLP	Withdrawal Low	Consumption High	Consumption MLP	Consumption Low
Lake Superior	1975	10	10	10	10	10	10
	1985	20	20	20	10	10	10
	2000	40	30	30	10	10	10
	2015	80	50	40	10	10	10
	2035	210	100	90	10	10	10
Lake Huron	1975	110	110	100	10	10	10
	1985	180	170	160	10	10	10
	2000	380	310	270	10	10	10
	2015	800	520	450	20	10	10
	2035	2120	1040	890	40	20	20
Lake Erie	1975	10	10	10	10	10	10
	1985	10	10	10	10	10	10
	2001	20	20	10	10	10	10
	2015	40	30	20	10	10	10
	2035	110	60	40	10	10	10
Lake Ontario/ St. Lawrence	1975	10	10	10	10	10	10
	1985	10	10	10	10	10	10
	2000	10	10	10	10	10	10
	2015	10	10	10	10	10	10
	2035	40	20	10	10	10	10
TOTALS	1975	130	130	130	10	10	10
	1985	220	200	190	10	10	10
	2000	450	370	310	10	10	10
	2015	930	610	520	30	20	10
	2035	2470	1220	1040	70	40	30

Mining Withdrawals

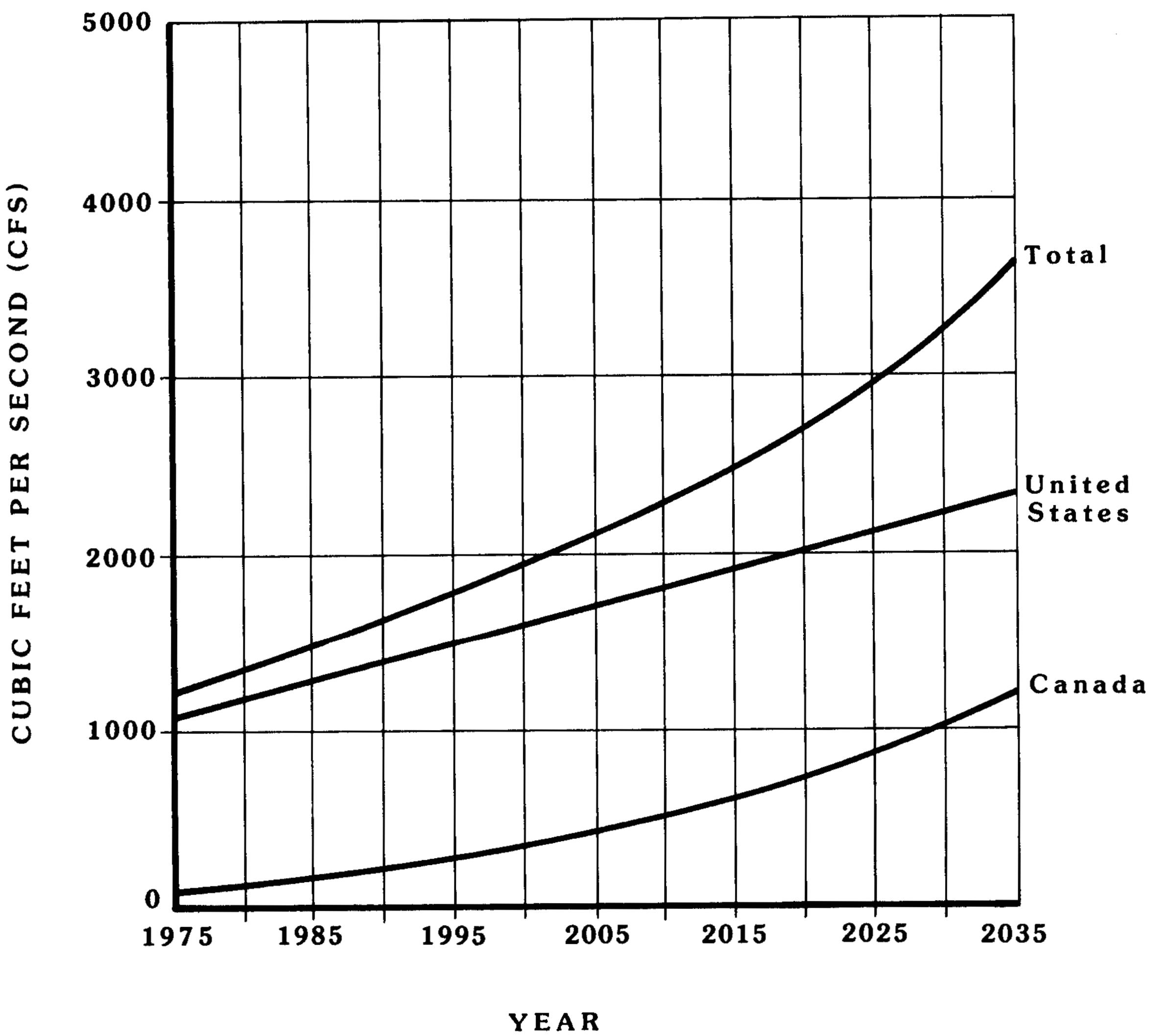


Figure F-11

Mining Consumption

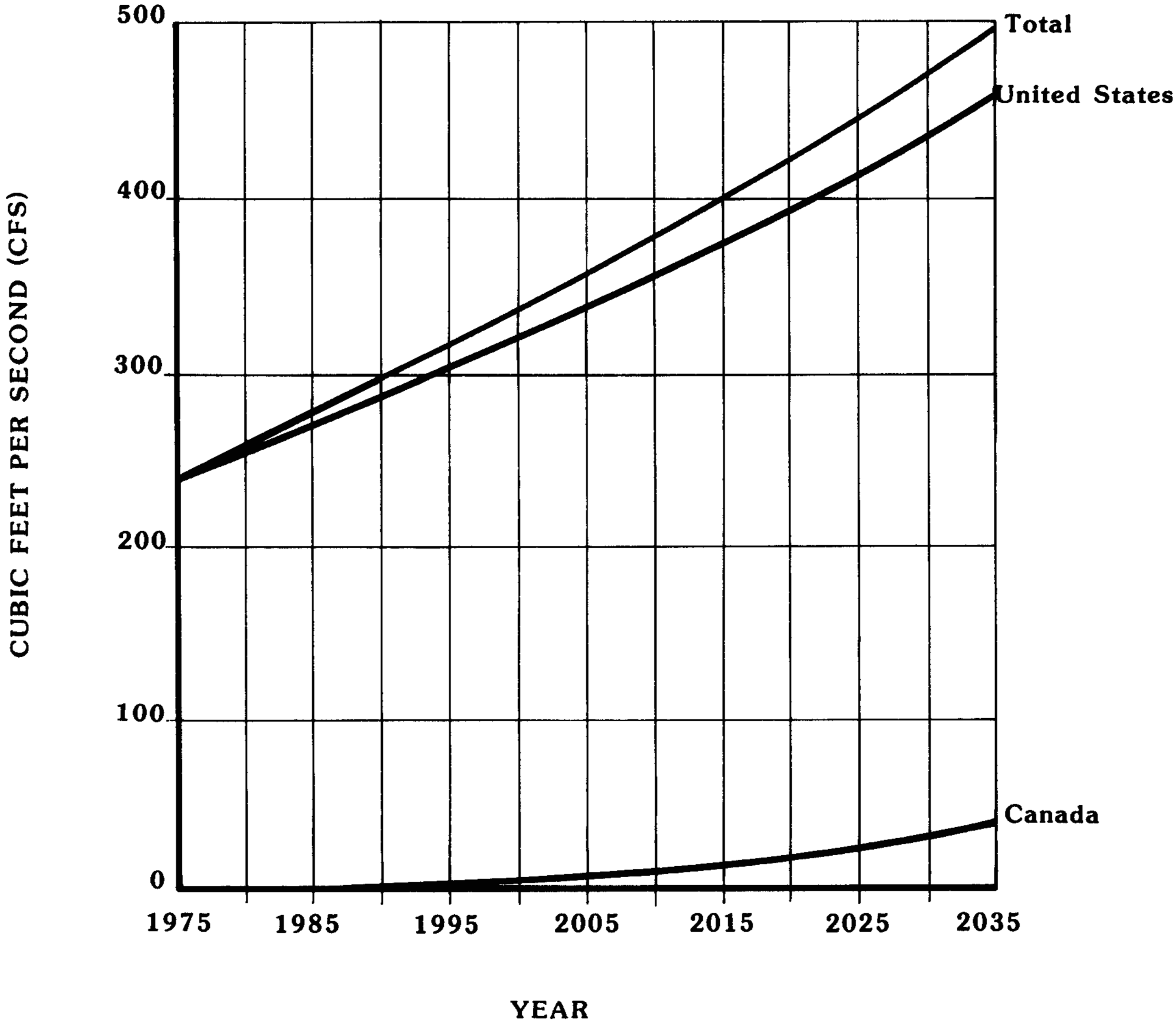


Figure F-12

2. Estimates of livestock production were derived from the OBERS SERIES E projections of human population which were translated into historical trends of commodity demands. Projected livestock production was allotted throughout the region on the basis of the population projections.

3. The relationship between numbers of livestock and associated commodities produced were estimated for each ASA with data from 1970 Agriculture Census reports. This information and the water use rates were used to develop conversion factors representing daily stockwater requirements divided by commodity produced. Conversion factors were assigned to each ASA in the region by visual interpolation of the state factors. These factors were assumed constant for 1975, 1985 and 2000 with no allowance for changes in livestock composition or production efficiencies.

4. The projected annual livestock water requirements for the period 1975 to 2000 were determined by multiplying the stock water use rates times the projected livestock production figures. Consumptive use rates are assumed to be 100 percent of withdrawal rates. This may not be true in all cases of stock water use, but quantities of return flow are extremely difficult to estimate and are considered to be negligible in this study. Therefore, withdrawal figures also represent consumptive use. Projections of water withdrawals and consumptive use for the period 2005 to 2035 were derived by extrapolation.

6.2 Rural-Stock Water Use: Canada

The projection of livestock water use involved a forecast of the number of animals by category. The categories used were beef cattle, dairy cattle, pigs, lambs and sheep, and poultry. It was assumed that dairy and meat products from Ontario livestock were destined for Ontario markets; no account was taken of either exports or imports. This assumption seems reasonable since Ontario is not a large exporter of livestock or foodstuffs; it also simplifies the forecasting process because it allows overlooking possible export-import effects. In forecasting the number of animals by category, the variable used was per capita consumption of meat products for which statistics are available back to 1939; a time series from 1945 to 1977 was used for this study. The procedure involved regression analysis, with time as the independent variable. The regression relationships were of the form:

$$Y = f\ (\text{time})$$

where Y is the per capita consumption of meat or dairy products.

Several functional forms for the regression lines were attempted, with the aim of obtaining a good "fit" to the data at the same time as allowing meat consumption to approach a maximum value over time. The latter condition was placed on the analysis because a simple linear fit to the data gave predictions of per capita consumption which were clearly not feasible. For example, the least squares fit of beef consumption data, based on a simple linear regression on untransformed data, gave a predicted value around 400 pounds per year by 2035 (1975 value equals 102 pounds). One type of curve which permits use of a maximum value is termed a logistic curve (30), and was used to fit the beef and poultry data. The per capita consumption of dairy products was found to decrease over time and an exponential curve best fit these data. The pork and mutton consumption data were found to be trendless, and the mean value over the period 1945 to 75 was used in the water use forecasting process for pigs and sheep. The specific equations used are shown in Table 39. Once the per capita consumption values were derived, they were multiplied by the forecasted medium population scenario (Section 2.2.3, Table 15), and then divided by average animal weights to give a predicted number of animals in the basin for each future year. The number of animals was then used as the basis for the water use forecast for each class of animal. Disaggregation of the total livestock water use into individual lake basins was carried out on the basis of a study by Bangay (1), which contains data back to 1931.

The estimated livestock distribution amongst basins in 1975 is shown in Table 40. When these numbers are multiplied by the coefficients of water use shown in Table 40 (39) and then aggregated, the resulting water withdrawal for the basin is 80 cfs. The projection equations for each type of livestock are given in Table 39. When the numbers of livestock are projected and translated into water use, the total withdrawal increases at an annual growth rate of 1.6 percent. All water withdrawals for stockwatering are considered here to be consumed.

A high stockwatering estimate was computed using meat and dairy consumption figures 20 percent above the MLP amounts. The low estimate used meat and dairy consumption figures 20 percent below the MLP; in addition the low estimate is based on the low population projection (Table 14). With the changed assumptions built into the projection model, water use for stockwatering attains a high estimate of 270 cfs and a low estimate of 170 cfs by 2035. These represent annual increases of 2.0 percent and 1.2 percent respectively over the forecast period.

7.1 Irrigation Water Use: United States Most Likely Projection

The NAS figures for agricultural water withdrawals and consumption were developed by the state offices of the U.S. Department of Agriculture (USDA) and the Soil Conservaton Service (SCS). The methodology used to obtain this data consisted of six steps (63):

1. Estimates of cropland acreages for each type of crop in each ASA were compiled from OBERS SERIES E projections of agricultural development and the SCS state crop production reports for 1975, 1985 and 2000.

TABLE 39 CANADA: EQUATIONS FOR PER CAPITA MEAT AND DAIRY PRODUCT USE

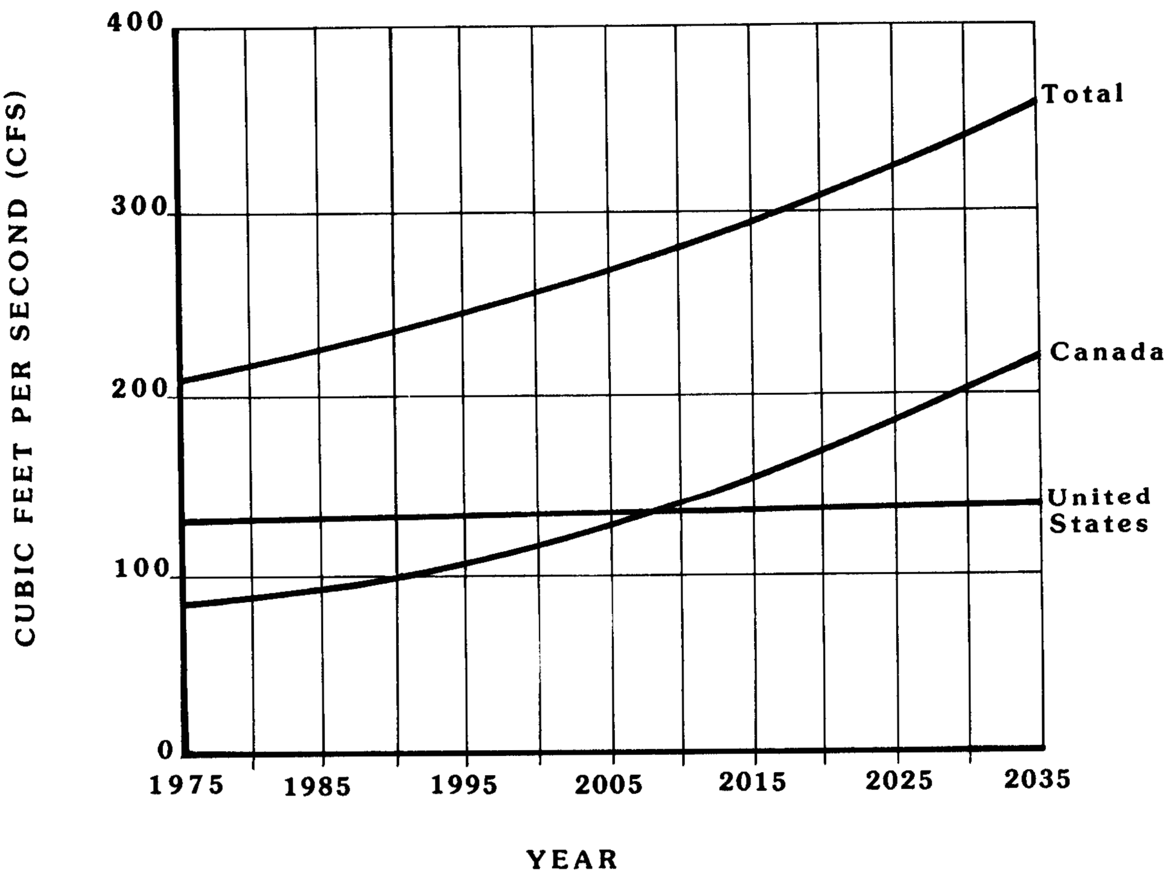
Product	Type of Equation	Maximum Value (lbs/yr)	Equation	Standard error of estimate
Beef	Logistic	125	$\ln\left(\frac{1}{Y} - \frac{1}{125}\right) = -1.23 - .066X$	.80
Dairy	Exponential	na	$\ln Y = 4.39 - .004X$	.49
Pigs	Constant	na	$Y = 55$	na
Poultry	Logistic	40	$\ln\left(\frac{1}{Y} - \frac{1}{40}\right) = 3.8 - .118X$	.92
Mutton	Constant	na	$Y = 3$	na

where Y = per capita value in pounds/year
X = year, with 1975, as 75, 1980 as 80, ... 2000 as 100, ... 2035 as 135

TABLE 40 CANADA: LIVESTOCK WATER USE COEFFICIENTS AND POPULATION DISTRIBUTION BY LAKE BASIN, 1975

Livestock Type	Population (1,000 Head)					Coefficients gallons/head/day
	Basin					
	Superior	Huron	Erie	Ontario	Total	
Dairy Cattle	4	164	179	149	496	30
Beef Cattle	21	972	676	443	2,112	12
Pigs	18	646	904	277	1,845	1.5
Sheep	1	58	35	35	129	1.5
Poultry	2,007	6,021	14,049	12,042	34,119	0.05

Rural - Stock Water Use*



* Withdrawals = Consumption

Figure F-13

2. Crop consumptive irrigation requirement coefficients for normal and high irrigation efficiencies for 1975 and 2000 were calculated by the SCS Special Projects Division to correspond with crop acreages in each water resources sub-area in each state. Crop consumptive irrigation requirements were computed with the use of a modified Blaney-Criddle method (63) that incorporates average monthly temperature and precipitation, crop type and water consumption, soil type, residual soil moisture, crop maturity, planting and harvesting dates, and length of day in consumptive use estimates.

3. Monthly annual irrigation water use coefficients were developed to reflect crop requirements and current and future water use efficiencies. These coefficients were derived as a function of crop consumption requirements and estimates of irrigation system conveyance and on-farm application efficiencies. Conveyance and on-farm application efficiencies were compiled from existing irrigation records and USDA reports for 1975, 1985 and 2000.

The assumed trend in irrigation water use efficiency reflects future improvements in irrigation system delivery and water management such as lining and piping of irrigation canals and ditches, regulated headgate operation, and efficient types of irrigation technology.

4. Total water use coefficients were multiplied by total cropland acreage to obtain estimates of water requirements for agriculture for 1975, 1985 and 2000. Precipitation records for the region were used to determine the historical quantities of water supplied by rainfall per acre of cropland. The difference between the total crop water requirement and the historical rainfall supply was taken as the total irrigation water requirement.

5. Crop consumptive use coefficients were applied to withdrawal figures for various areas to obtain total consumptive use estimates.

6. Projections of irrigation withdrawals and consumptive use to 2035 were obtained by extrapolation.

The methodology used to project the water demands for golf course irrigation is based on the following sequence:

1. Estimated demand in acres through 2020 by lake basin was extracted from GLBC, App. 15, p.8. This demand is based on Bureau of Outdoor Recreation (BOR) projected participation rates and OBERS SERIES C population projections.

2. Divide 1970 demand by supply in each lake basin and apply these factors to estimate supply through 2020 based on the assumption that golf course construction will continue in the future. The GLBC assumed no construction after 1980.

3. Adjust projections of golf course acreage down to reflect OBERS SERIES E population projections.

4. Apply water application rates from the GLBC App. 15 (Tables 15-6, 15-12) to golf course acreage to determine water volumes required to irrigate this total acreage.

5. Project population and participation rates to 2035 and apply to irrigation needs.

6. Adjust water needs down to reflect assumption that only 75 percent of designated golf course acreage is actually irrigated. This constitutes the projected water withdrawal for golf course irrigation (Table 41).

7. Although soil types vary throughout the basin, average consumption on golf courses is assumed to be 75 percent of withdrawals (GLBC, App. 15). This factor was applied to estimate consumptive water use (Table 41).

Water required for use on public lands constitutes a small proportion of the total irrigation water requirements. This includes water used in national parks and forests, and lands administered by the Bureau of Land Management for timberland and watershed irrigation, human and animal use, fire protection, and recreational and mining activities.

Estimates of annual and monthly withdrawal and consumptive water use in National Parks for 1975 were obtained from existing meter records and/or the Public Health Service's 1962 publication Manual of Individual Water Supply Systems and park visitation records. Water use for 1985 and 2000 was assumed to increase directly with the OBERS SERIES E Series population projections and capacity levels for individual parks (78).

1975 estimates of water requirements for national forests were obtained directly from past data records or with estimated coefficients of water use per acre where data was unavailable. Water use categories included in this analysis were domestic, recreation, stockwater, and irrigation, wildlife, industrial and fisheries supplies.

The following assumptions were made to generate the coefficients: 1) water use rates will remain constant in the future, 2) recreation and livestock activity will increase in the future, 3) requirements are based on compliance with state water quality standards, 4) ground water use will continue to increase, 5) energy production on forestlands will remain constant over time.

Projections of water use in the national forests for 1985 and 2000 were based on OBERS SERIES E population projections. The figures were derived from this information by judgemental extrapolation of historical demand and past uses based on expected administrative and resource management plans. They are about six percent of the irrigation sector.

TABLE 41 U.S.: GOLF COURSE IRRIGATION WATER USE (cfs)

Withdrawal

	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
Superior	2	3	3	3	3	4	4	4	4	4	4	4	4	4
Michigan	31	37	43	49	55	61	66	71	76	80	85	90	94	99
Huron	1	1	2	2	2	2	3	3	3	3	4	4	4	4
Erie	54	56	57	58	60	61	62	65	68	71	74	77	80	83
Ontario	9	10	12	13	14	16	17	18	19	19	20	21	22	23
	97	107	117	125	134	144	152	161	170	177	187	196	204	213

Consumption

	1970	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
Superior	2	2	2	2	2	3	3	3	3	3	3	3	3	3
Michigan	23	28	33	37	41	45	50	53	57	60	64	67	71	74
Huron	1	1	1	2	2	2	2	2	2	3	3	3	3	3
Erie	40	42	43	44	45	46	46	49	51	53	55	58	60	62
Ontario	7	8	9	10	11	12	13	13	14	15	15	16	16	17
	73	81	88	95	101	108	114	120	127	134	140	147	153	159

The forecasts for agricultural, recreational, and public land irrigation were summed to obtain irrigation totals.

7.2 Irrigation Water Use: Canada

Few data exist on irrigation water use in Ontario. Statistics Canada commenced publication of irrigated acreages in 1960, and then only on a 10-year time interval. Using the compound growth rate between 1960 and 1970, the 1970 irrigated acreages were updated to 1975 (about 110,000 acres). For all counties wholly or partly within the Great Lakes basin, for which irrigated acreages were reported, it was assumed that 100 percent of that acreage was contained within the basin. Using an average coefficient of 5.87 inches of water per acre (80), the land area was converted to water use. Consumption was taken at 50 percent of withdrawal (39). Irrigated areas were allocated amongst lake basins on the basis of population distribution. This procedure is not correct strictly speaking, but was adopted in the absence of any better distributional data. A correct disaggregation would involve a detailed land use survey of the basin. Data on golf course irrigation was taken from Ontario MOE records and the Ontario Golfers Association (46). Golf courses were allocated uniquely among lake basins based on information from the same sources. It was assumed that 100 percent of this water was consumed.

Forecasting irrigation water use involves the same general problems of uncertainty as other sectors in this study. In Ontario, the major irrigated crops consist of tobacco, fruits and vegetables. With respect to all three commodities, detailed forecasting involves extensive market research and modelling. For example, in dealing with tobacco, it is suspected that recent links between smoking and cancer, with subsequent intensive anti-smoking campaigns, will over the long run, lead to significant declines in tobacco production. However, the production of other irrigated crops may take the place of tobacco culture. Assuming that such a substitution will occur, and that the growth in demand for irrigated crops is related to population growth, irrigation water use is projected on the basis of the medium population scenario.

For irrigation, the low water use estimates are based upon the assumption of developing 20 percent less irrigation land than the MLP in each of the forecast years. The high estimate includes 20 percent more land than the MLP. The low projection for golf course irrigation incorporates the low population estimate; the high projection uses a two percent population growth as its basis (i.e. a faster rate of golf course expansion than the expected population growth). The consumptive use rates are the same as those used in the MLP for both cropland and golf course irrigation.

For the high cropland irrigation forecast (Table 42), water use increases at an annual growth rate of 1.9 percent over the 60-year forecast period. The low forecast assumption yields a resultant

TABLE 42 CANADA: IRRIGATION WATER USE BY LAKE BASIN AND SELECTED YEAR

(cfs)

Basin	Year	Cropland Irrigation Withdrawal High	Cropland Irrigation Withdrawal MLP	Cropland Irrigation Withdrawal Low	Cropland Irrigation Consumption High	Cropland Irrigation Consumption MLP	Cropland Irrigation Consumption Low	Golf Course Irrigation Withdrawals & Consumption High	Golf Course Irrigation Withdrawals & Consumption MLP	Golf Course Irrigation Withdrawals & Consumption Low	Total Withdrawal High	Total Withdrawal MLP	Total Withdrawal Low	Total Consumption High	Total Consumption MLP	Total Consumption Low
Lake Superior	1975	-	-	-	-	-	-		10			10			10	
	1985	-	-	-	-	-	-	10	10	10	10	10	10	10	10	10
	2000	-	-	-	-	-	-	10	10	10	10	10	10	10	10	10
	2015	-	-	-	-	-	-	10	10	10	10	10	10	10	10	10
	2035	-	-	-	-	-	-	10	10	10	10	10	10	10	10	10
Lake Huron	1975		10			10			10			20			20	
	1985	10	10	10	10	10	10	10	10	10	20	20	20	20	20	20
	2000	10	10	10	10	10	10	20	20	20	30	30	30	30	30	30
	2015	10	10	10	10	10	10	30	20	20	40	30	30	40	30	30
	2035	20	20	10	10	10	10	40	30	30	60	50	40	50	40	40
Lake Erie	1975		60			30			20			80			50	
	1985	80	60	50	40	30	30	20	20	20	100	80	70	60	50	50
	2000	90	80	60	50	40	30	30	20	20	120	100	80	80	60	50
	2015	120	100	80	60	50	40	40	30	30	160	130	110	100	80	70
	2035	170	140	110	80	70	60	50	40	40	220	180	150	130	110	100
Lake Ontario/ St. Lawrence	1975		10			10			30			40			40	
	1985	20	10	10	10	10	10	30	30	30	50	40	40	40	40	40
	2000	20	20	10	10	10	10	40	40	40	60	60	50	50	50	50
	2015	30	20	20	10	10	10	60	50	40	90	70	60	70	60	50
	2035	40	30	30	20	20	10	80	60	60	120	90	90	100	80	70
TOTAL	1975		70			40			60			130			90	
	1985	110	90	70	50	40	40	70	70	70	170	150	140	120	110	100
	2000	130	110	90	60	50	40	90	80	80	220	190	170	160	130	120
	2015	160	140	110	80	70	60	120	100	100	290	240	210	200	170	150
	2035	230	190	150	110	90	80	190	140	120	410	330	290	300	240	210

Figures may not add due to rounding.

Irrigation Withdrawals

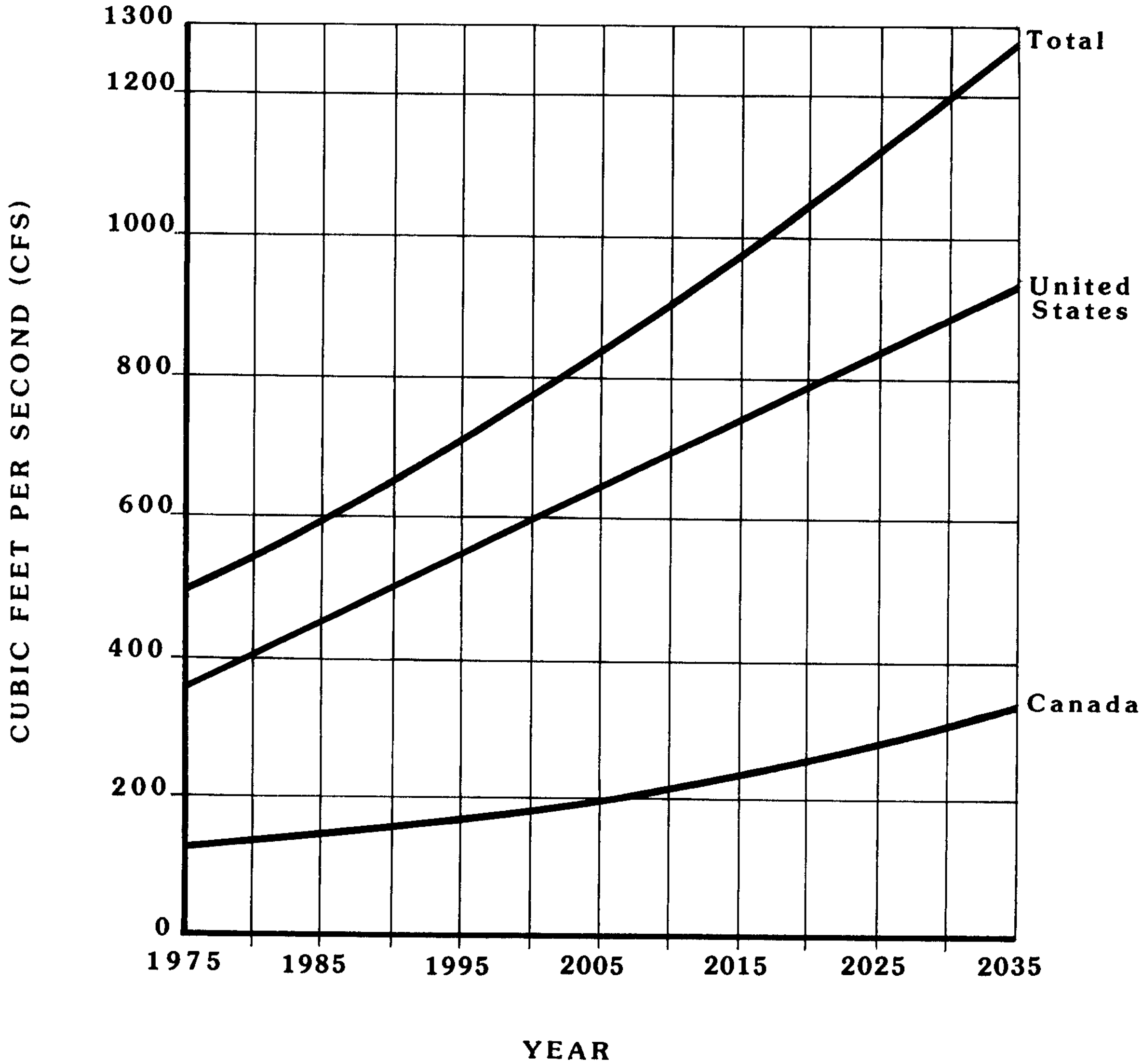


Figure F-14

Irrigation Consumption

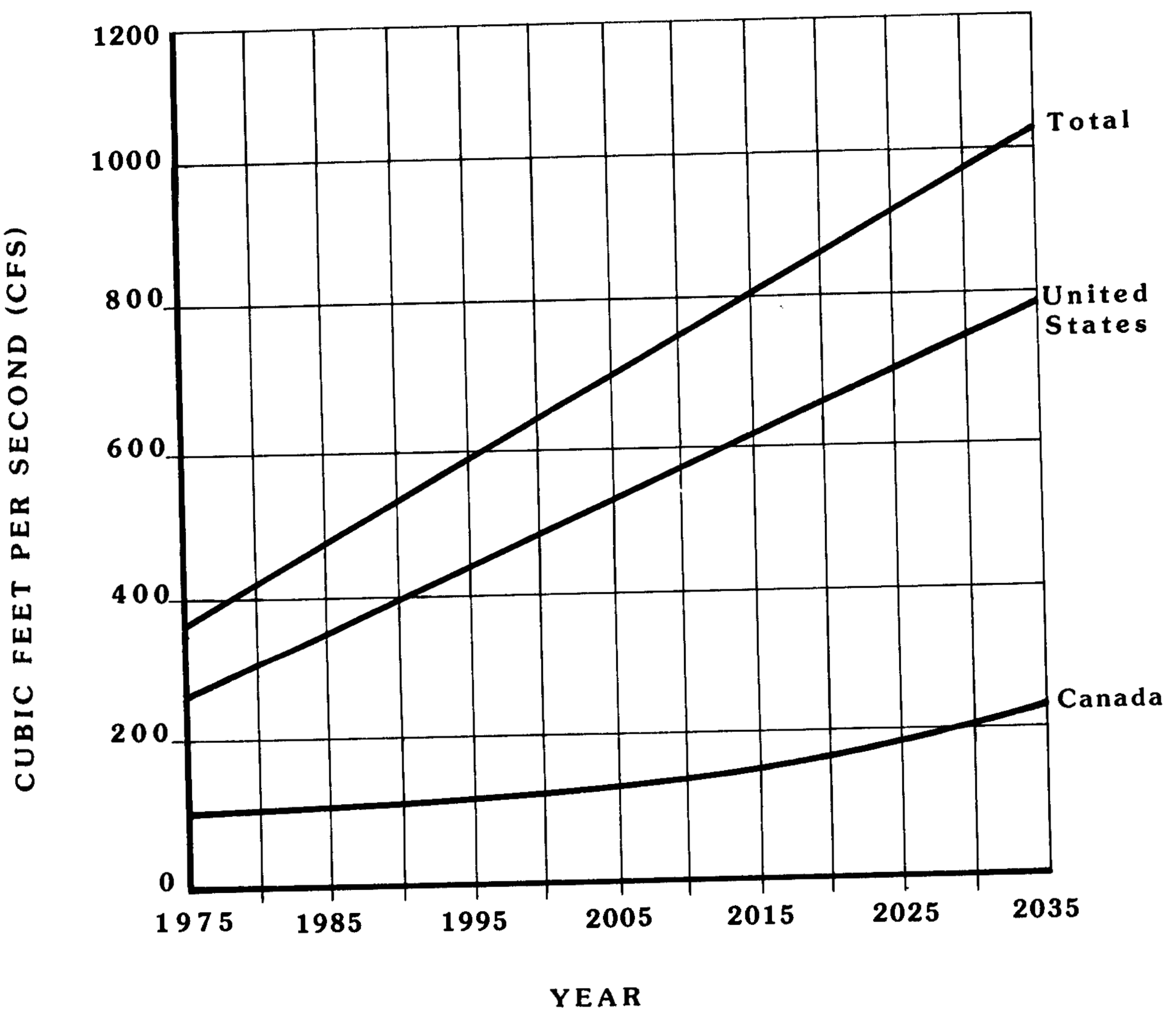


Figure F-15

growth rate of 1.2 percent. There is a simple linear relationship, therefore, between the variation in irrigated land and water use, that is, a 20 percent change in the amount of land irrigated produces a 20 percent change in water use. The range of water use for golf courses represents rates of increase of 2.0 percent and 1.4 percent respectively.

8.1 Power Generation Water Use: United States

8.1.1 U.S. Most Likely Projection

The figures (Table 48) representing the most likely projections for power withdrawals and consumptive use were derived in the following steps:

1. Total power plant capacity within each lake basin was calculated with information provided by the Great Lakes Basin Commission Framework Study, the 1979 East Central Area (ECAR) and Mid America Interpool Network (MAIN), coordinated bulk electrical supply reliability council reports, and the 1980 Atomic Industrial Forum.

The Framework Study provided the base generation for 1970 and plants scheduled for construction through 1980. Data from the reliability council and Atomic Industrial Forum reports were used to eliminate those plants scheduled or already removed from service, update reported plant capacities, and add those plants scheduled for construction by 1989.

2. Total nuclear and non-nuclear plant capacity for each ASA was combined to determine total power generation within each lake basin. Information about types of plants was obtained from the cited reports. Total fossil plant capacity in terms of megawatts (MW) for each lake basin were multiplied by a constant 4.15 and nuclear plant capacities were multiplied by a factor of 6.72 to obtain gigawatt hours (GW.h) generation.

Projected total thermal power generation in the region, percentage change in total generation, and the portion expected to be supplied by nuclear plants are shown in Table 45.

3. Relationships between nuclear and fossil fueled power generation and water usage with both once through and closed cycle cooling systems were calculated by data averaging (Table 43). These water use rates were derived from power and water use data and background information in the Framework Study and 1978 National Assessment Study.

They reflect 1) nuclear plants currently require approximately 50 percent more condenser water with once through cooling and approximately 1/3 more with closed cycle cooling than fossil-fueled plants of equal size and 2) the conversion from once through to closed cycle cooling results in a 96 percent decrease in withdrawals and a 130 to 160 percent increase in consumptive use.

TABLE 43 U.S.: AVERAGE WATER USE RATES FOR FOSSIL AND NUCLEAR POWER PLANTS

Plant Type	Withdrawal Rate (cfs/GWH)		Consumptive Use Rate (cfs/GWH)	
	Once Through	Closed Cycle	Once Through	Closed Cycle
Fossil	.1978	.0081	.0021	.0054
Nuclear	.2967	.0108	.0032	.0073

4. Water withdrawal and consumptive water use rates based on the mix of fossil fueled and nuclear plants anticipated to 2035 (Table 45) and on the projected percentage of once through and closed cycle cooling systems (Table 44) were calculated for five year increments through the projection period.

TABLE 44 U.S.: MIX OF COOLING SYSTEMS ANTICIPATED BETWEEN 1975 AND 2035

Year	% Once thru	% Closed cycle
1975	94.5	5.5
1980	89.2	10.8
1990	59	41
2000	41	59
2020	24	76
2035	18	82

5. Power generation estimates for nuclear and fossil fueled plants within each lake basin were then multiplied by the appropriate water use factors and summed to obtain total water withdrawal and consumptive use projections to 2035. Although power growth rates in individual lake basins may range from 1.06 to 8.86 percent, the basin-wide average growth rate in power demand was 4.09 percent from 1975 to 1980 and is projected to be 4.7 percent from 1980 to 2000 based on new and planned construction. Water withdrawals and consumptive use are assumed to increase in relation to a four percent annual increase in power demand through 2035 in accordance with the current conservation estimates of power generation increases made by the power utilities.

6. The proportion of water obtained from lake (Table 46) and non-lake sources was estimated from Federal Energy Regulatory Commission (FERC) projections of future plant sitings according to the expected location of power markets and availability of water supplies. These percentages were applied to the MLP to obtain water volume estimates from each source.

TABLE 45 U.S.: THERMAL ELECTRIC POWER GENERATION, PROJECTED CHANGE, AND NUCLEAR PORTION OF TOTAL (MLP)

	Total Generation (Gigawatt Hours)				Change in Total Generation (%)		
Lake Basin	1975	1985	2000	2035	1975-1985	1975-2000	1975-2035
Superior	3,500	3,890	7,200	29,800	11	106	751
Michigan	62,900	100,210	198,430	754,000	59	215	1,099
Huron	12,190	21,930	44,870	170,340	80	268	1,297
Erie	67,450	86,870	160,110	608,130	29	137	802
Ontario/ St. Lawrence	16,360	38,250	89,580	411,540	134	448	2,412
Total	162,400	251,150	500,200	1,973,820	55	208	1,115

Nuclear Portion of Total (%)

	1975	1985	2000	2035
	0	0	0	0
	24	41	46	46
	18	32	36	36
	6	13	16	16
	38	57	63	63
Total	20	34	39	39

TABLE 46 U.S.: PERCENTAGE OF TOTAL WATER USED FOR POWER GENERATION EXTRACTED FROM THE GREAT LAKES

	1975		1985		2000		2035	
Lake	W	C	W	C	W	C	W	C
Superior	82	82	86	86	86	86	88	86
Michigan	80	84	83	86	85	87	86	88
Huron	7	7	3	3	2	2	2	2
Erie	62	62	72	75	81	85	85	90
Ontario/ St. Lawrence	80	85	88	91	95	96	98	98

W (Withdrawals) C (Consumptive Use)

8.1.2 U.S. Alternative Projections

8.1.2.1 Projection 2

1. This projection is extracted from the GLBC Framework Study and was accomplished by the Federal Power Commission (FPC) using 1970 data (18) (Table 47). The power and water use projections for the period from 1970 to 1980 were obtained from the responsible reliability councils by a procedure similar to that described for the NAS (Projection 3). Only that power generation drawing from the water resources within the Great Lakes basin was included in this analysis.

Projections of future power requirements through 2020 were made by regional advisory committees appointed to assist the FPC in updating the National Power Survey. The committees relied primarily on extrapolated projections made by the major utilities in the region, and OBERS SERIES C projections of population and economic growth (18).

2. Another significant assumption made by the Framework Study was that fossil fueled plants would be phased out at the end of their useful life and that nuclear plants would supply 98 percent of energy needs by 2020. Greater efficiency and the use of less condenser water by the nuclear plants was expected to be achieved by 1980.

3. Projections of water withdrawals and consumptive use for the period from 2020 to 2035 were derived by the application of a 5.25 percent annual rate of power growth that was assumed by the FPC for the period prior to 2020.

8.1.2.2 Projection 3

1. Collection of power data to be used as input to the Great Lakes portion of this the NAS projection (Tables 47 and 48) was directed by the Chicago Regional Office of the Federal Energy Regulatory Commission. The bulk of the present and projected power generation data was supplied to the FERC office by the six electric reliability councils including the Mid-American Interpool Network, the East Central Area Reliability Coordination Agreement, the Northeast Power Coordinating Council, the New York Power Pool, the Mid-Atlantic Area Coordination Group, and the Mid-Continent Reliability Coordination Agreement whose networks include portions of but do not coincide with the boundaries of the Great Lakes basin. These councils are responsible for overseeing the electric power utilities facilities expansion and rate-setting activities (65).

2. Current and projected power capacity figures for the period from 1975 through 1995 were obtained directly from the utilities forecasts. Projections of power demands were based on considerations of expected demographic changes, area economic changes, increased electric rates, effects of energy conservation efforts, the substitution of electricity for scarce fossil fuels, scheduled load changes, load saturation areas, and other factors.

TABLE 47 U.S.: THERMAL ELECTRIC POWER GENERATION, PROJECTED CHANGE, AND NUCLEAR PORTION OF TOTAL FOR PROJECTION 3 (NAS)

Lake	Total Generation (Gigawatt Hours) 1975	1985	2000	Change in Total Generation (%) 1975-1985	1975-2000	Nuclear Portion of Total (%) 1975	1985	2000
Superior	3,334	3,761	36,655	13	999	0	0	94
Michigan	85,995	141,286	308,756	64	259	32	64	83
Huron	5,650	9,836	36,126	74	539	0	0	78
Erie	70,674	147,850	316,305	109	348	0	48	68
Ontario/ St. Lawrence	16,948	35,579	123,480	110	629	37	47	73
	182,600	338,310	821,322	85	350	17	53	76

Demand within a specific area is unlikely to match generation in that same area. The utilities also provided annual estimates of water withdrawals, return flows, types of power plants in operation and rates of water consumption for the period from 1975 to 1990 to the reliability councils (65). The water demand forecasts were obtained by extrapolation of the historical trends of each power market area (PSA) using regression and correlation analysis. The extrapolations were adjusted to reflect scheduled major load changes, effects of energy conservation, and pollution abatement requirements.

3. The information supplied by the councils covered power and water needs for 80 percent of the Great Lakes region; the FERC office prepared estimates for the remaining 20 percent. This was accomplished by extrapolation of the council figures to 100 percent of estimated population and industrial needs. Population and industrial use forecasts and location of urban and industrial centers were used to derive a best estimate of the distribution of the anticipated power and water demands.

4. FERC used the OBERS SERIES E population and economic growth projections to extend the 1985 projections of power and water use to 2000. Anticipated increase in use of electricity in the total energy picture was factored into the projection.

5. Projections of water withdrawals and consumptive use for the period from 2000 to 2035 were derived by applying a four percent annual power growth rate as compared to the 6.2 percent growth rate used from 1975 to 2000. This method assumes achievement of a steady state condition for withdrawals and consumptive use due to the institution of closed cycle systems. According to the FERC, most utilities are now utilizing projected annual growth between three and five percent (53).

The NAS power and water demand estimates and projections (Tables 47 and 48) differ significantly from those in the MLP (Table 45). The NAS used data from the reliability councils that includes the entire Great Lakes region and their forecasts within the Great Lakes basin reflect power <u>demand</u> rather than power <u>generation</u>. These two terms must be maintained in proper perspective. Demand in the NAS projections will be satisfied by generation somewhere within the region. The critical difference is that this consumptive use study is concerned only with water use in the Great Lakes basin and water use in this subarea of the Great Lakes region does not equate with energy demand. The NAS projections in Table 47 reflect the energy demands in the Great Lakes basin. The nuclear portion in Lake Superior, for example, will be obtained from a source outside the Great Lakes drainage basin. Table 45, in contrast to Table 47, reflects only the anticipated power generation and consequently the water use within the drainage basin. Differences in the totals are the anticipated energy demands within the basin that will be satisfied by a power plant somewhere else in the region.

8.1.2.3 Projection 4

This projection (Table 48) uses the same assumptions and data base as described in the MLP to 2000. The same assumptions concerning mix of power plants and cooling systems are then applied to an assumed annual power generation growth rate of five percent. This projection, as such, represents a high estimate of projected water consumption.

8.1.2.4 Projection 5

This projection (Table 48) uses the same assumptions and data base as described in the MLP to 2000. The same assumptions concerning mix of power plants and cooling systems are then applied to an assumed annual power growth rate of three percent. It then represents a low estimate of projected water consumption.

8.1.2.5 Projection 6

These water withdrawal and consumptive use projections (Table 48) are based on the assumption that power companies could justify variances from the current waste heat mandates of the Clean Water Act. The primary assumption is that flow-through technology rather than closed cycle cooling will be used at those existing plants that have not incorporated closed cycle and at projected plants. Remainder of the assumptions concerning mix of power plants are those used to derive the MLP. The reliance on flow-through systems is expressed in large increases in water withdrawals with relatively little increase in consumptive use.

1. Regional power generation projections for nuclear and fossil-fueled plants were multiplied by the 1975 average withdrawal water use rate of 0.2061 cfs/GW.h.

This average rate reflects the 80 percent fossil-20 percent nuclear mix of plants and the 95 percent once through-five percent closed cycle mix of cooling techniques in existence in 1975. This rate differs from that in the MLP in that the MLP rate decreases incrementally through the projection period.

2. Regional power generation projections for nuclear and fossil fueled plants were multiplied by the 1975 average consumptive use rate of 0.0026 cfs/GW.h to derive total consumptive use.

This rate reflects the predominant use of flow-through technology. The exceptions to this practice are those plants in existence in 1975 where cooling towers have been installed to minimize environmental impacts. Water use by inland plants in existence in 1975 is reflected in the 1975 average consumptive rate. The consumptive use rate differs from that in the MLP in that the MLP rate increases incrementally through the projection period.

TABLE 48 U.S.: POWER GENERATION WATER USE PROJECTIONS (cfs)

	Most Likely Projection		Projection 2		Projection 3		Projection 4		Projection 5		Projection 6	
	W	C	W	C	W	C	W	C	W	C	W	C
1975	33470	420	25510	390	37700	270	33470	420	33470	420	33470	420
1980	36630	600	24350	520	36410	530	36630	600	36630	600	41140	530
1985	39930	830	20760	880	35110	770	39930	830	39930	830	51760	650
1990	42370	1170	17180	1230	31730	1210	42370	1170	42370	1170	65130	820
1995	44730	1630	13590	1580	28350	1640	44730	1630	44730	1630	81940	1030
2000	48170	2250	10010	1940	24850	2140	48170	2250	48170	2250	103090	1300
2005	51730	2800	8870	2500	30230	2600	54260	2940	49290	2670	125420	1580
2010	55900	3550	7740	3060	36780	3170	61520	3910	50750	3230	152600	1920
2015	60990	4500	6610	3620	44750	3860	70400	5200	52760	3900	185660	2340
2020	67180	5590	5470	4180	54450	4690	81360	6770	55380	4610	225880	2850
2025	74410	6930	7120	5440	66250	5710	94520	8810	58440	5450	274820	3470
2030	83230	8440	9250	7080	80610	6940	110900	11240	62280	6310	334360	4220
2035	94740	10460	12030	9220	98070	8450	132440	14620	67560	7460	406800	5130

W (Withdrawals)

C (Consumptive Use)

United States Thermal Power Plant Ranges - Withdrawals

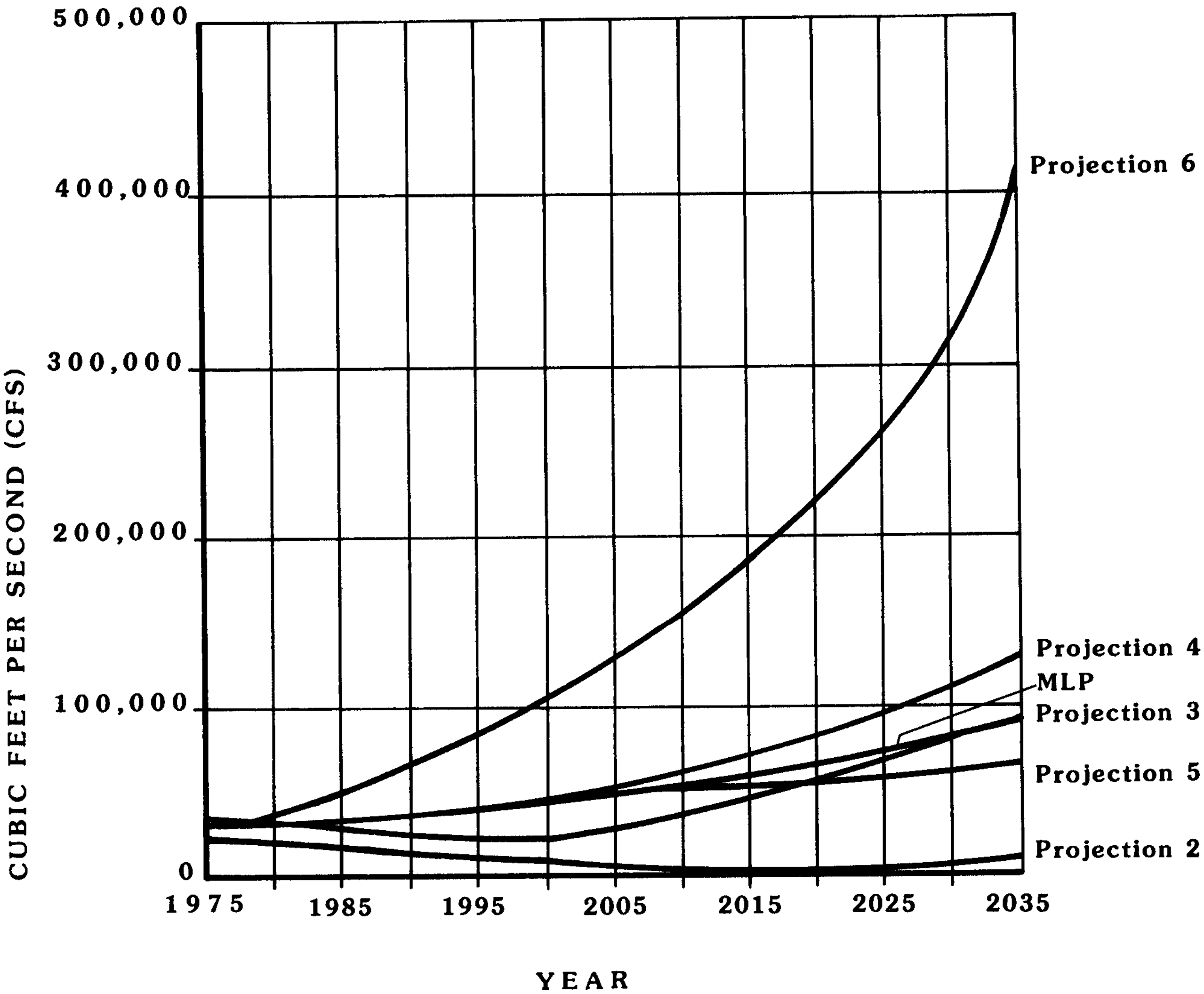


Figure F-16

United States Thermal Power Plant Ranges - Consumption

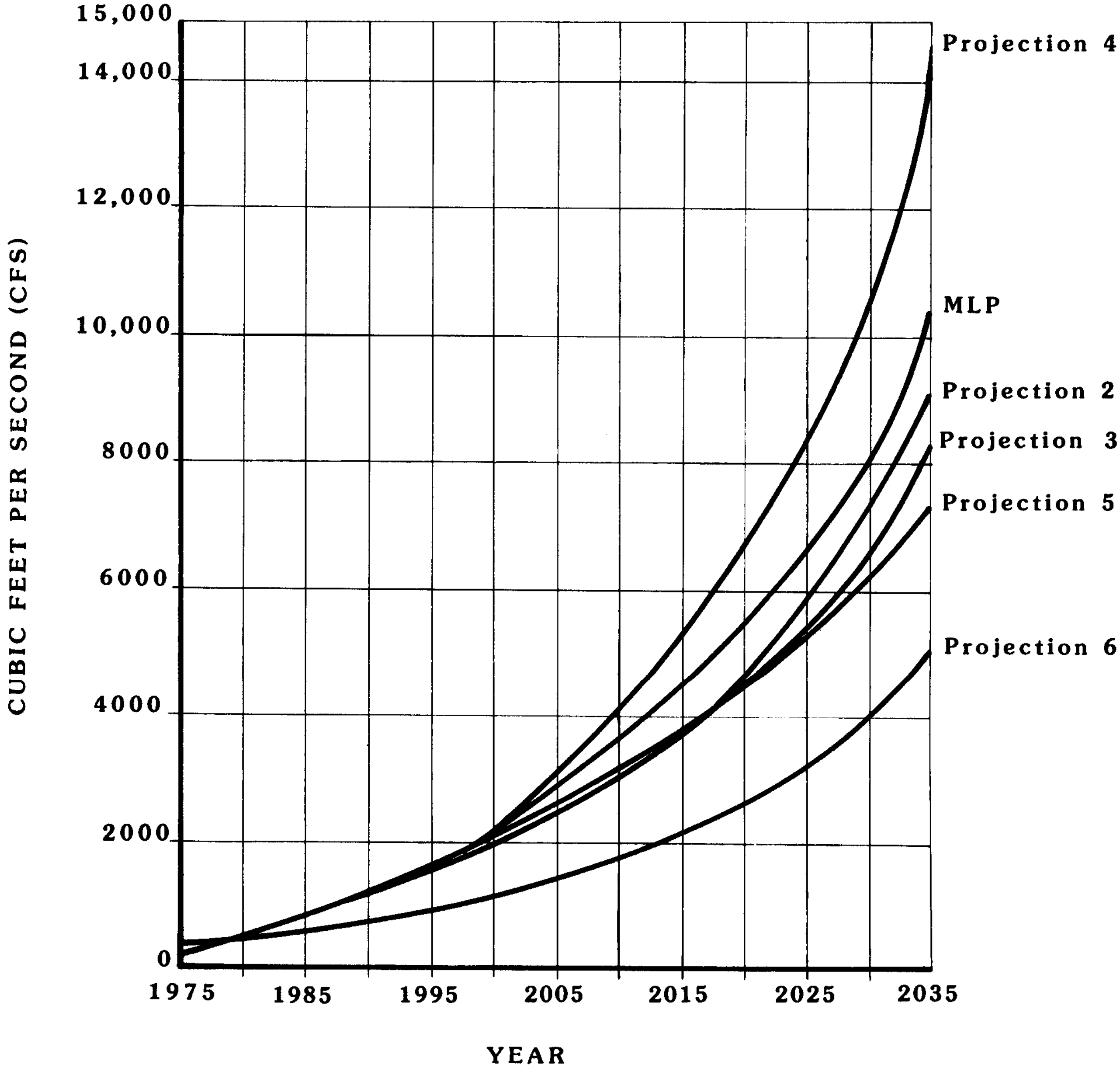


Figure F-17

8.2 Power Generation Water Use: Canada

Thermal power generation, the largest water user in the Canadian basin, is an extremely important sector of the Ontario economy. Its output is a vital foundation for all socio-economic activities in the province. The total installed capacity of all power production plants in the province was 18,300 megawatts (MW) in 1975 (47). Thermal power production facilities accounted for 63 percent of this total capacity; all of these facilities are located within the Great Lakes basin. Of the 11,000 MW of installed thermal power generating capacity, 79 percent is accounted for by conventional coal and oil fired plants, 21 percent by nuclear plants and a negligible amount by other plant types such as gas turbine operations.

8.2.1 Assumptions for MLP Projections

The energy forecasts in this section are taken from several sources, and tend to be chosen on the conservative side of current predictions. As in other sectors, many assumptions underlie the MLP projections for thermal power generation. The main ones are that all thermal plants will employ once-through cooling systems, and that no substantial curtailments will be forced by environmental considerations. Some of these assumptions will be altered in order to obtain a range of projections.

8.2.2 Methodology

Since the methodology used in making the thermal water use forecasts differ completely from the methodology used in other industrial sectors, it is necessary to describe the procedures used. Assistance was provided by the provincial power utility, Ontario Hydro in developing this methodology (36). Throughout this section, only the Ontario Hydro system is considered, since minor industrial power producers were included in the manufacturing water uses. Also the forecasts are made assuming the non-conventional sources (e.g. solar power) will contribute under 10 percent of needs by 2035.

Forecasting water use for thermal power production must occur with the framework of overall power system planning (52). In this planning process, the emerging demands are quantified, the amount of power required to meet them is calculated, and the existing power network is expanded accordingly. However, since the normal corporate planning process extends at most to 25 years in the future, official projections of energy demands, peak loads, etc., are available only for the first part of the study period. Also, firm planning (called a "committed expansion program" by Ontario Hydro) for future facility location is available only to 1990. Thus, the methodology adopted had to allow for the long time frame of this study and the lack of a committed generation program past 1990. As in other sectors, a MLP and a number of alternatives were constructed.

A forecast of peak energy demands made by Ontario Hydro (Table 50), provided the starting point for the projection of water use (47). The agency allows at least a 25 percent excess of installed generating capacity over the peak demands. Thus, for each five-year period beginning in 1975, the installed generation requirements could be calculated up to 2005. After 2005, the installed generating requirements were extended by extrapolation on the basis of four percent annual growth. This process provided a MLP of the capacity which will be required in the system. For the alternatives, growth rates in the peak energy demands and thus the installed generating requirements were taken at five, four and three percent annual growth rates to provide high, medium and low estimates, respectively.

With the required capacities in place, the generating facilities were broken down into hydraulic, fossil and nuclear types. For the years to 1990, Ontario Hydro has a committed expansion program (Table 49), making it relatively simple to expand the current system. For 1990 to 2000, the agency has an unofficial and completely tentative program. Past that year, the excess of installed generating requirements over the capacity of the system in 2000 was divided 65 percent nuclear and 35 percent fossil generating plants, with no expansion seen for the hydraulic system. For the medium and low alternatives this split was taken at 85 percent nuclear and 15 percent fossil.

With the broad outlines of the system in place, it was necessary then to determine the energy production from the hydraulic, nuclear and fossil fuel plants. This involves the use of a plant load factor,which quantifies the percentage of time during a year in which a plant operates. For this study, system-wide averages were adopted, based upon current experience and informed guesswork. For the hydraulic plants, currently 38,384 gigawatt-hours (GW.h) are produced by an installed capacity of 6,156 megawatts (MW). This yields a plant load factor of 70 percent, which was assumed to apply throughout the study. The plant load factor (PLF) for nuclear plants was assumed at 75 percent, with the PLF for fossil fuel fired plants varying to meet the remainder of the energy demand. For the energy demand projections, MLP figures were provided by Ontario Hydro, while the alternatives used five, four and three percent growth rates in line with the peak demand scenarios outlined above.

Once the actual energy production for each type of plant was calculated, water withdrawals and consumption were calculated using constant coefficients. For nuclear plants withdrawals average two cfs per megawatt, which translates to 45 gallons per kilowatt-hour (KW.h) of energy production. The corresponding figures for fossil fueled plants are 1.2 cfs and 27 gallons per KW.h. For both types of plant, consumption was taken at 0.75 percent of withdrawal (58).

The location of future thermal stations is a complex function of several variables, among them the availability of water supplies, the proximity to markets and the location of transmission lines. It is believed that most stations in the future will be located around

TABLE 49 CANADA: ONTARIO HYDRO GENERATION EXPANSION PLAN, 1980 - 2000

In Place by the End of:	Facility Name	Capacity (MW)	Type
1980	Lennox	1,732	coal
	Nanticoke	1,593	coal
1985	Pickering B (4 units)	2,064	nuclear
	Bruce B (2 units)	3,024	nuclear
1990	Darlington	3,524	nuclear
2000	unspecified hydraulic	1,100	
	unspecified nuclear	11,450	
	unspecified fossil	2,750	

NOTE: The last entries constitute an uncommitted expansion by Ontario Hydro, are based on preliminary analysis, and are subject to changes in line with emerging demand conditions. Their adoption was based upon judgement by Tate (58), not upon any urging by Ontario Hydro officials.

the Great Lakes, and for the period to 2000 there is some idea as to the precise location. After 2000 it is assumed that 95 percent of the installed capacity, and accordingly 95 percent of the water use, will be in the basin. Known stations and their water uses were allocated easily among the lake basins. After 2000, however, the distribution of capacity was determined judgementally on the basis of past location decisions and the future distribution of population and industrial activity.

8.2.3 MLP Power Production and Water Use

Peak demands on the Ontario Hydro system totalled 13,500 MW during 1975 (Table 50), giving a required installed generating capacity of 16,875 MW. According to Ontario Hydro data (55), the total capacity of the system was 17,320 MW (excluding purchases), resulting in a substantial over-capacity. According to Hydro officials, this over-capacity resulted from efforts to maintain an absolutely secure power supply, from the need to meet U.S. demands, and other reasons. The over-capacity is expected to be reduced gradually between now and the turn of the century, and installed generating capacity after 2000 will be 25 percent in excess of peak demands (36). After 2000, for the MLP, peak demands are projected at four percent. By 2035, they will be 164,524 MW, yielding a requirement for installed generating capacity of 205,655 MW. The expansions in peak demand and required installed generating capacity represent 4.26 percent annual growth rates over the entire time period.

In 1975 the hydraulic generating capacity was 6,156 MW, 36 percent of the system's total generating capacity. Fossil fueled plants accounted for an additional 8,825 MW (51 percent), and nuclear plants the remainder. The expansion program of Ontario Hydro, committed to 1990 and uncommitted to 2000 (Table 49), is built into the capacity figures of Table 50. This expansion program displays a growing reliance on nuclear power, this form of generation providing 48 percent of total installed generating capacity by 2000, and 61 percent by 2035. Hydraulic facilities will expand a mere 1,100 MW by 2000 and not at all after that date under the MLP assumptions. After 2000 the split between additions to nuclear capacity and additions to fossil fueled capacity was taken at 65:35, as confirmed by Ontario Hydro officials.

With regard to energy production, the system met a demand of 81,503 GW.h in 1975, broken down amongst the various plant types in accordance with the load factors given earlier. By 2035, the total energy demand is projected to be 1,069,209 GW.h, a 4.4 percent rate of annual increase. The total energy demand includes a net export of 3,000 GW.h per year throughout the time period. The various generating facilities will be used to meet these demands in the way shown in Table 50.

TABLE 50 CANADA: MLP WATER USE, PEAK DEMAND, REQUIRED INSTALLED GENERATING CAPACITY AND ENERGY GENERATION

Year	Peak Demand (MW)	Required Installed Generating Capacity	Capacity by Generation Type (MW)				Energy Generation by Generation Type (GWh)			
			Total	Hydraulic	Nuclear	Fossil	Required	Hydraulic	Nuclear	Fossil
1975	13,500	16,875	17,320	6,156	2,284	8,825	81,503	38,384	11,859	31,260
1985	21,176	26,470	28,593	6,156	10,272	12,165	126,959	38,000	67,487	21,472
2000	41,693	52,116	52,116	7,265	25,246	19,605	243,572	39,500	165,900	38,172
2015	75,087	93,858	93,858	7,265	52,378	34,215	454,517	39,500	344,123	79,895
2035	164,524	205,655	205,655	7,265	125,046	73,344	1,069,209	39,500	821,552	108,157

WATER USE MLP
(cfs)

	Water Withdrawal			Water Consumption		
	Nuclear	Fossil	Total	Nuclear	Fossil	Total
1975	2,715	3,881	6,600	20	30	50
1985	15,409	2,941	18,350	115	22	137
2000	36,260	5,006	41,270	271	37	308
2015	70,819	9,864	80,680	561	78	639
2035	182,717	14,433	197,150	1341	204	1544

Water withdrawals in 1975 at Ontario thermal plants totalled 6,600 cfs on the basis of the coefficients given in Section 8.2.2. This amount is confirmed by the responses to the Environment Canada survey of water use for thermal power generation. By 2035, this withdrawal rises to 197,150 cfs, an increase of 5.8 percent per annum. The inherent shift to nuclear power plants, a larger water user than fossil plants, in the MLP causes the water use growth rate to be 1.7 percent per annum above the growth of power generating capacity. Taking consumption to be 0.75 percent of withdrawals, the total amount of water consumed by thermal power plants in 1975 was 50 cfs and will increase to 1,540 cfs by 2035.

The breakdown of total water use by lake basin is given in Table 51. This was done by locating each existing and planned plant by basin and disaggregating total water use in line with the capacities of these plants. After 1990, when the precise location of plants is unknown, constancy was assumed in the lake basin proportions. Since water use distribution amongst lake basins was assumed constant for all scenarios, similar tables to Table 51 (i.e. for the MLP) have not been developed.

8.2.4 Alternative Water Use Projections for Canada

A total of six alternatives to the MLP were prepared; three dealing with changes in the growth rate and three with different cooling technologies. This section summarizes the results of these simulations, discussing similarities and differences between the alternatives, but not developing each alternative in detail as was done for the MLP.

8.2.4.1. Economic Growth

The first three alternatives (Table 52) concentrate on the effects of varying the demands for energy, and on subsequent changes in production capacities. All these scenarios emphasize nuclear power as the dominant future means of power production. The high growth scenario uses a growth rate of five percent per annum from 1980 to project peak demands and energy demands, while the medium and low growth scenarios use four percent and three percent growth rates. The difference between the MLP and the medium growth alternative is that the four percent growth rate is applied right from 1980 in the latter, whereas the former used Ontario Hydro's slightly higher growth rate to 2005. Also the medium and low growth alternatives split the additions to capacity required, over and above the committed and uncommitted program in a ratio of 85 percent nuclear to 15 percent fossil.

TABLE 51 CANADA: MLP WATER USE FOR THERMAL POWER GENERATION, 1975-2035, BY LAKE BASIN (cfs)
(cfs)

Basin	Year	Withdrawal	Consumption
Lake Superior	1975	40	0
	1985	110	0
	2000	880	10
	2015	1,760	10
	2035	4,350	30
Lake Huron	1975	980	10
	1985	4,760	40
	2000	11,970	90
	2015	23,020	180
	2035	55,890	440
Lake Erie	1975	1,010	10
	1985	1,320	10
	2000	4,170	30
	2015	8,970	80
	2035	22,680	180
Lake Ontario/ St. Lawrence	1975	4,570	40
	1985	12,160	90
	2000	24,250	180
	2015	46,930	370
	2035	114,230	890
TOTALS	1975	6,600	50
	1985	18,350	140
	2000	41,270	310
	2015	80,680	640
	2035	197,150	1,540

Figures may not add due to rounding.

TABLE 52 CANADA: PEAK DEMAND, REQUIRED INSTALLED GENERATING CAPACITY AND ENERGY GENERATION UNDER VARYING ECONOMIC ASSUMPTIONS

Year	Growth Rate	Peak Demand (MW)	Required Installed Generating Capacity (MW)	Capacity by Generation Type (MW)				Energy Generation by Generation (GWh)			
				Total	Hydraulic	Nuclear	Fossil	Required	Hydraulic	Nuclear	Fossil
1975	All	13,500	16,895	17,320	6,156	2,284	8,825	81,503	38,384	11,859	31,260
1985	High	19,217	24,021	28,495	6,484	8,824	13,187	129,723	35,000	57,793	39,130
	Medium	18,319	22,898	26,983	6,484	7,312	13,187	126,444	35,000	48,039	43,404
	Low	17,455	21,819	24,770	6,484	5,248	13,038	120,622	35,000	34,479	51,143
2000	High	39,950	49,938	49,913	7,584	25,310	17,019	269,686	41,200	166,287	65,199
	Medium	32,991	41,240	41,713	7,584	18,860	15,269	225,315	41,200	123,910	60,205
	Low	27,194	33,993	34,462	6,484	13,560	14,418	186,251	35,000	89,089	62,162
2015	High	83,055	103,818	102,818	7,584	60,656	35,578	560,658	41,200	398,055	121,402
	Medium	59,416	74,270	74,240	7,584	46,052	20,633	403,378	41,200	302,561	59,616
	Low	42,368	52,960	52,960	7,584	27,135	17,970	288,500	41,200	178,282	69,018
2035	High	220,369	270,461	270,461	7,584	169,317	93,560	1,487,591	41,200	1,112,412	333,982
	Medium	130,188	162,735	162,735	7,584	121,246	33,904	880,277	41,200	796,586	42,491
	Low	76,521	95,652	95,652	7,584	63,655	24,415	518,644	41,200	418,206	59,237

The high growth scenario has the highest projection of power production and water use (Table 53). Both water withdrawal and consumption increase by 6.6 percent in this projection. The shift to nuclear power is apparent here because the water use growth rate is higher than the capacity expansion rate. The lowest water uses are contained in the low growth scenario with a capacity expansion rate of 3.0 percent per annum (p.a.) and a water use growth rate of 4.7 percent p.a.

8.2.4.2 Technological Change

The technological alternatives focus upon changes in the type of cooling system employed in Ontario thermal generating stations. All current cooling systems are of the once through type. The medium technology alternative employs cooling ponds on all new capacity installed in the future, re-using water from the cooling ponds so that the only water required is that to make up what is lost through evaporation and to replace blow-down of water too hard for subsequent use. The intensive technology alternative employs cooling towers instead of cooling ponds, but the recirculation specifications are the same as for the medium alternative. It is also assumed that all current capacity and its replacement will retain a once-through cooling system. These two alternatives, according to Ontario Hydro officials, are only remote possibilities, as the Great Lakes system is currently seen as virutally limitless source of water. They are included here merely to show the effects on withdrawal and consumption if recirculating systems should be required in the future, for example, to limit possible environmental damages.

The calculation of water use is based upon previous work by the Great Lakes Basin Commission on thermal water use (18). In order not to include the effects of complex growth rates, the MLP power and energy projections are used for medium and intensive technology alternatives. The water withdrawal for fossil fueled stations averages 1.2 cfs per MW, or 27 mgd per GW.h. This coefficient will give the gross water use, which is equivalent to water withdrawal for plants with no recirulation. According to Ontario Hydro, the average heat rise across the condenser at currently operating plants is 18°F, and using the GLBC graph for fossil fueled plants (Figure 18), 27 mg per GW.h (i.e. 100 acre-feet/GW.h) is used by a plant with an average heat rate of 9,500 BTU per KW.h. From Figure 19, consumptive use in such a plant would be 0.92 acre-feet, or 0.21 million gallons per GW.h. For cooling ponds, this consumptive use coefficient is 0.25 million gallons per GW.h, and for cooling towers, 0.33 million gallons per GW.h. These coefficients are shown in Table 54, along with similar ones for nuclear plants (Figure 20).

The water withdrawal and consumption figures for the technological change options are shown also in Table 54. The extensive option is for once-through cooling, which is the same as the MLP. The medium option uses cooling ponds, while the intensive option uses cooling towers. Since, under the medium and intensive options, the only new water required is to replace consumption, the

TABLE 53 CANADA: THERMAL POWER GENERATION WATER USE UNDER VARYING ECONOMIC GROWTH RATES
(cfs)

Year	Economic Growth	Withdrawal Nuclear	Withdrawal Fossil	Withdrawal Total	Consumption Nuclear	Consumption Fossil	Consumption Total
1975		2,720	3,880	6,600	20	30	50
1985	High	13,230	5,370	18,600	100	40	140
	Medium	11,000	5,960	16,960	80	40	120
	Low	7,890	7,030	14,920	60	50	110
2000	High	36,170	8,510	44,680	270	60	330
	Medium	26,950	7,860	34,810	200	60	260
	Low	19,380	8,110	27,490	140	60	200
2015	High	580	15,840	102,420	650	120	770
	Medium	65,810	7,780	73,590	490	60	550
	Low	38,770	9,010	47,780	290	70	360
2035	High	241,950	43,580	285,530	1,810	330	2,140
	Medium	173,260	5,550	178,810	1,300	40	1,340
	Low	90,960	7,730	98,690	680	60	740

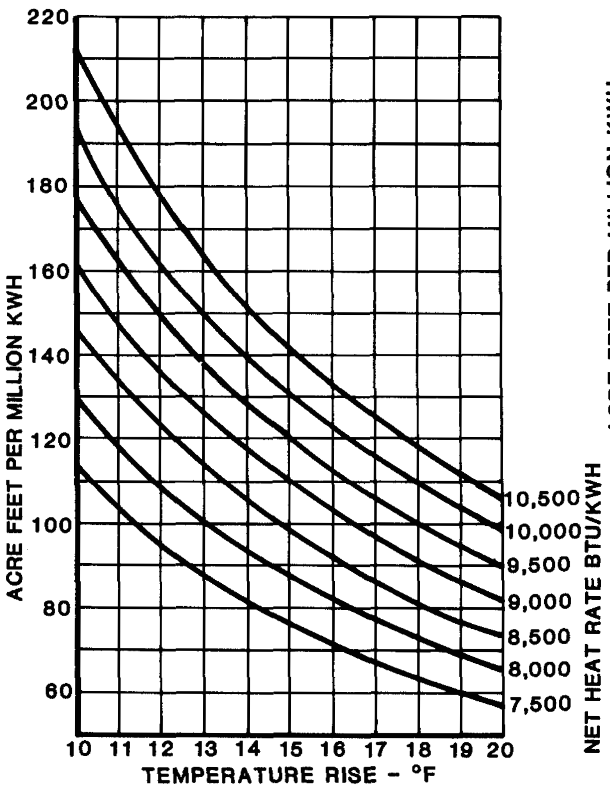


Figure F-18
Cooling Water Requirements
(Fossil Fuel Generating Plants)

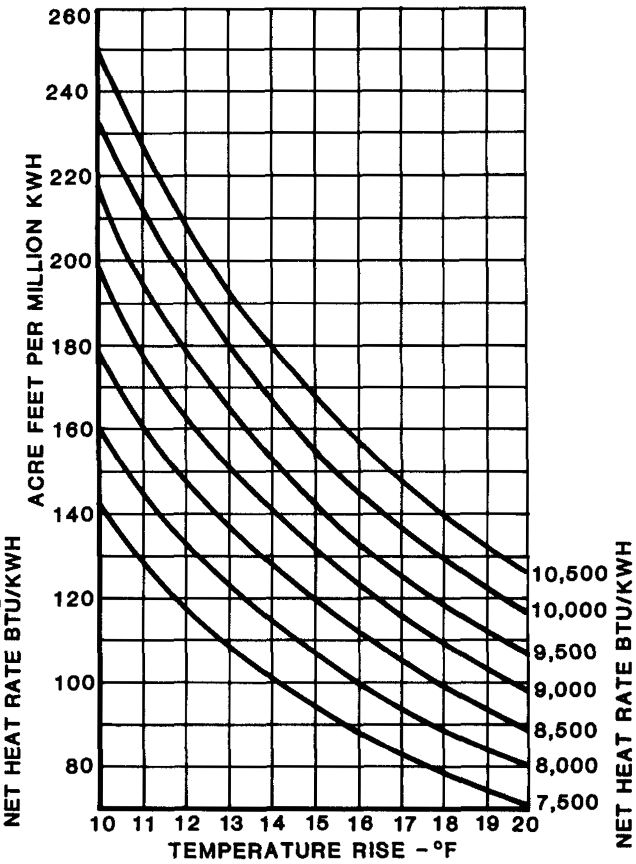


Figure F-20
Cooling Water Requirements
(Nuclear Generating Plants)

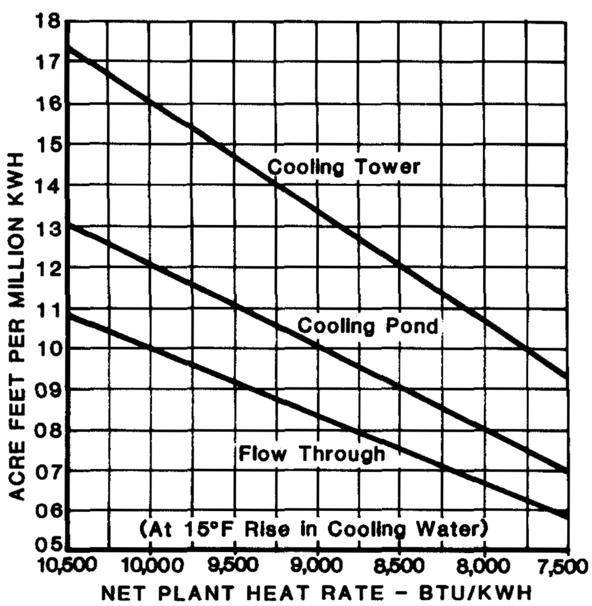


Figure F-19
Consumptive Water Use
(Fossil Fuel Generating Plants)

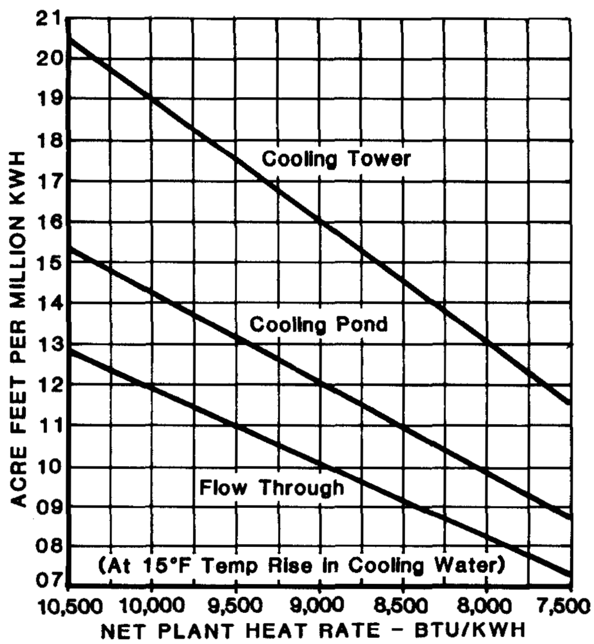


Figure F-21
Consumptive Water Use
(Nuclear Generating Plants)

TABLE 54 CANADA: THERMAL POWER GENERATION WATER USE UNDER VARYING TECHNOLOGICAL ASSUMPTIONS

Year	Generation (GW.h/yr)	Water Withdrawal (mgd/GW.h/yr)	Total Water Withdrawal (mgd)			Water Consumption (mgd/GW.h/yr)			Total Water Consumption (mgd)		
			Extensive	Medium	Intensive	Extensive	Medium	Intensive	Extensive	Medium	Intensive
A. FOSSIL-FUELLED PLANTS											
1975	31,260	27	2,090	—	—	0.21	—	—	16	—	—
1985	21,472	27	1,584	2,115	2,123	0.21	0.25	0.33	12	15	19
2000	38,172	27	2,696	2,011	2,019	0.21	0.25	0.33	21	26	33
2015	79,895	27	5,312	2,060	2,092	0.21	0.25	0.33	46	49	65
2035	108,157	27	7,772	2,188	2,253	0.21	0.25	0.33	62	72	94
B. NUCLEAR PLANTS											
1975	11,859	45	1,462	—	—	0.35	—	—	11	—	—
1985	67,487	45	8,298	1,529	1,559	0.35	0.42	.56	62	78	103
2000	165,900	45	19,526	1,653	1,717	0.35	0.42	.56	152	182	243
2015	344,123	45	38,136	1,812	1,927	0.35	0.42	.56	247	356	475
2035	821,552	45	98,394	2,290	2,565	0.35	0.42	.56	765	918	1,223
C. TOTALS											
1975	—	—	3,552	—	—	—	—	—	27	—	—
1985	—	—	9,882	3,644	3,682	—	—	—	74	93	122
2000	—	—	22,222	3,664	3,736	—	—	—	173	208	276
2015	—	—	43,448	3,872	4,019	—	—	—	343	405	540
2035	—	—	106,166	4,478	4,818	—	—	—	827	990	1,317

NOTE: mgd is in imperial gallons. To convert to cfs multiply by 1.857.

water withdrawals increase very slowly over time. Consumptive use is highest for the cooling tower option with an average annual increase of 6.8 percent as opposed to the MLP rate of increase of 5.9 percent.

8.2.5 Water Use Ranges

On the basis of the alternative projections developed in this section, ranges of water withdrawal and consumptive use can be derived (Table 55 and Figures 22 and 23). For withdrawal, two estimates for the low projection are shown. The first of the latter would pertain under the low growth scenario, with no alteration in the cooling systems in use. The second would come about only with adoption of closed-cycle cooling using cooling ponds (i.e. the medium technology scenario). The two estimates are shown because of the radically different nature of the cooling systems assumed. Similarily, two high projections are shown for consumptive use, the second pertaining only to the adoption of closed cycle cooling via the use of cooling towers. Since water withdrawal in a closed cycle system is only for replacement of consumptive use, and since cooling ponds present slightly lower amounts of consumptive uses, the medium technology scenario gives the lowest water withdrawal, while the cooling tower option gives the highest estimate of consumptive use.

9.1 Comparison With International Great Lakes Levels Board (IGLLB) Report

Municipal withdrawals are substantially higher in the IGLLB estimate (Table 56). An important element is the high average annual population growth rate used in the IGLLB study. In the present study the OBERS SERIES E 0.9 to 0.3 percent growth rate in U.S. population is projected whereas the IGLLB report projected a 1.4 percent annual growth rate. A 1.4 percent growth rate is currently projected in Canada as contrasted with the earlier 2.1 percent per year. In addition, the portion of municipal pumpage allocated to industry is included in the Levels Board estimate. This portion is unstated in the report and background, but is estimated at 22 percent on the basis of current research. This allowance would reduce the Levels Board estimate to within 12 percent of the current Canadian forecast, and only about eight percent higher than the current 2030 projection despite a significantly greater municipal population. The current estimates are based upon complex, area-specific coefficient generators, in contrast to a constant coefficient of 128 gallons per capita-day for the IGLLB estimates. The coefficient calculation used in the current estimates would tend to make the per capita use higher than the earlier estimates but the IGLLB higher population assumption more than offsets this tendency, with the result that the two estimates are actually rather close. The IGLLB report estimated that consumptive use will be a constant percentage of withdrawals through the projection period amounting to 10 percent of municipal, 40 percent of rural-domestic and 95 percent of livestock withdrawals. The U.S. consumes an average of 11 percent and the Canadians 15 percent of municipal withdrawals. Rural-domestic per capita consumptive use will increase about 25 percent. Even

TABLE 55 CANADA: WATER USE RANGES FOR THERMAL POWER GENERATION (cfs)

Year	Withdrawal[1]				Consumption[2]			
	High	MLP	Low1	Low2	High1	High2	MLP	Low
1975	-	6,600	-	-	-	-	50	-
1985	18,600	18,350	14,920	6,770	140	230	140	110
2000	44,680	41,270	27,490	6,650	330	510	310	200
2015	102,420	80,680	47,780	7,020	770	1,000	640	360
2035	285,530	197,150	98,690	8,100	2,140	2,440	1,540	740

Notes:

1. Two low estimates are included to cover the possibility of radical changes in cooling systems.
The second low figure would occur only with the adoption of cooling ponds on all new capacity.

2. The second "high" estimate would occur only with the adoption of cooling towers on all new capacity.

Canada: Thermal Power Plant Ranges - Withdrawals

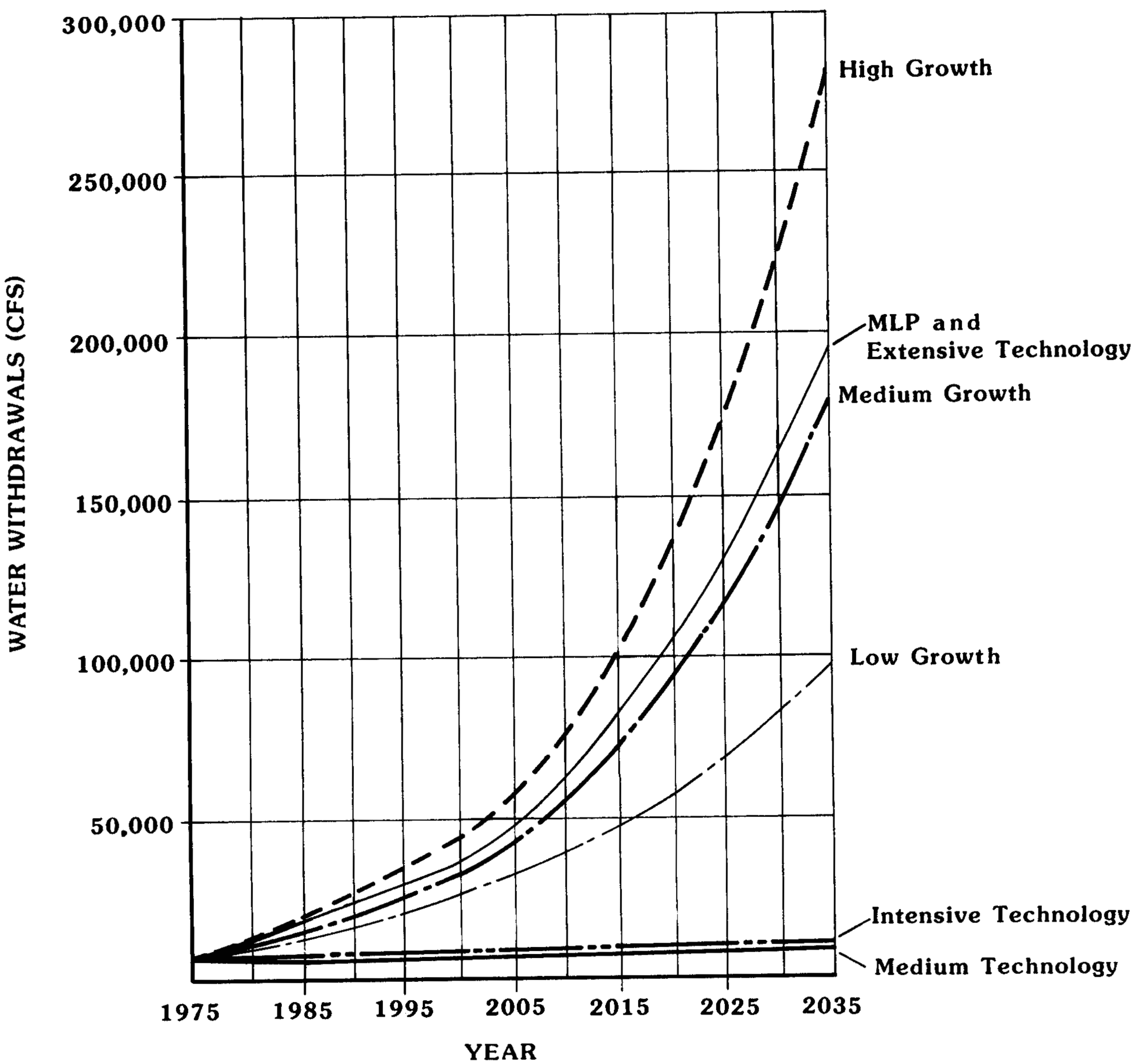


Figure F-22

Canada:
Thermal Power Plant
Ranges - Consumption

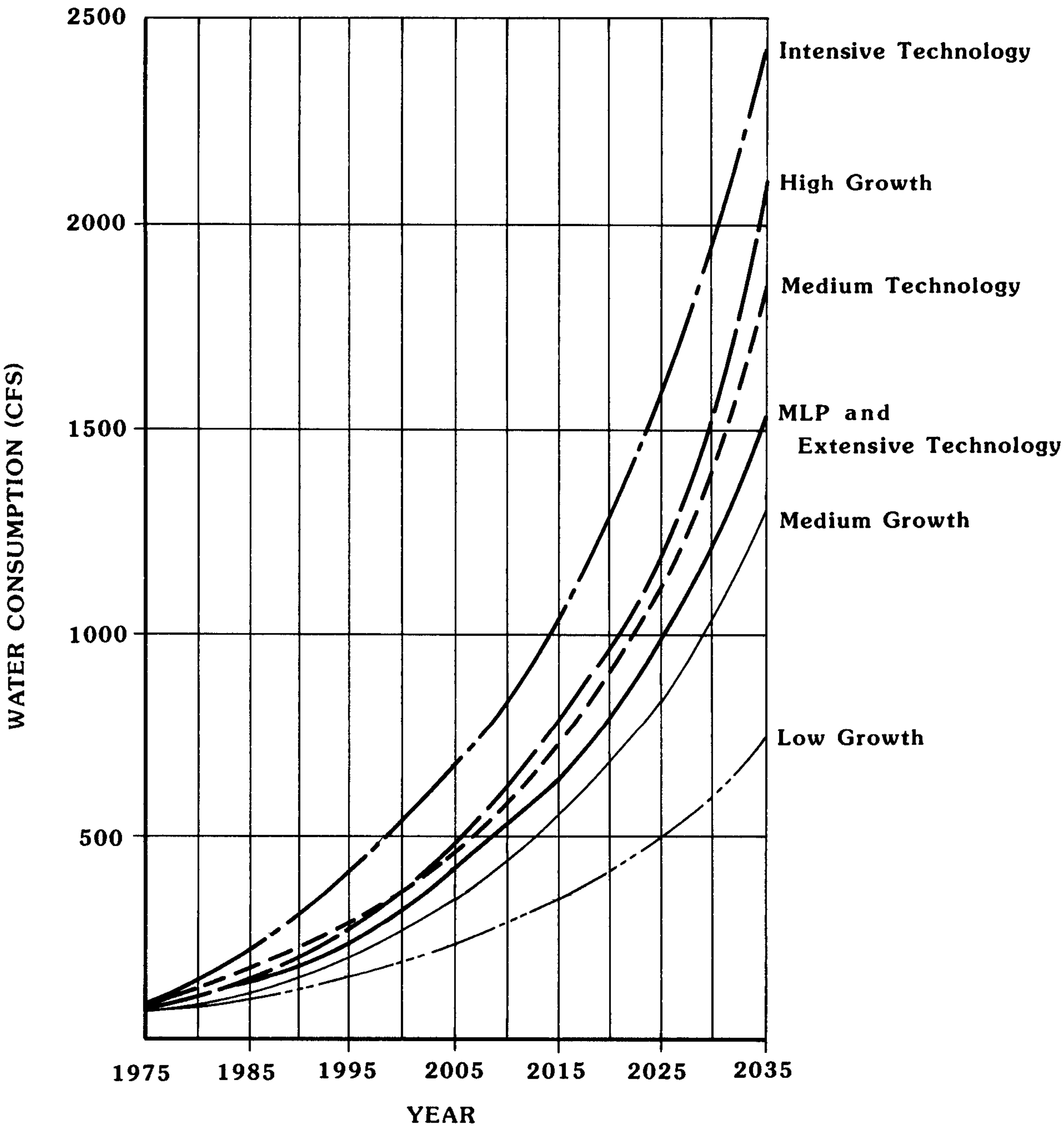


Figure F-23

Power Withdrawals

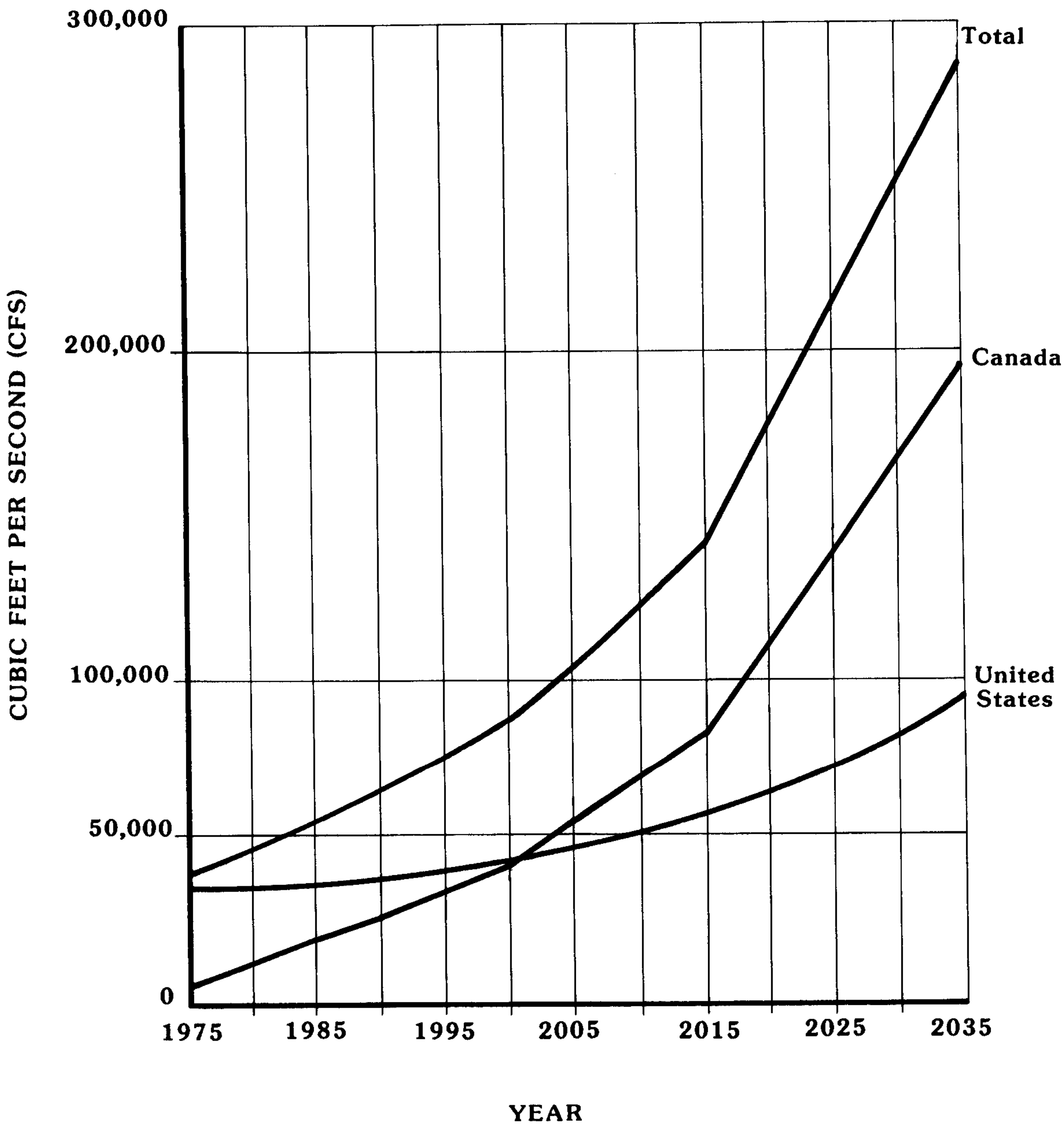


Figure F-24

Power Consumption

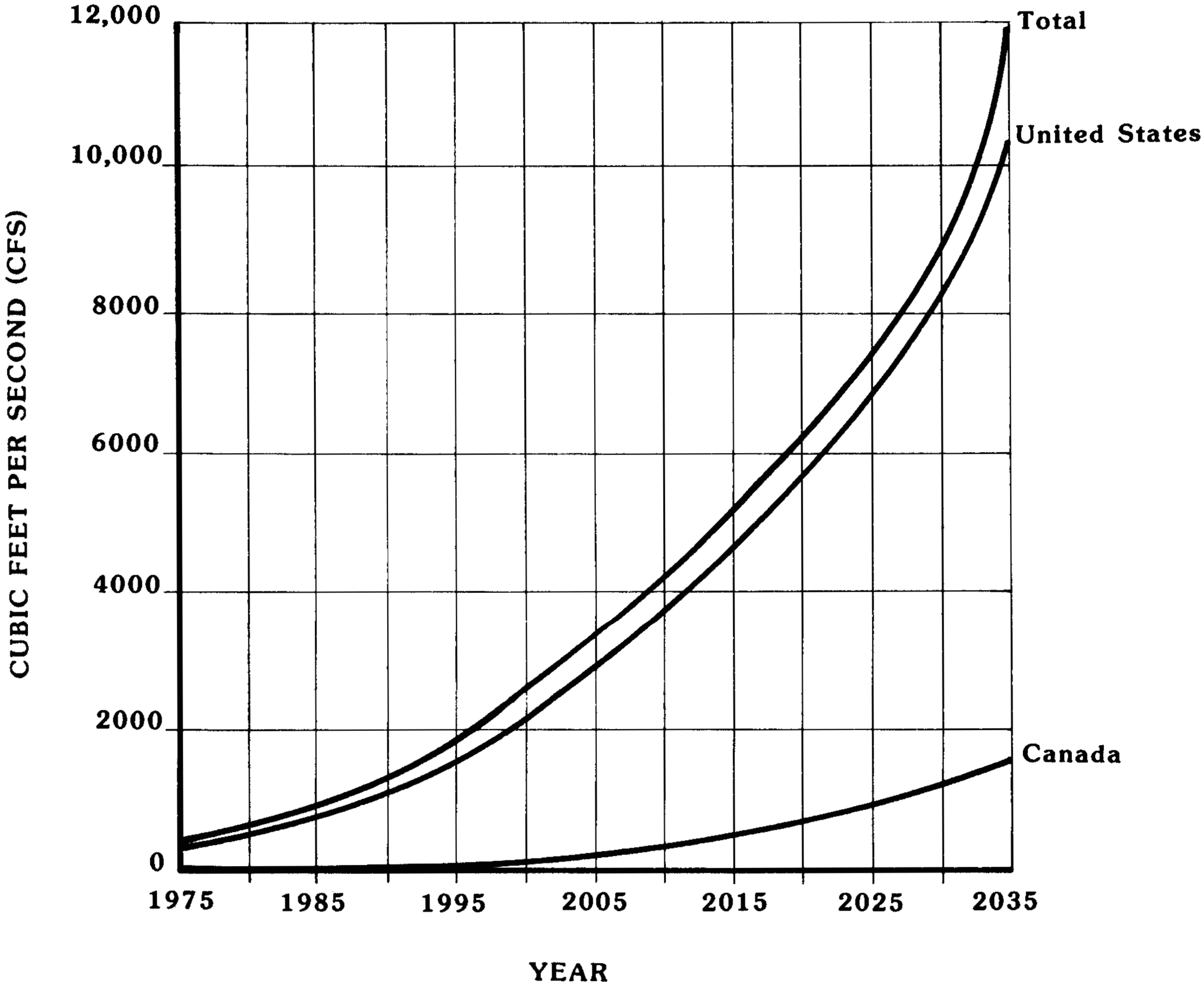


Figure F-25

though each component is different the U.S. mix is about the same and the current Canadian mix is higher. The IGLLB projection to 2030 is 49 percent higher than the current U.S. projection and three percent higher than the current Canadian projection. The combined projection increases to 36 percent higher, reflecting primarily the difference in population projections.

The IGLLB estimates of industrial (manufacturing) water use are considerably less than even the low estimate of future use from the current study (Table 56). Three principal reasons account for the discrepancy. First, the Canadian estimates for the IGLLB study were based upon water use data and coefficients from U.S. studies. This methodology is quite crude and will produce erroneous results. The current estimates use Canadian data and thus are much more accurate. Secondly, more industries are included in the current estimates, making them larger than those produced by the IGLLB. The industrial sector in the 1969 report did not include mining, so water use as well as total withdrawals would be somewhat different although mining is only two to ten percent of industrial use. Third, and perhaps most serious from the forecasting point of view, the IGLLB forecast is based upon population growth, and thus ignores factors such as markets, which can make industrial growth rates different than the population growth rate. The IGLLB report projected a 3.8 percent growth rate whereas the current U.S. projection of industrial growth uses 1.6 percent per annum and the Canadian projection is 3.7 percent. The earlier report used a constant consumptive use of four percent of withdrawals through the projection period. The U.S. consumption in 1975 was actually 12 percent of withdrawals and, reflecting environmental concerns that have developed in the interim, will be 25 percent of withdrawals in 2030. The near term IGLLB projections are 38 to 47 percent of current U.S. projections but by 2030 are only 15 percent lower and are within confidence limits of the current projection. The higher growth rate in current Canadian assumptions coupled with no environmental controls results in a difference increasing to about 450 percent by 2030. The combined current projection of industrial consumption is about 25 percent higher than that in the IGLLB report. Moving the 22 percent of water for manufacturing from the municipal-rural sector would reduce the difference to 18 percent.

The IGLLB study contains a total agricultural consumption at about 39 percent of the present MLP (Table 56). Irrigation in the IGLLB report included only agriculture and 98 percent of all water withdrawn was assumed to be consumed. MLP consumption in this report is based on crop coefficients and acreage. These aggregated crop coefficients average 74 percent of withdrawals in 1975 increasing to 86 percent in 2030. The principal reason for the increasing percentage in this report is improved efficiency in conveyance and distribution systems leading to decreasing withdrawals in this sector. The IGLLB study, in addition, did not make an allowance for golf course irrigation. If the amount of water used for golf courses is subtracted from the present MLP, the cropland irrigation plus stockwatering consumption is actually below that of the IGLLB study.

The higher percentage consumptive use in the IGLLB report offsets the lesser projection of irrigated acreage resulting in similar projected growth rates. However, the lower base in the IGLLB report results in a projection that is 28 percent of the current 77 U.S. projection, 77 percent of the current Canadian projection and 39 percent of the combined projections by the year 2030.

In the earlier part of the power forecast (Table 56), it is clear that the IGLLB study estimates are considerably higher than the present Canadian study. This is due to a large expansion foreseen in the IGLLB study to occur by 1985. This did not materialize, resulting in an overestimate of consumptive use. By 2030, however, a higher growth rate in the current study than in the IGLLB study brings the latter's estimate to within six percent of the current Canadian projection.

In the U.S. portion of the basin, the IGLLB report indicated that consumptive use of water for power generation was 0.5 percent of withdrawals in the period 1955 to 1965. This percentage was projected as a constant to 2030 and combined with a four percent annual growth rate in power demand to develop water use projections. Changes in mix of plants' cooling systems, technology or environmental perceptions were not considered. In this report, consumptive use was 1.3 percent of withdrawals in 1975 and will increase to 10 percent by 2030; nuclear plants generated 20 percent of the total power in 1975 and will increase to 39 percent after 2000. These forecasts reflect environmental concerns that developed after 1969 and evolving changes in technology. The other basic difference is that the IGLLB projections were based on power demands in the Great Lakes basin whereas the present projections are based on power generation. The difference in these two concepts is extremely important and is apparent in projections by the regional power councils. Based on these differences, the IGLLB projection of consumptive water use in the U.S. portion of the basin is 22 percent of the current MLP projection in 2030. For the total basin, the IGLLB power projection is 33 percent of the current MLP projection.

TABLE 56 COMPARISON OF WATER CONSUMPTION REPORTED IN THE IGLLB STUDY WITH THE PRESENT STUDY (cfs)

	Power		Agriculture		Industry		Mun-Rural		Total	
	IGLLB	IDCUB	IGLLB	IDCUB	IGLLB	IDCUB	IGLLB	IDCUB	IGLLB	IDCUB
U.S.										
1965	150		100		560		1070		1880	
1985	340	830	120	380	1170	3060	1330	1210	2960	5480
2000	720	2250	150	500	2060	4360	1620	1340	4550	8460
2030	1860	8440	210	750	6390	7390	2440	1640	10900	18200
Canada										
1965	30		45		100		220		395	
1985	550	140	70	110	160	340	290	310	1070	900
2000	750	310	90	130	210	610	370	380	1420	1430
2030	1390	1320	170	220	390	1730	630	610	2580	3880
Total										
1965	180		145		660		1290		2270	
1985	890	970	190	490	1330	3400	1620	1520	4030	6380
2000	1470	2560	240	640	2270	4980	1990	1720	5970	9900
2030	3250	9760	380	970	6780	9120	3070	2250	13480	22080

IGLLB - International Great Lakes Levels Board

IDCUB - International Diversions and Consumptive Uses Board

Section 10

REFERENCES

1. Bangay, G. E., Livestock and Poultry Wastes in the Great Lakes Basin: Environmental Concerns and Management Issues, Social Science Series 15, Inland Waters Directorate, Environment Canada, 1976.

2. ....., Population Estimates for the Great Lakes Basins and their Major Tributaries, Social Science Series No. 1, Inland Waters Directorate, Environment Canada, (Burlington), 1973.

3. Bower, B. T., "The Economics of Industrial Water Utilization", Water Research, A. V. Kneese and S. Smith; Editors, (Baltimore, John Hopkins Press), 1966.

4. Brooks, D. B., "Economic Impact of Low Energy Growth in Canada: An Initial Analysis", Discussion Paper 126, Economic Council of Canada, 1978.

5. Bureau of the Census, U.S. Department of Commerce, "Water Use in Manufacturing", 1972 Census of Manufactures Special Report Series, MC72 (SR)-4, (Washington), 1975.

6. Davis, H. C., "Multiregional Input-Output Techniques and Western Water Resources Development", Economic Evaluation of Water, Part V, Water Resources Center, University of California, (Berkeley), 1968.

7. Department of Energy, Mines and Resources, Canada, Energy Demand Projections: A Total Energy Approach, Report ER77-4 (Ottawa), 1977.

8. ....., Inland Waters Branch, The Consumptive Use of Great Lakes Water Within the Canadian Section of the Watershed, unpublished working paper.

9. Department of Fisheries and the Environment, National Inventory of Municipal Waterworks and Wastewater Systems, Ottawa, 1977.

10. Department of Regional Economic Expansion, Ontario Region, Canada, unpublished working paper provided by Messrs. Dalimore and Gibson, June, 1979.

11. Department of Treasury, Economics and Intergovernmental Affairs, (TEIGA), Ontario, Ontario's Changing Population, Volume 2, (Toronto), 1976.

12. ....., Ontario, unpublished population projections by County, 1970-2000, May 1978.

13. ....., Ontario, unpublished population forecasts supplied by Mr. R. Kogler.

14. Foot, D. K., J. E. Pesando, J. A. Sawyer and J. W. L. Winder, The Ontario Economy, 1977-87, (Toronto: Ontario Economic Council), 1977.

15. Frank, R. H., Ministry of Treasury, Economics and Intergovernmental Affairs, Ontario, personal communication.

16. Frank, S. M. B. and D. Haronitis, "The Input Output Structure of the Ontario Economy", Ontario Economic Review, Department of Treasury and Economics, Ontario, 1968.

17. Gander, J. E. and F. W. Belaire, Energy Futures for Canadians, Report EP78-1, Department of Energy, Mines and Resources.

18. Great Lakes Basin Commission, Framework Study, Appendix 10, Power, Federal Power Commission Chicago Regional Office, 1975.

19. ....., State-Regional Future, Great Lakes Region, 1975 National Water Assessment, July 1976.

20. Grima, A. P., Residential Water Demand: Alternative Choices of Management, (Toronto: University of Toronto Press), 1972.

21. Haites, E. F. and J. L. Sullivan, Projections of the Demand for Energy in Ontario to the year 2000-Part 1, Royal Commission on Electric Power Planning, (Toronto), 1978.

22. Howe, C. W. and F. P. Linaweaver, "The Impact of Price on Residential Water Damand and It's Relation to System Design and Price Structure" Water Resources Research, First Quarter, 1970.

23. ....., C. S. Russell and R. A. Young, Future Water Demands: The Impacts of Technological Change, Public Policies, and Changing Market Conditions on the Water Use Patterns of Selected Sectors of the United States Economy: 1970-1990, Appendix 3, (Resources for the Future Inc.), 1970.

24. Hudson, E. A. and D. W. Jorgenson, "Economic Impact of Policies to Reduce U.S. Energy Growth", Discussion Paper 644, (Cambridge, Mass.: Harvard Institute of Economic Research), 1978.

25. Information abstracted from working files of the Ontario Ministry of Environment's Water Resources Branch.

26. International Great Lakes Diversions and Consumptive Uses Study Board, Plan of Study, November 1977.

27. International Joint Commission, International Great Lakes Levels Board, A Survey of Consumptive Use of Water in the Great Lakes Basin, by the Regulation Sub-committee of the Working Committee, 1969.

28. International Joint Commission, Report of the Great Lakes Levels Board, (Ottawa), 1972.

29. Isard, W., Methods of Regional Analysis: An Introduction to Regional Science, (M.I.T. Press), 1966.

30. James, E. and K. James, Mathematics Dictionary, (Toronto: Van Nostrand Reinhold), 1976.

31. Kollar, K. L. and P. McCauley, U.S. Department of Commerce, personal communication, 1979.

32. Laura, Dr. D., former member of W.R.C. and Second National Assessment Task Force, personal communication, March 1978.

33. Lee, T. R., Approaches to Water Requirements Forecasting: A Canadian Perspective, Social Science Series No. 9, Canada Centre for Inland Waters, Department of the Environment, Canada, (Burlington), 1972.

34. Lofting, E. M. and H. C. Davis, "The Interindustry Water Content Matrix: Applications on a Multiregional Basis", Water Resources Research, August 1968.

35. ....., and P. H. McGauhey, "An Interindustry Analysis of the California Water Economy", Economic Evaluation of Water, Part III, Water Resources Center, University of California, (Berkeley), 1966.

36. McIntyre, G. and R. Bartholomew, Ontario Hydro, personal communication, 1979.

37. Miernyk, W. H., The Elements of Input-Output Analysis, (New York: Random House), 1966.

38. Ministry of the Environment, Ontario, unpublished Records of Water Takings.

39. Montreal Engineering Company, Estimates of Current Water Use in Canada, Department of the Environment, Canada, (Ottawa), 1972.

40. Mui, J., Ontario Hydro, personal communication, 1979.

41. Murray, C. R., "Estimated Use of Water in the United States", (1965), U.S. Geological Survey Circular 556, (Washington), 1968.

42. ....., "Estimated Use of Water in the United States in 1970", U.S. Geological Survey Circular 675, (Washington), 1972.

43. ....., "Estimated Use of Water in the United States in 1975", U.S. Geological Survey Circular 765, (Washington), 1977.

44. Myer, L. and R. Clemens, Great Lakes Basin Water Conservation Plan, personal communication.

45. Myer, L., R. Clemens and D. Whitehill, Water Conservation in Municipally Supplied Areas, Great Lakes Basin Water Conservation Plan, October 1978.

46. Ontario Golfer's Association, 1979.

47. Ontario Hydro, "Total System Ontario Primary Demands Based on Preliminary Load Forecast Report 790212" unpublished table, March 8, 1979.

48. Perloff, H. S., S. Dunn Jr., E. E. Lampard and R. F. Muth, Regions, Resources and Economic Growth, (Nebraska, University of Nebraska Press).

49. Pinsak, A. P., H. D. Wicke and C. F. Jenkins, Consumptive Water Use in the U.S. Section of the Great Lakes Basin, 1975-2035, U.S. Department of Commerce, NOAA, (Ann Arbor, Michigan), 1980.

50. Royal Commission on Electric Power Planning, Ontario, A Race Against Time: Interim Report on Nuclear Power in Ontario, (Toronto), 1978.

51. Sawyer, J. A., D. P. Dungan and J. W. L. Winder, The Ontario Economy, 1978-1987, (Toronto: Ontario Economic Council), 1978.

52. Sewell, W. R. D. and B. T. Bower, Forecasting the Demands for Water, Policy and Planning Branch, Department of Energy, Mines and Resources, (Ottawa), 1968.

53. Simon, D., NAS Power Study Director, Federal Power Commission Chicago Regional Office, personal communication.

54. Sonnen, C. A. and P. M. Jacobson, Estimates of Economic Activity in the Regions of the Canadian Great Lakes Basin, Canada Centre for Inland Waters, Department of the Environment, Canada, (Burlington), 1975.

55. Statistics Canada, Electric Power Statistics: Annual Survey of Capability and Load, Catalogue #57-204, (Ottawa), 1976.

56. ....., Manufacturing Industries of Canada: National and Provincial Areas, Catalogue #31-203, (Ottawa), published annually since 1949.

57. ....., Standard Industrial Classification Manual, Catalogue #12-501, (Ottawa), 1970.

58. Tate, D. M., Consumptive Water Use in the Canadian Section of the Great Lakes Basin, 1975-2035, Environment Canada, (Ottawa), 1979.

59. ....., Manufacturing Water Use in Canada, 1972-A Summary, Social Science Series No. 17, Department of Fisheries and the Environment Canada, Inland Waters Directorate, (Ottawa), 1977.

60. Tate, D. M., Water Use and Demand Forecasting in Canada: A Review, International Institute for Applied Systems Analysis, Research memorandum RM78-16, (Laxenberg, Austria), 1978.

61. ....., and D. Lacelle, "Municipal Water Use in Canada", Canadian Water Resources Journal, Vol. 3, No. 2, 1978.

62. Tiemens, M. F. and P. H. Graham, Role of Water Conservation in the Construction Grants Program, published as part of the proceedings of a water conservation conference, December 1978.

63. U.S. Dept. of Agriculture, Soil Conservation Service, Irrigation Water Requirements, Tech. Release No. 21, April 1967.

64. U.S. Great Lakes Basin Commission, Report of the Great Lakes Basin Framework Study, (Ann Arbor), 1975.

65. U.S. Water Resources Council, Methodology and Assumptions for Electric Power Generation Uses of Water, Work Statement Document, February 1975.

66. U.S. Water Resources Council, Domestic Water Use From Central Systems; Nationwide Analysis Report, Appendix C-3, July 1975.

67. ....., Domestic Water Use From Central Systems; Nationwide Analysis Report, Appendix C-3, July 1975.

68. ....., Guidelines for FPC Staff Participation in the Nationwide Analysis Phase of the WRC Second National Assessment, April 1974.

69. ....., Methodologies and Assumptions for Water Use Supply Data, NAS Accessory publication, February 1975.

70. ....., Methodologies and Assumptions for Water Use and Supply Data, unpublished working paper, 1975.

71. ....., The Nation's Water Resources, 1975-2000: Second National Water Assessment, (Washington), 1978.

72. ....., The Nation's Water Resources, Great Lakes Region, preliminary summary of the Second National Water Assessment, April 1978.

73. ....., The Nation's Water Resources, The Second National Water Assessment, Great Lakes Region Summary.

74. ....., The Nation's Water Resources: The Second National Water Assessment, Statistical Appendix, Vol. A-1, April 1978.

75. ....., OBERS "SERIES E" Projections, Regional Economic Activity in the U.S., Vol. 3, 1972.

76. ....., The Nation's Water Resources, The Second National Water Assessment, Statistical Appendix, Water Supply and Use Data, Vol. A-2, April 1978.

77. U.S. Water Resources Council, OBERS "SERIES E" Projections and Historical Data, Population, Personal Income and Earnings, June 1974.

78. ....., OBERS Projections: Regional Economic Activity in the U.S., Series E, Vol. 1 (Washington), 1974.

79. ....., unpublished summary material, January 1977.

80. Vallery, D., Ministry of the Environment, personal communication, 1979.

81. Water Supply Work Group, Great Lakes Basin Framework Study, Appendix 6, Water Supply - Municipal, Industrial, Rural, 1975.

Section 11

DATA SET

TABLES: PAGE NO.

Water Use Data by Lake Basin

Total Water Use Data

United States Water Use Data

Canada Water Use Data

NOTE: "Lake Ontario" includes the International Section of the St. Lawrence River.

NOTE: Due to separate methods employed in the tabulation and rounding of data, there may be negligible differences between forecast numbers in this Data Set and the SUMMARY TABLES (6-1,6-2,6-3) in the main report (Section 6).

TABLE 1 GREAT LAKES TOTAL WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
SUPR LAK	2030	2300	2620	3140	3660	4190	4790	5560	6370	7650	9050	10540	12230
MICH LAK	21030	22410	24030	25330	26720	28520	30030	31750	33760	36150	38890	42170	46360
HURN LAK	3280	5350	7510	10210	12970	15780	19860	24030	28240	37090	46020	55070	64270
ERIE LAK	20710	22950	25150	28080	30580	33330	37360	41650	46390	53520	61260	69800	79540
ON/L LAK	12580	17600	22980	28660	34360	40400	49850	59510	69550	89310	109590	130540	152470
TOTL LAK	59630	70610	82290	95420	108290	122220	141890	162500	184310	223720	264810	308120	354870
SUPR NOL	310	300	310	330	340	340	350	370	400	440	460	510	570
MICH NOL	4390	4610	4660	4850	5050	5260	5570	5890	6260	6700	7190	7740	8470
HURN NOL	2940	3380	3830	4250	4810	5480	5960	6550	7270	8100	9090	10280	11760
ERIE NOL	6450	6170	6050	5680	5520	5450	5790	6160	6610	7120	7710	8410	9270
ON/L NOL	1900	1900	1750	1560	1600	1730	1850	2010	2190	2370	2610	2890	3170
TOTL NOL	15990	16360	16600	16670	17320	18260	19520	20980	22730	24730	27060	29830	33240
SUPR TOT	2340	2600	2930	3470	4000	4530	5140	5930	6770	8090	9510	11050	12800
MICH TOT	25420	27020	28690	30180	31770	33780	35600	37640	40020	42850	46080	49910	54830
HURN TOT	6220	8730	11340	14460	17780	21260	25820	30580	35510	45190	55110	65350	76030
ERIE TOT	27160	29120	31200	33760	36100	38780	43150	47810	53000	60640	68970	78210	88810
ON/L TOT	14480	19500	24730	30220	35960	42130	51700	61520	71740	91680	112200	133430	155640
GTLK TOT	75620	86970	98890	112090	125610	140480	161410	183480	207040	248450	291870	337950	388110

TABLE 2 GREAT LAKES TOTAL CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
SUPR LAK	200	210	220	250	280	310	340	370	400	450	490	550	610
MICH LAK	1030	1200	1370	1630	1950	2310	2630	3020	3490	4000	4610	5290	6130
HURN LAK	250	290	330	380	460	540	630	720	800	970	1130	1300	1460
ERIE LAK	1680	1860	2090	2450	2830	3270	3730	4280	4880	5540	6330	7150	8140
ON/L LAK	330	420	540	690	860	1080	1320	1600	1910	2380	2860	3400	4090
TOTL LAK	3490	3980	4550	5400	6380	7510	8650	9990	11480	13340	15420	17690	20430
SUPR NOL	50	60	60	70	70	70	80	90	100	100	110	120	130
MICH NOL	500	570	650	690	760	830	890	980	1090	1180	1280	1390	1540
HURN NOL	180	230	270	320	390	460	520	640	770	870	1030	1200	1340
ERIE NOL	530	560	600	650	690	730	820	870	970	1040	1140	1230	1350
ON/L NOL	200	220	230	250	270	290	300	320	370	370	420	450	480
TOTL NOL	1460	1640	1810	1980	2180	2380	2610	2900	3300	3560	3980	4390	4840
SUPR TOT	250	270	280	320	350	380	420	460	500	550	600	670	740
MICH TOT	1530	1770	2020	2320	2710	3140	3520	4000	4580	5180	5890	6680	7670
HURN TOT	430	520	600	700	850	1000	1150	1360	1570	1840	2160	2500	2880
ERIE TOT	2210	2420	2690	3100	3520	4000	4550	5150	5850	6580	7470	8380	9490
ON/L TOT	530	640	770	940	1130	1370	1620	1920	2280	2750	3280	3850	4570
GTLK TOT	4950	5620	6360	7380	8560	9890	11260	12890	14780	16900	19400	22080	25350

TABLE 3 TOTAL WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	5610	5970	6340	6730	7100	7450	7850	8260	8660	9080	9500	9920	10390
MUN NOLK	1450	1560	1640	1740	1860	1950	2050	2180	2300	2420	2550	2690	2820
MUN TOTL	7060	7530	7980	8470	8960	9400	9900	10440	10960	11500	12050	12610	13210
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	560	580	610	630	640	640	640	670	680	680	690	730	740
DOM TOTL	560	580	610	630	640	640	640	670	680	680	690	730	740
MAN LAKE	23660	25070	26870	28940	31360	34120	37200	40630	44580	49180	54600	60920	68340
MAN NOLK	2370	2570	2830	3110	3470	3860	4270	4740	5300	5950	6710	7600	8680
MAN TOTL	26030	27640	29700	32050	34830	37980	41470	45370	49880	55130	61310	68520	77020
MIN LAKE	860	950	1030	1130	1210	1290	1370	1480	1550	1640	1720	1810	1900
MIN NOLK	350	400	450	530	610	690	790	870	1010	1120	1280	1500	1710
MIN TOTL	1210	1350	1480	1660	1820	1980	2160	2350	2560	2760	3000	3310	3610
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	210	220	230	240	250	250	260	280	290	310	340	340	360
STK TOTL	210	220	230	240	250	250	260	280	290	310	340	340	360
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	480	550	610	690	750	790	860	920	990	1060	1130	1200	1280
IRR TOTL	480	550	610	690	750	790	860	920	990	1060	1130	1200	1280
PWR LAKE	29500	38620	48050	58620	68620	79360	95470	112130	129520	163820	198990	235470	274240
PWR NOLK	10570	10480	10230	9730	9740	10080	10650	11320	12160	13190	14360	15770	17650
PWR TOTL	40070	49100	58280	68350	78360	89440	106120	123450	141680	177010	213350	251240	291890
TOT LAKE	59630	70610	82290	95420	108290	122220	141890	162500	184310	223720	264810	308120	354870
TOT NOLK	15990	16360	16600	16670	17320	18260	19520	20980	22730	24730	27060	29830	33240
TOT TOTL	75620	86970	98890	112090	125610	140480	161410	183480	207040	248450	291870	337950	388110

TABLE 4 TOTAL CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	660	710	730	790	830	880	940	980	1030	1090	1150	1200	1260
MUN NOLK	170	170	190	190	190	190	200	220	240	250	250	270	280
MUN TOTL	830	880	920	980	1020	1070	1140	1200	1270	1340	1400	1470	1540
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	330	360	380	390	390	390	390	390	400	410	420	420	430
DOM TOTL	330	360	380	390	390	390	390	390	400	410	420	420	430
MAN LAKE	2280	2540	2830	3270	3740	4230	4740	5280	5810	6470	7130	7830	8570
MAN NOLK	210	240	270	320	380	420	480	540	640	650	720	820	920
MAN TOTL	2490	2780	3100	3590	4120	4650	5220	5820	6450	7120	7850	8650	9490
MIN LAKE	190	200	220	230	260	260	270	290	310	320	340	350	370
MIN NOLK	60	60	60	60	60	70	80	80	100	110	120	130	130
MIN TOTL	250	260	280	290	320	330	350	370	410	430	460	480	500
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	210	220	230	240	250	250	260	280	300	310	340	340	360
STK TOTL	210	220	230	240	250	250	260	280	300	310	340	340	360
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	360	420	480	540	580	630	670	740	810	850	920	960	1030
IRR TOTL	360	420	480	540	580	630	670	740	810	850	920	960	1030
PWR LAKE	360	530	770	1110	1550	2140	2700	3440	4330	5460	6800	8310	10230
PWR NOLK	120	170	200	240	330	430	530	650	810	980	1210	1450	1770
PWR TOTL	480	700	970	1350	1880	2570	3230	4090	5140	6440	8010	9760	12000
TOT LAKE	3490	3980	4550	5400	6380	7510	8650	9990	11480	13340	15420	17690	20430
TOT NOLK	1460	1640	1810	1980	2180	2380	2610	2900	3300	3560	3980	4390	4840
TOT TOTL	4950	5620	6360	7380	8560	9890	11260	12890	14780	16900	19400	22080	25350

TABLE 5   TOTAL LAKE SUPERIOR WITHDRAWAL WATER USE   CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	70	70	70	80	80	80	80	80	80	90	90	90	100
MUN NOLK	40	40	40	30	30	30	30	30	30	30	30	30	30
MUN TOTL	110	110	110	110	110	110	110	110	110	120	120	120	130
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
DOM TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
MAN LAKE	1070	1230	1440	1670	1940	2250	2580	2980	3430	3970	4610	5340	6220
MAN NOLK	40	40	40	50	60	60	60	70	70	90	90	100	120
MAN TOTL	1110	1270	1480	1720	2000	2310	2640	3050	3500	4060	4700	5440	6340
MIN LAKE	270	290	300	320	330	340	360	380	390	400	420	430	440
MIN NOLK	80	80	90	100	110	120	130	130	150	160	170	200	220
MIN TOTL	350	370	390	420	440	460	490	510	540	560	590	630	660
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
STK TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	10	10	20	20	20	20	20	30	30	30	30	30	40
IRR TOTL	10	10	20	20	20	20	20	30	30	30	30	30	40
PWR LAKE	620	710	810	1070	1310	1520	1770	2120	2470	3190	3930	4680	5470
PWR NOLK	130	120	110	120	110	100	100	100	110	120	130	140	150
PWR TOTL	750	830	920	1190	1420	1620	1870	2220	2580	3310	4060	4820	5620
TOT LAKE	2030	2300	2620	3140	3660	4190	4790	5560	6370	7650	9050	10540	12230
TOT NOLK	310	300	310	330	340	340	350	370	400	440	460	510	570
TOT TOTL	2340	2600	2930	3470	4000	4530	5140	5930	6770	8090	9510	11050	12800

TABLE 6   TOTAL LAKE SUPERIOR CONSUMPTIVE WATER USE   CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	20	20	20	20	20	20	20	20	20	20	20	20	20
MUN NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
MUN TOTL	20	20	20	20	20	20	20	20	20	20	20	20	20
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
DOM TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
MAN LAKE	70	70	80	90	110	130	150	170	180	200	220	250	280
MAN NOLK	0	10	10	10	10	10	10	10	10	10	10	10	10
MAN TOTL	70	80	90	100	120	140	160	180	190	210	230	260	290
MIN LAKE	100	110	110	120	120	120	130	130	140	140	150	150	150
MIN NOLK	30	30	30	30	30	30	30	30	40	40	50	50	50
MIN TOTL	130	140	140	150	150	150	160	160	180	180	200	200	200
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
STK TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	10	10	10	20	20	20	20	30	30	30	30	30	40
IRR TOTL	10	10	10	20	20	20	20	30	30	30	30	30	40
PWR LAKE	10	10	10	20	30	40	40	50	60	90	100	130	160
PWR NOLK	0	0	0	0	0	0	10	10	10	10	10	20	20
PWR TOTL	10	10	10	20	30	40	50	60	70	100	110	150	180
TOT LAKE	200	210	220	250	280	310	340	370	400	450	490	550	610
TOT NOLK	50	60	60	70	70	70	80	90	100	100	110	120	130
TOT TOTL	250	270	280	320	350	380	420	460	500	550	600	670	740

TABLE 7 TOTAL LAKE MICHIGAN WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	2190	2310	2440	2560	2680	2790	2910	3020	3130	3230	3340	3440	3550
MUN NOLK	580	630	670	720	780	830	890	950	1010	1080	1140	1210	1280
MUN TOTL	2770	2940	3110	3280	3460	3620	3800	3970	4140	4310	4480	4650	4830
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	250	260	270	270	270	270	270	280	280	280	280	280	290
DOM TOTL	250	260	270	270	270	270	270	280	280	280	280	280	290
MAN LAKE	8760	8880	9010	9180	9340	9530	9700	9870	10040	10210	10380	10550	10710
MAN NOLK	760	770	780	800	820	830	850	860	870	880	900	910	930
MAN TOTL	9520	9650	9790	9980	10160	10360	10550	10730	10910	11090	11280	11460	11640
MIN LAKE	180	200	210	230	240	260	270	290	300	320	330	350	370
MIN NOLK	50	50	50	60	60	60	70	70	80	80	90	90	100
MIN TOTL	230	250	260	290	300	320	340	360	380	400	420	440	470
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	70	70	70	70	70	70	70	70	70	80	80	80	80
STK TOTL	70	70	70	70	70	70	70	70	70	80	80	80	80
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	200	250	290	330	360	390	430	460	490	520	560	590	630
IRR TOTL	200	250	290	330	360	390	430	460	490	520	560	590	630
PWR LAKE	9900	11020	12370	13360	14460	15940	17150	18570	20290	22390	24840	27830	31730
PWR NOLK	2480	2580	2530	2600	2690	2810	2990	3200	3460	3780	4140	4580	5160
PWR TOTL	12380	13600	14900	15960	17150	18750	20140	21770	23750	26170	28980	32410	36890
TOT LAKE	21030	22410	24030	25330	26720	28520	30030	31750	33760	36150	38890	42170	46360
TOT NOLK	4390	4610	4660	4850	5050	5260	5570	5890	6260	6700	7190	7740	8470
TOT TOTL	25420	27020	28690	30180	31770	33780	35600	37640	40020	42850	46080	49910	54830

TABLE 8 TOTAL LAKE MICHIGAN CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	150	160	160	170	180	190	200	200	210	220	230	240	240
MUN NOLK	30	30	40	40	40	40	40	50	50	50	50	50	60
MUN TOTL	180	190	200	210	220	230	240	250	260	270	280	290	300
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	150	160	160	160	160	160	160	160	170	170	170	170	180
DOM TOTL	150	160	160	160	160	160	160	160	170	170	170	170	180
MAN LAKE	720	810	900	1030	1160	1290	1410	1530	1650	1770	1890	2020	2140
MAN NOLK	60	70	80	90	100	110	120	130	140	150	160	170	180
MAN TOTL	780	880	980	1120	1260	1400	1530	1660	1790	1920	2050	2190	2320
MIN LAKE	30	30	30	30	40	40	40	50	50	50	50	60	60
MIN NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
MIN TOTL	40	40	40	40	50	50	50	60	60	60	60	70	70
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	70	70	70	70	70	70	70	70	80	80	80	80	80
STK TOTL	70	70	70	70	70	70	70	70	80	80	80	80	80
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	150	190	240	260	290	320	350	380	410	440	470	500	530
IRR TOTL	150	190	240	260	290	320	350	380	410	440	470	500	530
PWR LAKE	130	200	280	400	570	790	980	1240	1580	1960	2440	2970	3690
PWR NOLK	30	40	50	60	90	120	140	180	230	280	340	410	500
PWR TOTL	160	240	330	460	660	910	1120	1420	1810	2240	2780	3380	4190
TOT LAKE	1030	1200	1370	1630	1950	2310	2630	3020	3490	4000	4610	5290	6130
TOT NOLK	500	570	650	690	760	830	890	980	1090	1180	1280	1390	1540
TOT TOTL	1530	1770	2020	2320	2710	3140	3520	4000	4580	5180	5890	6680	7670

TABLE 9 TOTAL LAKE HURON WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	310	330	360	390	410	440	460	500	530	560	590	620	650
MUN NOLK	90	100	100	110	120	130	130	140	150	150	160	170	180
MUN TOTL	400	430	460	500	530	570	590	640	680	710	750	790	830
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	70	80	80	90	100	100	100	110	110	110	120	130	130
DOM TOTL	70	80	80	90	100	100	100	110	110	110	120	130	130
MAN LAKE	1740	1930	2180	2450	2770	3140	3510	3930	4410	4990	5650	6440	7360
MAN NOLK	410	490	600	700	830	990	1130	1290	1490	1720	1990	2310	2700
MAN TOTL	2150	2420	2780	3150	3600	4130	4640	5220	5900	6710	7640	8750	10060
MIN LAKE	90	100	120	130	140	150	160	170	180	190	200	210	220
MIN NOLK	130	170	200	240	290	350	410	480	570	670	790	940	1100
MIN TOTL	220	270	320	370	430	500	570	650	750	860	990	1150	1320
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	40	50	50	50	60	60	60	70	70	80	90	90	100
STK TOTL	40	50	50	50	60	60	60	70	70	80	90	90	100
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	40	40	40	50	60	60	60	60	80	80	80	90	90
IRR TOTL	40	40	40	50	60	60	60	60	80	80	80	90	90
PWR LAKE	1140	2990	4850	7240	9650	12050	15730	19430	23120	31350	39580	47800	56040
PWR NOLK	2160	2450	2760	3010	3350	3790	4070	4400	4800	5290	5860	6550	7460
PWR TOTL	3300	5440	7610	10250	13000	15840	19800	23830	27920	36640	45440	54350	63500
TOT LAKE	3280	5350	7510	10210	12970	15780	19860	24030	28240	37090	46020	55070	64270
TOT NOLK	2940	3390	3830	4250	4810	5480	5960	6550	7270	8100	9090	10280	11760
TOT TOTL	6220	8730	11340	14460	17780	21260	25820	30580	35510	45190	55110	65350	76030

TABLE 10 TOTAL LAKE HURON CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	170	180	180	190	200	210	220	240	250	260	270	280	290
MUN NOLK	10	10	20	20	20	20	20	20	20	30	30	30	30
MUN TOTL	180	190	200	210	220	230	240	260	270	290	300	310	320
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	40	50	50	60	60	60	60	60	60	70	70	70	70
DOM TOTL	40	50	50	60	60	60	60	60	60	70	70	70	70
MAN LAKE	60	80	100	130	170	220	260	300	340	430	510	600	680
MAN NOLK	20	20	30	40	50	60	70	100	140	120	140	170	210
MAN TOTL	80	100	130	170	220	280	330	400	480	550	650	770	890
MIN LAKE	10	10	10	10	20	20	20	20	20	30	30	30	30
MIN NOLK	10	10	10	10	10	20	20	20	20	20	20	30	30
MIN TOTL	20	20	20	20	30	40	40	40	40	50	50	60	60
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	40	50	50	50	60	60	60	70	70	80	90	90	100
STK TOTL	40	50	50	50	60	60	60	70	70	80	90	90	100
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	30	40	40	40	50	50	50	60	70	70	80	80	80
IRR TOTL	30	40	40	40	50	50	50	60	70	70	80	80	80
PWR LAKE	10	20	40	50	70	90	130	160	190	250	320	390	460
PWR NOLK	30	50	70	100	140	190	240	310	390	480	600	730	900
PWR TOTL	40	70	110	150	210	280	370	470	580	730	920	1120	1360
TOT LAKE	250	290	330	380	460	540	630	720	800	970	1130	1300	1460
TOT NOLK	180	230	270	320	390	460	520	640	770	870	1030	1200	1340
TOT TOTL	430	520	600	700	850	1000	1150	1360	1570	1840	2160	2500	2880

TABLE 11 TOTAL LAKE ERIE WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	2350	2500	2650	2810	2970	3130	3290	3450	3610	3780	3940	4100	4270
MUN NOLK	480	510	540	570	610	630	660	700	730	770	810	850	890
MUN TOTL	2830	3010	3190	3380	3580	3760	3950	4150	4340	4550	4750	4950	5160
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	160	160	170	170	170	170	170	170	170	170	170	180	180
DOM TOTL	160	160	170	170	170	170	170	170	170	170	170	180	180
MAN LAKE	9570	10050	10660	11400	12290	13260	14500	15810	17320	19070	21150	23590	26440
MAN NOLK	900	960	1030	1110	1220	1340	1490	1650	1850	2070	2330	2640	3010
MAN TOTL	10470	11010	11690	12510	13510	14600	15990	17460	19170	21140	23480	26230	29450
MIN LAKE	250	280	310	340	380	410	440	480	510	550	580	610	650
MIN NOLK	70	80	90	100	110	120	130	140	160	160	180	200	220
MIN TOTL	320	360	400	440	490	530	570	620	670	710	760	810	870
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	60	60	70	70	70	70	80	80	90	90	100	100	110
STK TOTL	60	60	70	70	70	70	80	80	90	90	100	100	110
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	160	180	180	200	220	220	240	260	270	300	320	340	360
IRR TOTL	160	180	180	200	220	220	240	260	270	300	320	340	360
PWR LAKE	8540	10120	11530	13530	14940	16530	19130	21910	24950	30120	35590	41500	48180
PWR NOLK	4620	4220	3970	3460	3120	2900	3020	3160	3340	3560	3800	4100	4500
PWR TOTL	13160	14340	15500	16990	18060	19430	22150	25070	28290	33680	39390	45600	52680
TOT LAKE	20710	22950	25150	28080	30580	33330	37360	41650	46390	53520	61260	69800	79540
TOT NOLK	6450	6170	6050	5680	5520	5450	5790	6160	6610	7120	7710	8410	9270
TOT TOTL	27160	29120	31200	33760	36100	38780	43150	47810	53000	60640	68970	78210	88810

TABLE 12 TOTAL LAKE ERIE CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	210	230	240	270	280	300	320	330	350	360	390	400	420
MUN NOLK	80	80	80	80	80	80	90	100	100	100	100	120	120
MUN TOTL	290	310	320	350	360	380	410	430	450	460	490	520	540
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	90	100	110	110	100	100	100	100	100	100	100	100	100
DOM TOTL	90	100	110	110	100	100	100	100	100	100	100	100	100
MAN LAKE	1330	1450	1600	1830	2070	2310	2600	2900	3200	3550	3900	4270	4660
MAN NOLK	120	130	140	160	190	210	240	260	300	320	350	390	430
MAN TOTL	1450	1580	1740	1990	2260	2520	2840	3160	3500	3870	4250	4660	5090
MIN LAKE	40	40	50	50	60	60	60	70	80	80	90	90	100
MIN NOLK	10	10	10	10	10	10	20	20	20	30	30	30	30
MIN TOTL	50	50	60	60	70	70	80	90	100	110	120	120	130
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	60	60	70	70	70	70	80	80	90	90	100	100	110
STK TOTL	60	60	70	70	70	70	80	80	90	90	100	100	110
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	120	120	130	150	150	160	170	180	200	210	230	230	250
IRR TOTL	120	120	130	150	150	160	170	180	200	210	230	230	250
PWR LAKE	100	140	200	300	420	600	750	980	1250	1550	1950	2390	2960
PWR NOLK	50	60	60	70	90	100	120	130	160	190	230	260	310
PWR TOTL	150	200	260	370	510	700	870	1110	1410	1740	2180	2650	3270
TOT LAKE	1680	1860	2090	2450	2830	3270	3730	4280	4880	5540	6330	7150	8140
TOT NOLK	530	560	600	650	690	730	820	870	970	1040	1140	1230	1350
TOT TOTL	2210	2420	2690	3100	3520	4000	4550	5150	5850	6580	7470	8380	9490

TABLE 13 TOTAL LAKE ONTARIO WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	690	760	820	890	960	1010	1110	1210	1310	1420	1540	1670	1820
MUN NOLK	260	280	290	310	320	330	340	360	380	390	410	430	440
MUN TOTL	950	1040	1110	1200	1280	1340	1450	1570	1690	1810	1950	2100	2260
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	70	70	80	90	90	90	90	100	110	110	110	130	130
DOM TOTL	70	70	80	90	90	90	90	100	110	110	110	130	130
MAN LAKE	2520	2980	3580	4240	5020	5940	6910	8040	9380	10940	12810	15000	17610
MAN NOLK	260	310	380	450	540	640	740	870	1020	1190	1400	1640	1920
MAN TOTL	2780	3290	3960	4690	5560	6580	7650	8910	10400	12130	14210	16640	19530
MIN LAKE	70	80	90	110	120	130	140	160	170	180	190	210	220
MIN NOLK	20	20	20	30	40	40	50	50	50	50	50	70	70
MIN TOTL	90	100	110	140	160	170	190	210	220	230	240	280	290
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	40	40	40	50	50	50	50	60	60	60	70	70	70
STK TOTL	40	40	40	50	50	50	50	60	60	60	70	70	70
TRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
TRR NOLK	70	70	80	90	90	100	110	110	120	130	140	150	160
TRR TOTL	70	70	80	90	90	100	110	110	120	130	140	150	160
PWR LAKE	9300	13780	18490	23420	28260	33320	41690	50100	58690	76770	95050	113660	132820
PWR NOLK	1180	1110	860	540	470	480	470	460	450	440	430	400	380
PWR TOTL	10480	14890	19350	23960	28730	33800	42160	50560	59140	77210	95480	114060	133200
TOT LAKE	12580	17600	22980	28660	34360	40400	49850	59510	69550	89310	109590	130540	152470
TOT NOLK	1900	1900	1750	1560	1600	1730	1850	2010	2190	2370	2610	2890	3170
TOT TOTL	14480	19500	24730	30220	35960	42130	51700	61520	71740	91680	112200	133430	155640

TABLE 14 TOTAL LAKE ONTARIO CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	110	120	130	140	150	160	180	190	200	230	240	260	290
MUN NOLK	50	50	50	50	50	50	50	50	70	70	70	70	70
MUN TOTL	160	170	180	190	200	210	230	240	270	300	310	330	360
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	40	40	50	50	60	60	60	60	60	60	70	70	70
DOM TOTL	40	40	50	50	60	60	60	60	60	60	70	70	70
MAN LAKE	100	130	150	190	230	280	320	380	440	520	610	690	810
MAN NOLK	10	10	10	20	30	30	40	40	50	50	60	80	90
MAN TOTL	110	140	160	210	260	310	360	420	490	570	670	770	900
MIN LAKE	10	10	20	20	20	20	20	20	20	20	20	20	30
MIN NOLK	0	0	0	0	0	0	0	0	10	10	10	10	10
MIN TOTL	10	10	20	20	20	20	20	20	30	30	30	30	40
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	40	40	40	50	50	50	50	60	60	60	70	70	70
STK TOTL	40	40	40	50	50	50	50	60	60	60	70	70	70
TRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
TRR NOLK	50	60	60	70	70	80	80	90	100	100	110	120	130
TRR TOTL	50	60	60	70	70	80	80	90	100	100	110	120	130
PWR LAKE	110	160	240	340	460	620	800	1010	1250	1610	1990	2430	2960
PWR NOLK	10	20	20	10	10	20	20	20	20	20	30	30	40
PWR TOTL	120	180	260	350	470	640	820	1030	1270	1630	2020	2460	3000
TOT LAKE	330	420	540	690	860	1080	1320	1600	1910	2380	2860	3400	4090
TOT NOLK	200	220	230	250	270	290	300	320	370	370	420	450	480
TOT TOTL	530	640	770	940	1130	1370	1620	1920	2280	2750	3280	3850	4570

TABLE 15 UNITED STATES TOTAL WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	4890	5200	5500	5820	6130	6420	6730	7040	7340	7640	7940	8230	8530
MUN NOLK	1240	1320	1390	1460	1570	1630	1720	1810	1900	1990	2080	2180	2270
MUN TOTL	6130	6520	6890	7280	7700	8050	8450	8850	9240	9630	10020	10410	10800
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	500	520	530	540	550	550	550	580	580	580	580	600	610
DOM TOTL	500	520	530	540	550	550	550	580	580	580	580	600	610
MAN LAKE	18820	19110	19460	19950	20450	21030	21640	22230	22830	23440	24080	24730	25370
MAN NOLK	1630	1650	1680	1730	1790	1840	1890	1930	1990	2040	2090	2140	2220
MAN TOTL	20450	20760	21140	21680	22240	22870	23530	24160	24820	25480	26170	26870	27590
MIN LAKE	860	950	1030	1130	1210	1290	1370	1480	1550	1640	1720	1810	1900
MIN NOLK	220	240	250	290	300	320	350	360	400	400	420	460	490
MIN TOTL	1080	1190	1280	1420	1510	1610	1720	1840	1950	2040	2140	2270	2390
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	130	130	130	130	130	130	130	130	130	140	140	140	140
STK TOTL	130	130	130	130	130	130	130	130	130	140	140	140	140
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	350	410	460	530	570	600	660	710	750	800	850	890	940
IRR TOTL	350	410	460	530	570	600	660	710	750	800	850	890	940
PWR LAKE	22900	26150	29700	32640	34990	38090	41070	44580	48840	54010	60060	67450	77090
PWR NOLK	10570	10480	10230	9730	9740	10080	10650	11320	12160	13190	14360	15770	17650
PWR TOTL	33470	36630	39930	42370	44730	48170	51720	55900	61000	67200	74420	83220	94740
TOT LAKE	47470	51410	55690	59540	62780	66830	70810	75330	80560	86730	93800	102220	112890
TOT NOLK	14640	14750	14670	14410	14650	15150	15950	16840	17910	19140	20520	22180	24320
TOT TOTL	62110	66160	70360	73950	77430	81980	86760	92170	98470	105870	114320	124400	137210

TABLE 16 UNITED STATES TOTAL CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	550	590	600	650	680	720	770	790	830	870	910	940	980
MUN NOLK	130	130	150	150	150	150	160	170	180	180	180	190	200
MUN TOTL	680	720	750	800	830	870	930	960	1010	1050	1090	1130	1180
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	300	330	330	330	330	330	330	330	340	350	350	350	360
DOM TOTL	300	330	330	330	330	330	330	330	340	350	350	350	360
MAN LAKE	2100	2310	2550	2930	3320	3720	4140	4580	5000	5460	5930	6400	6870
MAN NOLK	170	200	220	260	300	330	360	390	440	470	500	550	600
MAN TOTL	2270	2510	2770	3190	3620	4050	4500	4970	5440	5930	6430	6950	7470
MIN LAKE	190	200	220	230	260	260	270	290	310	320	340	350	370
MIN NOLK	60	60	60	60	60	60	70	70	80	80	90	90	90
MIN TOTL	250	260	280	290	320	320	340	360	390	400	430	440	460
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	130	130	130	130	130	130	130	130	140	140	140	140	140
STK TOTL	130	130	130	130	130	130	130	130	140	140	140	140	140
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	260	310	370	420	460	500	530	590	640	670	710	740	790
IRR TOTL	260	310	370	420	460	500	530	590	640	670	710	740	790
PWR LAKE	300	440	630	920	1300	1830	2280	2910	3690	4600	5720	6980	8690
PWR NOLK	120	170	200	240	330	430	530	650	810	980	1210	1450	1770
PWR TOTL	420	610	830	1160	1630	2260	2810	3560	4500	5580	6930	8430	10460
TOT LAKE	3140	3540	4000	4730	5560	6530	7460	8570	9830	11250	12900	14670	16910
TOT NOLK	1170	1330	1460	1590	1760	1930	2110	2330	2630	2870	3180	3510	3950
TOT TOTL	4310	4870	5460	6320	7320	8460	9570	10900	12460	14120	16080	18180	20860

TABLE 17 UNITED STATES LAKE SUPERIOR WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	40	40	40	50	50	50	50	50	50	60	60	60	60
MUN NOLK	30	30	30	20	20	20	20	20	20	20	20	20	20
MUN TOTL	70	70	70	70	70	70	70	70	70	80	80	80	80
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
DOM TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
MAN LAKE	380	380	390	400	410	420	430	440	450	460	470	470	480
MAN NOLK	30	30	30	40	40	40	40	40	40	50	50	50	60
MAN TOTL	410	410	420	440	450	460	470	480	490	510	520	520	540
MIN LAKE	270	290	300	320	330	340	360	380	390	400	420	430	440
MIN NOLK	70	70	70	80	80	90	90	90	100	100	100	110	120
MIN TOTL	340	360	370	400	410	430	450	470	490	500	520	540	560
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
STK TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	10	10	20	20	20	20	20	30	30	30	30	30	30
IRR TOTL	10	10	20	20	20	20	20	30	30	30	30	30	30
PWR LAKE	580	640	700	710	690	640	600	650	710	780	870	980	1120
PWR NOLK	130	120	110	120	110	100	100	100	110	120	130	140	150
PWR TOTL	710	760	810	830	800	740	700	750	820	900	1000	1120	1270
TOT LAKE	1270	1350	1430	1480	1480	1450	1440	1520	1600	1700	1820	1940	2100
TOT NOLK	280	270	270	290	280	280	280	290	310	330	340	360	390
TOT TOTL	1550	1620	1700	1770	1760	1730	1720	1810	1910	2030	2160	2300	2490

TABLE 18 UNITED STATES LAKE SUPERIOR CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	10	10	10	10	10	10	10	10	10	10	10	10	10
MUN NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
MUN TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
DOM TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
MAN LAKE	50	50	50	60	70	80	90	100	110	110	120	130	140
MAN NOLK	0	10	10	10	10	10	10	10	10	10	10	10	10
MAN TOTL	50	60	60	70	80	90	100	110	120	120	130	140	150
MIN LAKE	100	110	110	120	120	120	130	130	140	140	150	150	150
MIN NOLK	30	30	30	30	30	30	30	30	30	30	40	40	40
MIN TOTL	130	140	140	150	150	150	160	160	170	170	190	190	190
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
STK TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	10	10	10	20	20	20	20	30	30	30	30	30	30
IRR TOTL	10	10	10	20	20	20	20	30	30	30	30	30	30
PWR LAKE	10	10	10	20	20	30	30	40	50	70	80	100	130
PWR NOLK	0	0	0	0	0	0	10	10	10	10	10	20	20
PWR TOTL	10	10	10	20	20	30	40	50	60	80	90	120	150
TOT LAKE	170	180	180	210	220	240	260	280	310	330	360	390	430
TOT NOLK	50	60	60	70	70	70	80	90	90	90	100	110	110
TOT TOTL	220	240	240	280	290	310	340	370	400	420	460	500	540

TABLE 19 UNITED STATES LAKE HURON WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	250	270	290	310	330	350	370	400	420	440	460	480	500
MUN NOLK	40	40	40	40	50	50	50	50	50	50	50	50	50
MUN TOTL	290	310	330	350	380	400	420	450	470	490	510	530	550
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	50	60	60	60	70	70	70	80	80	80	80	90	90
DOM TOTL	50	60	60	60	70	70	70	80	80	80	80	90	90
MAN LAKE	970	980	990	1020	1040	1070	1110	1140	1170	1210	1240	1280	1310
MAN NOLK	80	80	90	90	90	100	100	100	100	100	100	100	110
MAN TOTL	1050	1060	1080	1110	1130	1170	1210	1240	1270	1310	1340	1380	1420
MIN LAKE	90	100	120	130	140	150	160	170	180	190	200	210	220
MIN NOLK	20	30	30	30	30	40	40	40	50	50	50	60	60
MIN TOTL	110	130	150	160	170	190	200	210	230	240	250	270	280
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
STK TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	20	20	20	30	30	30	30	30	40	40	40	40	40
IRR TOTL	20	20	20	30	30	30	30	30	40	40	40	40	40
PWR LAKE	160	120	90	80	80	80	80	90	100	110	120	130	150
PWR NOLK	2160	2450	2760	3010	3350	3790	4070	4400	4800	5290	5860	6550	7460
PWR TOTL	2320	2570	2850	3090	3430	3870	4150	4490	4900	5400	5980	6680	7610
TOT LAKE	1470	1470	1490	1540	1590	1650	1720	1800	1870	1950	2020	2100	2180
TOT NOLK	2380	2690	3010	3270	3630	4090	4370	4710	5130	5620	6190	6900	7820
TOT TOTL	3850	4160	4500	4810	5220	5740	6090	6510	7000	7570	8210	9000	10000

TABLE 20 UNITED STATES LAKE HURON CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	160	170	170	180	190	200	210	220	230	240	250	260	270
MUN NOLK	0	0	10	10	10	10	10	10	10	10	10	10	10
MUN TOTL	160	170	180	190	200	210	220	230	240	250	260	270	280
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	30	40	40	40	40	40	40	40	40	50	50	50	50
DOM TOTL	30	40	40	40	40	40	40	40	40	50	50	50	50
MAN LAKE	20	30	40	50	70	100	120	150	170	190	220	250	270
MAN NOLK	0	0	0	10	10	10	10	10	20	20	20	20	30
MAN TOTL	20	30	40	60	80	110	130	160	190	210	240	270	300
MIN LAKE	10	10	10	10	20	20	20	20	20	30	30	30	30
MIN NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
MIN TOTL	20	20	20	20	30	30	30	30	30	40	40	40	40
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
STK TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	10	20	20	20	30	30	30	30	40	40	40	40	40
IRR TOTL	10	20	20	20	30	30	30	30	40	40	40	40	40
PWR LAKE	0	0	0	0	0	0	10	10	10	10	10	10	20
PWR NOLK	30	50	70	100	140	190	240	310	390	480	600	730	900
PWR TOTL	30	50	70	100	140	190	250	320	400	490	610	740	920
TOT LAKE	190	210	220	240	280	320	360	400	430	470	510	550	590
TOT NOLK	90	130	160	200	250	300	350	420	520	620	740	870	1050
TOT TOTL	280	340	380	440	530	620	710	820	950	1090	1250	1420	1640

TABLE 21 UNITED STATES LAKE ERIE WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	2270	2420	2560	2710	2860	3010	3160	3310	3460	3610	3760	3910	4060
MUN NOLK	380	400	420	440	470	480	500	520	540	560	580	600	620
MUN TOTL	2650	2820	2980	3150	3330	3490	3660	3830	4000	4170	4340	4510	4680
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	140	140	140	140	140	140	140	140	140	140	140	140	140
DOM TOTL	140	140	140	140	140	140	140	140	140	140	140	140	140
MAN LAKE	8230	8380	8560	8820	9110	9440	9800	10160	10520	10890	11290	11710	12120
MAN NOLK	720	730	740	760	790	820	850	880	920	950	980	1020	1060
MAN TOTL	8950	9110	9300	9580	9900	10260	10650	11040	11440	11840	12270	12730	13180
MIN LAKE	250	280	310	340	380	410	440	480	510	550	580	610	650
MIN NOLK	60	70	80	90	100	100	110	120	130	130	140	150	160
MIN TOTL	310	350	390	430	480	510	550	600	640	680	720	760	810
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	30	30	30	30	30	30	30	30	30	30	30	30	30
STK TOTL	30	30	30	30	30	30	30	30	30	30	30	30	30
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	90	100	100	110	120	120	130	140	140	160	160	170	180
IRR TOTL	90	100	100	110	120	120	130	140	140	160	160	170	180
PWR LAKE	7530	8960	10210	11260	11720	12360	13360	14540	15980	17720	19760	22250	25500
PWR NOLK	4620	4220	3970	3460	3120	2900	3020	3160	3340	3560	3800	4100	4500
PWR TOTL	12150	13180	14180	14720	14840	15260	16380	17700	19320	21280	23560	26350	30000
TOT LAKE	18280	20040	21640	23130	24070	25220	26760	28490	30470	32770	35390	38480	42330
TOT NOLK	6040	5690	5480	5030	4770	4590	4780	4990	5240	5530	5830	6210	6690
TOT TOTL	24320	25730	27120	28160	28840	29810	31540	33480	35710	38300	41220	44690	49020

TABLE 22 UNITED STATES LAKE ERIE CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	200	220	230	250	260	280	300	310	330	340	360	370	390
MUN NOLK	60	60	60	60	60	60	70	70	70	70	70	80	80
MUN TOTL	260	280	290	310	320	340	370	380	400	410	430	450	470
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	80	90	90	90	80	80	80	80	80	80	80	80	80
DOM TOTL	80	90	90	90	80	80	80	80	80	80	80	80	80
MAN LAKE	1280	1380	1520	1730	1950	2160	2420	2680	2940	3240	3530	3820	4120
MAN NOLK	110	120	130	150	170	190	210	230	260	280	300	330	360
MAN TOTL	1390	1500	1650	1880	2120	2350	2630	2910	3200	3520	3830	4150	4480
MIN LAKE	40	40	50	50	60	60	60	70	80	80	90	90	100
MIN NOLK	10	10	10	10	10	10	20	20	20	20	20	20	20
MIN TOTL	50	50	60	60	70	70	80	90	100	100	110	110	120
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	30	30	30	30	30	30	30	30	30	30	30	30	30
STK TOTL	30	30	30	30	30	30	30	30	30	30	30	30	30
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	70	70	80	90	90	100	100	110	120	120	130	130	140
IRR TOTL	70	70	80	90	90	100	100	110	120	120	130	130	140
PWR LAKE	90	130	190	280	400	570	710	920	1170	1460	1820	2230	2780
PWR NOLK	50	60	60	70	90	100	120	130	160	190	230	260	310
PWR TOTL	140	190	250	350	490	670	830	1050	1330	1650	2050	2490	3090
TOT LAKE	1610	1770	1990	2310	2670	3070	3490	3980	4520	5120	5800	6510	7390
TOT NOLK	410	440	460	500	530	570	630	670	740	790	860	930	1020
TOT TOTL	2020	2210	2450	2810	3200	3640	4120	4650	5260	5910	6660	7440	8410

TABLE 23 UNITED STATES LAKE ONTARIO WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	140	160	170	190	210	220	240	260	280	300	320	340	360
MUN NOLK	210	220	230	240	250	250	260	270	280	280	290	300	300
MUN TOTL	350	380	400	430	460	470	500	530	560	580	610	640	660
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	50	50	50	60	60	60	60	70	70	70	70	80	80
DOM TOTL	50	50	50	60	60	60	60	70	70	70	70	80	80
MAN LAKE	480	490	510	530	550	570	600	620	650	670	700	720	750
MAN NOLK	40	40	40	40	50	50	50	50	60	60	60	60	60
MAN TOTL	520	530	550	570	600	620	650	670	710	730	760	780	810
MIN LAKE	70	80	90	110	120	130	140	160	170	180	190	210	220
MIN NOLK	20	20	20	30	30	30	40	40	40	40	40	50	50
MIN TOTL	90	100	110	140	150	160	180	200	210	220	230	260	270
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	20	20	20	20	20	20	20	20	20	20	20	20	20
STK TOTL	20	20	20	20	20	20	20	20	20	20	20	20	20
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	30	30	30	40	40	40	50	50	50	50	60	60	60
IRR TOTL	30	30	30	40	40	40	50	50	50	50	60	60	60
PWR LAKE	4730	5410	6330	7230	8040	9070	9880	10730	11760	13010	14470	16260	18590
PWR NOLK	1180	1110	860	540	470	480	470	460	450	440	430	400	380
PWR TOTL	5910	6520	7190	7770	8510	9550	10350	11190	12210	13450	14900	16660	18970
TOT LAKE	5420	6140	7100	8060	8920	9990	10860	11770	12860	14160	15680	17530	19920
TOT NOLK	1550	1490	1250	970	920	930	950	960	970	960	970	970	950
TOT TOTL	6970	7630	8350	9030	9840	10920	11810	12730	13830	15120	16650	18500	20870

TABLE 24 UNITED STATES LAKE ONTARIO CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	30	30	30	40	40	40	50	50	50	60	60	60	70
MUN NOLK	40	40	40	40	40	40	40	40	50	50	50	50	50
MUN TOTL	70	70	70	80	80	80	90	90	100	110	110	110	120
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	30	30	30	30	40	40	40	40	40	40	40	40	40
DOM TOTL	30	30	30	30	40	40	40	40	40	40	40	40	40
MAN LAKE	30	40	40	60	70	90	100	120	130	150	170	180	200
MAN NOLK	0	0	0	0	10	10	10	10	10	10	10	20	20
MAN TOTL	30	40	40	60	80	100	110	130	140	160	180	200	220
MIN LAKE	10	10	20	20	20	20	20	20	20	20	20	20	30
MIN NOLK	0	0	0	0	0	0	0	0	10	10	10	10	10
MIN TOTL	10	10	20	20	20	20	20	20	30	30	30	30	40
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	20	20	20	20	20	20	20	20	20	20	20	20	20
STK TOTL	20	20	20	20	20	20	20	20	20	20	20	20	20
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	20	20	20	30	30	30	30	40	40	40	40	40	50
IRR TOTL	20	20	20	30	30	30	30	40	40	40	40	40	50
PWR LAKE	70	100	150	220	310	440	550	700	880	1100	1370	1670	2070
PWR NOLK	10	20	20	10	10	20	20	20	20	20	30	30	40
PWR TOTL	80	120	170	230	320	460	570	720	900	1120	1400	1700	2110
TOT LAKE	140	180	240	340	440	590	720	890	1080	1330	1620	1930	2370
TOT NOLK	120	130	130	130	150	160	160	170	190	190	200	210	230
TOT TOTL	260	310	370	470	590	750	880	1060	1270	1520	1820	2140	2600

TABLE 25 CANADA TOTAL WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	720	770	840	910	970	1030	1120	1220	1320	1440	1560	1690	1860
MUN NOLK	210	240	250	280	290	320	330	370	400	430	470	510	550
MUN TOTL	930	1010	1090	1190	1260	1350	1450	1590	1720	1870	2030	2200	2410
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	60	60	80	90	90	90	90	90	100	100	110	130	130
DOM TOTL	60	60	80	90	90	90	90	90	100	100	110	130	130
MAN LAKE	4840	5960	7410	8990	10910	13090	15560	18400	21750	25740	30520	36190	42970
MAN NOLK	740	920	1150	1380	1680	2020	2380	2810	3310	3910	4620	5460	6460
MAN TOTL	5580	6880	8560	10370	12590	15110	17940	21210	25060	29650	35140	41650	49430
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	130	160	200	240	310	370	440	510	610	720	860	1040	1220
MIN TOTL	130	160	200	240	310	370	440	510	610	720	860	1040	1220
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	80	90	100	110	120	120	130	150	160	170	200	200	220
STK TOTL	80	90	100	110	120	120	130	150	160	170	200	200	220
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	130	140	150	160	180	190	200	210	240	260	280	310	340
IRR TOTL	130	140	150	160	180	190	200	210	240	260	280	310	340
PWR LAKE	6600	12470	18350	25980	33630	41270	54400	67550	80680	109810	138930	168020	197150
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	6600	12470	18350	25980	33630	41270	54400	67550	80680	109810	138930	168020	197150
TOT LAKE	12160	19200	26600	35880	45510	55390	71080	87170	103750	136990	171010	205900	241980
TOT NOLK	1350	1610	1930	2260	2670	3110	3570	4140	4820	5590	6540	7650	8920
TOT TOTL	13510	20810	28530	38140	48180	58500	74650	91310	108570	142580	177550	213550	250900

TABLE 26 CANADA TOTAL CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	110	120	130	140	150	160	170	190	200	220	240	260	280
MUN NOLK	40	40	40	40	40	40	40	50	60	70	70	80	80
MUN TOTL	150	160	170	180	190	200	210	240	260	290	310	340	360
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	30	30	50	60	60	60	60	60	60	60	70	70	70
DOM TOTL	30	30	50	60	60	60	60	60	60	60	70	70	70
MAN LAKE	180	230	280	340	420	510	600	700	810	1010	1200	1430	1700
MAN NOLK	40	40	50	60	80	90	120	150	200	180	220	270	320
MAN TOTL	220	270	330	400	500	600	720	850	1010	1190	1420	1700	2020
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	0	0	0	0	0	10	10	10	20	30	30	40	40
MIN TOTL	0	0	0	0	0	10	10	10	20	30	30	40	40
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	80	90	100	110	120	120	130	150	160	170	200	200	220
STK TOTL	80	90	100	110	120	120	130	150	160	170	200	200	220
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	100	110	110	120	120	130	140	150	170	180	210	220	240
IRR TOTL	100	110	110	120	120	130	140	150	170	180	210	220	240
PWR LAKE	60	90	140	190	250	310	420	530	640	860	1080	1330	1540
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	60	90	140	190	250	310	420	530	640	860	1080	1330	1540
TOT LAKE	350	440	550	670	820	980	1190	1420	1650	2090	2520	3020	3520
TOT NOLK	290	310	350	390	420	450	500	570	670	690	800	880	890
TOT TOTL	640	750	900	1060	1240	1430	1690	1990	2320	2780	3320	3900	4490

TABLE 27 CANADA LAKE SUPERIOR WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	30	30	30	30	30	30	30	30	30	30	30	30	40
MUN NOLK	10	10	10	10	10	10	10	10	10	10	10	10	10
MUN TOTL	40	40	40	40	40	40	40	40	40	40	40	40	50
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
MAN LAKE	690	850	1050	1270	1530	1830	2150	2540	2980	3510	4140	4870	5740
MAN NOLK	10	10	10	10	20	20	20	30	30	40	40	50	60
MAN TOTL	700	850	1060	1280	1550	1850	2170	2570	3010	3550	4180	4920	5800
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	10	10	20	20	30	30	40	40	50	60	70	90	100
MIN TOTL	10	10	20	20	30	30	40	40	50	60	70	90	100
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
STK TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
TRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
TRR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	10
TRR TOTL	0	0	0	0	0	0	0	0	0	0	0	0	10
PWR LAKE	40	70	110	360	620	880	1170	1470	1760	2410	3060	3700	4350
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	40	70	110	360	620	880	1170	1470	1760	2410	3060	3700	4350
TOT LAKE	760	950	1190	1660	2180	2740	3350	4040	4770	5950	7230	8600	10130
TOT NOLK	30	30	40	40	60	60	70	80	90	110	120	150	180
TOT TOTL	790	980	1230	1700	2240	2800	3420	4120	4860	6060	7350	8750	10310

TABLE 28 CANADA LAKE SUPERIOR CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	10	10	10	10	10	10	10	10	10	10	10	10	10
MUN NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
MUN TOTL	10	10	10	10	10	10	10	10	10	10	10	10	10
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
MAN LAKE	20	20	30	30	40	50	60	70	70	90	100	120	140
MAN NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
MAN TOTL	20	20	30	30	40	50	60	70	70	90	100	120	140
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	0	0	0	0	0	0	0	0	10	10	10	10	10
MIN TOTL	0	0	0	0	0	0	0	0	10	10	10	10	10
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
STK TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
TRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
TRR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	10
TRR TOTL	0	0	0	0	0	0	0	0	0	0	0	0	10
PWR LAKE	0	0	0	0	10	10	10	10	10	20	20	30	30
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	0	0	0	0	10	10	10	10	10	20	20	30	30
TOT LAKE	30	30	40	40	60	70	80	90	90	120	130	160	180
TOT NOLK	0	0	0	0	0	0	0	0	10	10	10	10	20
TOT TOTL	30	30	40	40	60	70	80	90	100	130	140	170	200

TABLE 29 CANADA LAKE HURON WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	60	60	70	80	80	90	90	100	110	120	130	140	150
MUN NOLK	50	60	60	70	70	80	80	90	100	100	110	120	130
MUN TOTL	110	120	130	150	150	170	170	190	210	220	240	260	280
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	20	20	20	30	30	30	30	30	30	30	40	40	40
DOM TOTL	20	20	20	30	30	30	30	30	30	30	40	40	40
MAN LAKE	770	950	1190	1430	1730	2070	2400	2790	3240	3780	4410	5160	6050
MAN NOLK	330	410	510	610	740	890	1030	1190	1390	1620	1890	2210	2590
MAN TOTL	1100	1360	1700	2040	2470	2960	3430	3980	4630	5400	6300	7370	8640
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	110	140	170	210	260	310	370	440	520	620	740	880	1040
MIN TOTL	110	140	170	210	260	310	370	440	520	620	740	880	1040
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	30	40	40	40	50	50	50	60	60	70	80	80	90
STK TOTL	30	40	40	40	50	50	50	60	60	70	80	80	90
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	20	20	20	20	30	30	30	30	40	40	40	50	50
IRR TOTL	20	20	20	20	30	30	30	30	40	40	40	50	50
PWR LAKE	980	2870	4760	7160	9570	11970	15650	19340	23020	31240	39460	47670	55890
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	980	2870	4760	7160	9570	11970	15650	19340	23020	31240	39460	47670	55890
TOT LAKE	1810	3880	6020	8670	11380	14130	18140	22230	26370	35140	44000	52970	62090
TOT NOLK	560	690	820	980	1180	1390	1590	1840	2140	2480	2900	3380	3940
TOT TOTL	2370	4570	6840	9650	12560	15520	19730	24070	28510	37620	46900	56350	66030

TABLE 30 CANADA LAKE HURON CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	10	10	10	10	10	10	10	20	20	20	20	20	20
MUN NOLK	10	10	10	10	10	10	10	10	10	20	20	20	20
MUN TOTL	20	20	20	20	20	20	20	30	30	40	40	40	40
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	10	20	20	20	20	20	20	20	20	20	20
DOM TOTL	10	10	10	20	20	20	20	20	20	20	20	20	20
MAN LAKE	40	50	60	80	100	120	140	150	170	240	290	350	410
MAN NOLK	20	20	30	30	40	50	60	90	120	100	120	150	180
MAN TOTL	60	70	90	110	140	170	200	240	290	340	410	500	590
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	0	0	0	0	0	10	10	10	10	10	10	20	20
MIN TOTL	0	0	0	0	0	10	10	10	10	10	10	20	20
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	30	40	40	40	50	50	50	60	60	70	80	80	90
STK TOTL	30	40	40	40	50	50	50	60	60	70	80	80	90
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	20	20	20	20	20	20	20	30	30	30	40	40	40
IRR TOTL	20	20	20	20	20	20	20	30	30	30	40	40	40
PWR LAKE	10	20	40	50	70	90	120	150	180	240	310	380	440
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	10	20	40	50	70	90	120	150	180	240	310	380	440
TOT LAKE	60	80	110	140	180	220	270	320	370	500	620	750	870
TOT NOLK	90	100	110	120	140	160	170	220	250	250	290	330	290
TOT TOTL	150	180	220	260	320	380	440	540	620	750	910	1080	1240

TABLE 31 CANADA LAKE ERIE WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	80	80	90	100	110	120	130	140	150	170	180	190	210
MUN NOLK	100	110	120	130	140	150	160	180	190	210	230	250	270
MUN TOTL	180	190	210	230	250	270	290	320	340	380	410	440	480
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	20	20	30	30	30	30	30	30	30	30	30	40	40
DOM TOTL	20	20	30	30	30	30	30	30	30	30	30	40	40
MAN LAKE	1340	1670	2100	2580	3180	3820	4700	5650	6800	8180	9860	11880	14320
MAN NOLK	180	230	290	350	430	520	640	770	930	1120	1350	1620	1950
MAN TOTL	1520	1900	2390	2930	3610	4340	5340	6420	7730	9300	11210	13500	16270
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	10	10	10	10	10	20	20	20	30	30	40	50	60
MIN TOTL	10	10	10	10	10	20	20	20	30	30	40	50	60
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	30	30	40	40	40	40	50	50	60	60	70	70	80
STK TOTL	30	30	40	40	40	40	50	50	60	60	70	70	80
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	70	80	80	90	100	100	110	120	130	140	160	170	180
IRR TOTL	70	80	80	90	100	100	110	120	130	140	160	170	180
PWR LAKE	1010	1160	1320	2270	3220	4170	5770	7370	8970	12400	15830	19250	22680
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	1010	1160	1320	2270	3220	4170	5770	7370	8970	12400	15830	19250	22680
TOT LAKE	2430	2910	3510	4950	6510	8110	10600	13160	15920	20750	25870	31320	37210
TOT NOLK	410	480	570	650	750	860	1010	1170	1370	1590	1880	2200	2580
TOT TOTL	2840	3390	4080	5600	7260	8970	11610	14330	17290	22340	27750	33520	39790

TABLE 32 CANADA LAKE ERIE CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	10	10	10	20	20	20	20	20	20	20	30	30	30
MUN NOLK	20	20	20	20	20	20	20	30	30	30	30	40	40
MUN TOTL	30	30	30	40	40	40	40	50	50	50	60	70	70
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	20	20	20	20	20	20	20	20	20	20	20
DOM TOTL	10	10	20	20	20	20	20	20	20	20	20	20	20
MAN LAKE	50	70	80	100	120	150	180	220	260	310	370	450	540
MAN NOLK	10	10	10	10	20	20	30	30	40	40	50	60	70
MAN TOTL	60	80	90	110	140	170	210	250	300	350	420	510	610
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	0	0	0	0	0	0	0	0	0	10	10	10	10
MIN TOTL	0	0	0	0	0	0	0	0	0	10	10	10	10
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	30	30	40	40	40	40	50	50	60	60	70	70	80
STK TOTL	30	30	40	40	40	40	50	50	60	60	70	70	80
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	50	50	50	60	60	60	70	70	80	90	100	100	110
IRR TOTL	50	50	50	60	60	60	70	70	80	90	100	100	110
PWR LAKE	10	10	10	20	20	30	40	60	80	90	130	160	180
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	10	10	10	20	20	30	40	60	80	90	130	160	180
TOT LAKE	70	90	100	140	160	200	240	300	360	420	530	640	750
TOT NOLK	120	120	140	150	160	160	190	200	230	250	280	300	330
TOT TOTL	190	210	240	290	320	360	430	500	590	670	810	940	1080

TABLE 33 CANADA LAKE ONTARIO WITHDRAWAL WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	550	600	650	700	750	790	870	950	1030	1120	1220	1330	1460
MUN NOLK	50	60	60	70	70	80	80	90	100	110	120	130	140
MUN TOTL	600	660	710	770	820	870	950	1040	1130	1230	1340	1460	1600
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	20	20	30	30	30	30	30	30	40	40	40	50	50
DOM TOTL	20	20	30	30	30	30	30	30	40	40	40	50	50
MAN LAKE	2040	2490	3070	3710	4470	5370	6310	7420	8730	10270	12110	14280	16860
MAN NOLK	220	270	340	410	490	590	690	820	960	1130	1340	1580	1860
MAN TOTL	2260	2760	3410	4120	4960	5960	7000	8240	9690	11400	13450	15860	18720
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	0	0	0	0	10	10	10	10	10	10	10	20	20
MIN TOTL	0	0	0	0	10	10	10	10	10	10	10	20	20
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	20	20	20	30	30	30	30	40	40	40	50	50	50
STK TOTL	20	20	20	30	30	30	30	40	40	40	50	50	50
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	40	40	50	50	50	60	60	60	70	80	80	90	100
IRR TOTL	40	40	50	50	50	60	60	60	70	80	80	90	100
PWR LAKE	4570	8370	12160	16190	20220	24250	31810	39370	46930	63760	80580	97400	114230
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	4570	8370	12160	16190	20220	24250	31810	39370	46930	63760	80580	97400	114230
TOT LAKE	7160	11460	15880	20600	25440	30410	38990	47740	56690	75150	93910	113010	132550
TOT NOLK	350	410	500	590	680	800	900	1050	1220	1410	1640	1920	2220
TOT TOTL	7510	11870	16380	21190	26120	31210	39890	48790	57910	76560	95550	114930	134770

TABLE 34 CANADA LAKE ONTARIO CONSUMPTIVE WATER USE CFS

USE / YEAR	1975	1980	1985	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035
MUN LAKE	80	90	100	100	110	120	130	140	150	170	180	200	220
MUN NOLK	10	10	10	10	10	10	10	10	20	20	20	20	20
MUN TOTL	90	100	110	110	120	130	140	150	170	190	200	220	240
DOM LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
DOM NOLK	10	10	20	20	20	20	20	20	20	20	30	30	30
DOM TOTL	10	10	20	20	20	20	20	20	20	20	30	30	30
MAN LAKE	70	90	110	130	160	190	220	260	310	370	440	510	610
MAN NOLK	10	10	10	20	20	20	30	30	40	40	50	60	70
MAN TOTL	80	100	120	150	180	210	250	290	350	410	490	570	680
MIN LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
MIN TOTL	0	0	0	0	0	0	0	0	0	0	0	0	0
STK LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
STK NOLK	20	20	20	30	30	30	30	40	40	40	50	50	50
STK TOTL	20	20	20	30	30	30	30	40	40	40	50	50	50
IRR LAKE	0	0	0	0	0	0	0	0	0	0	0	0	0
IRR NOLK	30	40	40	40	40	50	50	50	60	60	70	80	80
IRR TOTL	30	40	40	40	40	50	50	50	60	60	70	80	80
PWR LAKE	40	60	90	120	150	180	250	310	370	510	620	760	890
PWR NOLK	0	0	0	0	0	0	0	0	0	0	0	0	0
PWR TOTL	40	60	90	120	150	180	250	310	370	510	620	760	890
TOT LAKE	190	240	300	350	420	490	600	710	830	1050	1240	1470	1720
TOT NOLK	80	90	100	120	120	130	140	150	180	180	220	240	250
TOT TOTL	270	330	400	470	540	620	740	860	1010	1230	1460	1710	1970

Great Lakes Total Consumption
By Lake Basin

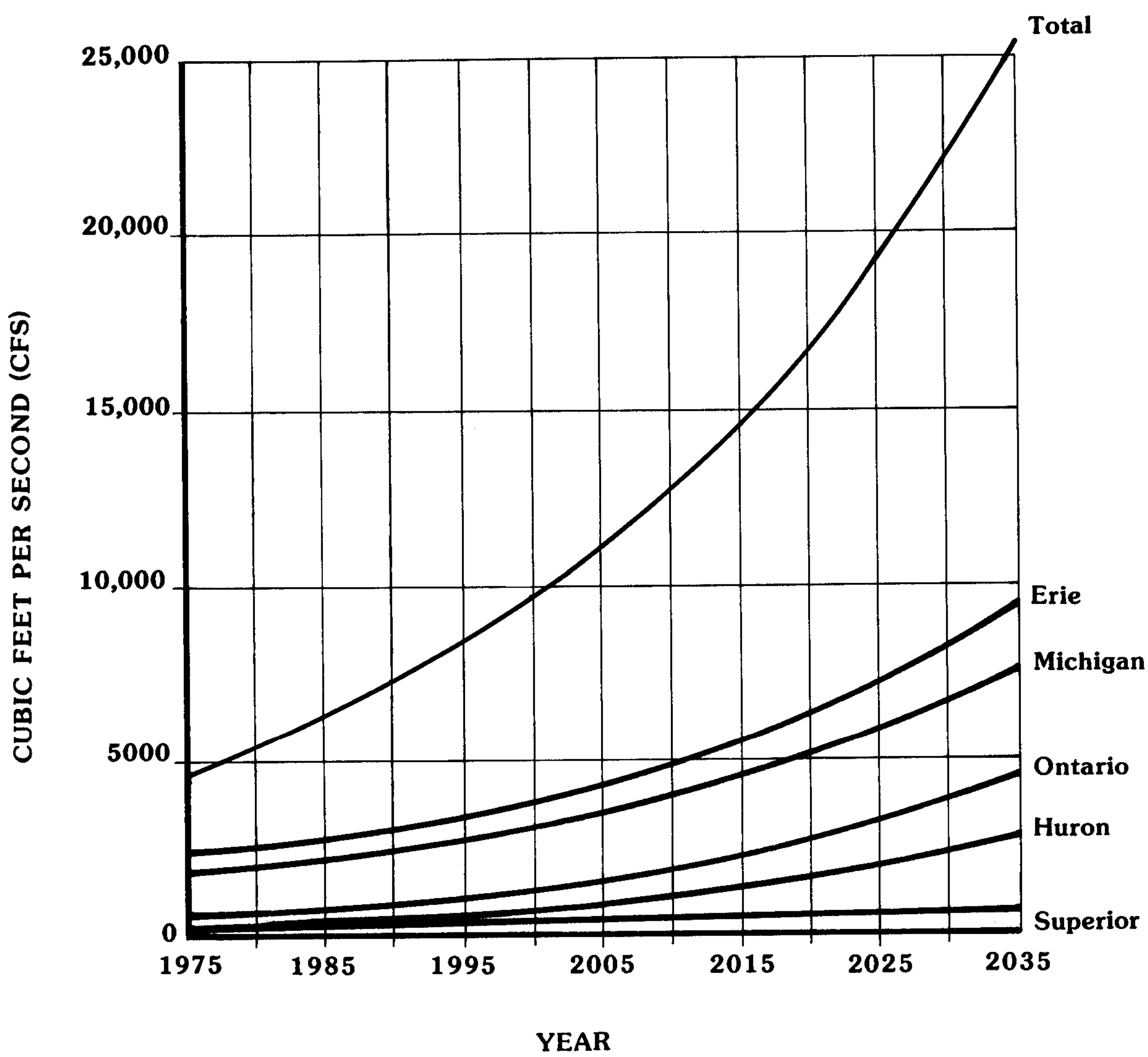


Figure F-26

Great Lakes Total Consumption By Water Use

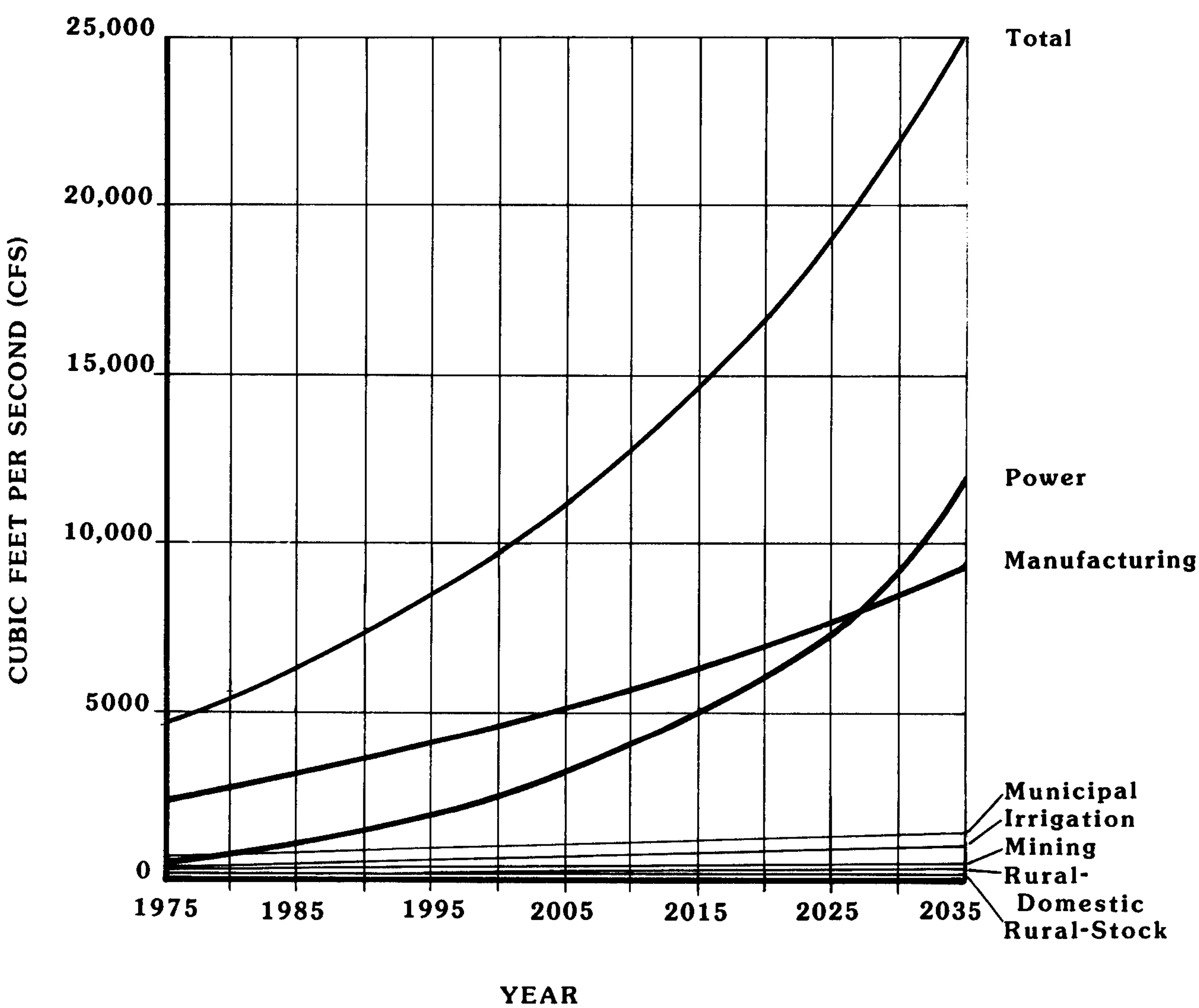


Figure F-27

Great Lakes Total Consumption by Nation

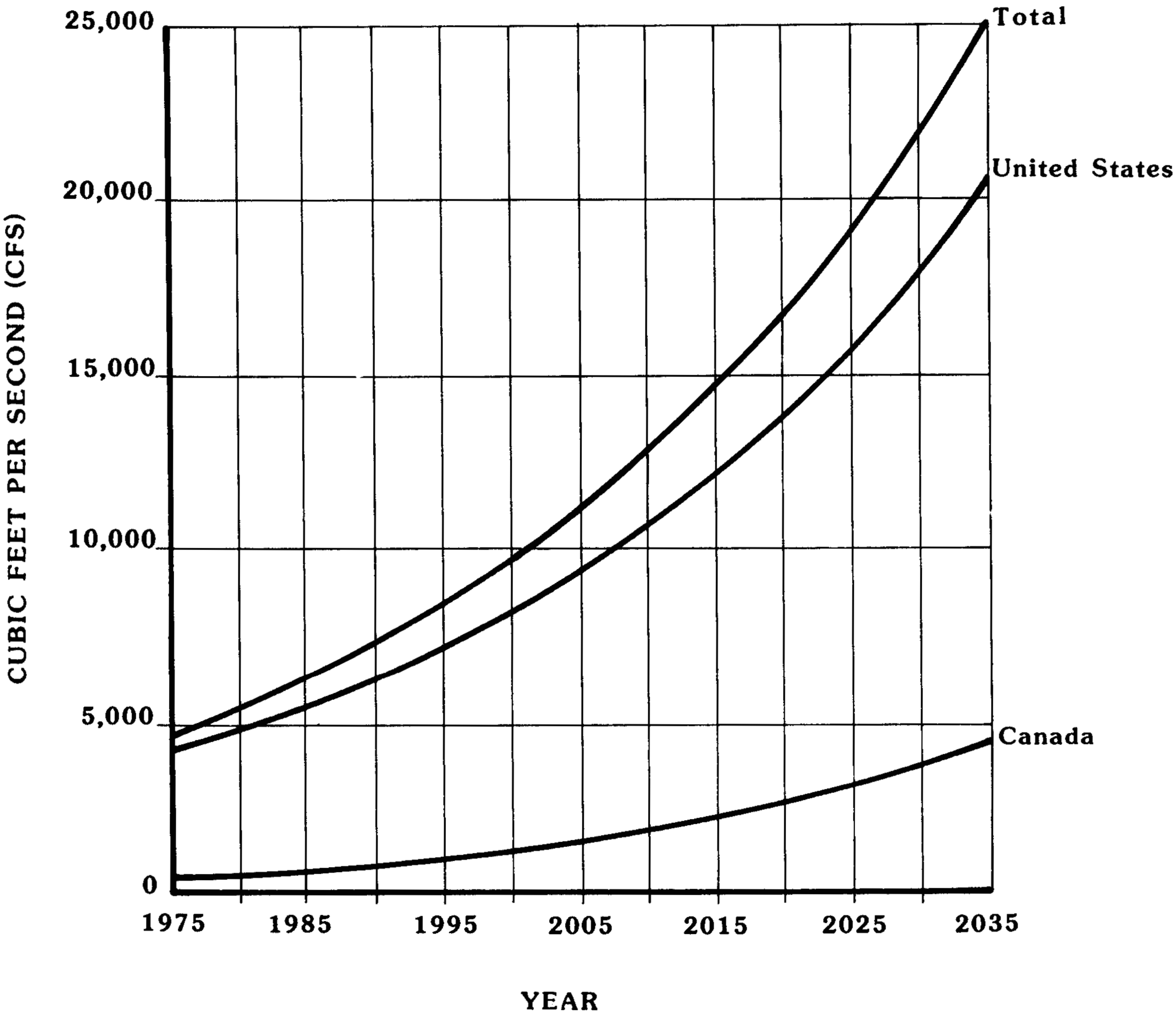


Figure F-28

☆U.S. GOVERNMENT PRINTING OFFICE: 1981—554-493