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Water Use in Canadian Industry, 1991

D.M. Tate and D.N. Scharf

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EXECUTIVE SUMMARY

- This paper reports on the fifth Environment Canada/Statistics Canada survey of industrial water use. Questionnaires, sent to just over 5100 establishments in the mineral extraction, manufacturing, and power generation sectors, were the primary survey instrument used. These were followed up by many telephone calls to clarify responses and to elicit further information. With respect to power generation, only plants in the thermal power sector are covered in this paper.

- The paper is largely descriptive in nature and is intended as a summary of survey results. The database containing the results of this survey (and previous ones) is a relatively rich primary source for future analysis in the field of water demand management.

- The remainder of this Executive Summary lists the conclusions that emerged from the paper.

- Canadian industry, composed for current purposes of the mineral extraction, manufacturing, and thermal power sectors, uses prodigious amounts of water as a basic and essential input to production. For the two largest users, thermal power and manufacturing, water use is very "extensive" in the sense that relatively little recirculation is used. The potential for increased recirculation, to make water use more efficient, is very large. The fact that action here occurs at a "snail-like" pace reflects the low cost of water to industrial users.

- Recirculation rates in manufacturing continue to decline, as they have done over the entire 1972–1991 period. This trend appears related to two primary factors: the large abundance of water relative to needs and the exceptionally low costs of self-supplied water.

- By far, the greatest proportion of industrial water is derived from self-supplied systems. All major industrial operations have their own intake facilities and draw only small amounts of water from municipalities, principally for sanitary and other domestic uses. There is, however, a significant variation from this general finding for industry groups characterized by smaller plants or by plants requiring potable water (e.g. the foods and beverages groups). These plants tend to draw more on municipal supplies than plants in the so-called heavy industries. To the extent that the former employ only rudimentary forms of water recirculation, they tend to exacerbate the overcapitalization of municipal water systems.

- Canadian industry, with few exceptions, still practises only elementary wastewater treatment methods. Even the most positive interpretation would find that just over 40% of discharges are treated by means of primary, mechanical methods. Even less is afforded more advanced treatment. The survey showed that between 50% and 60% of industrial discharges are untreated at present.

- The industrial plants included in the survey, for the most part, discharged their wastes, either untreated or partially treated, directly to surface waters. A relatively minor portion of waste water was discharged to municipal treatment systems. The amounts discharged to municipal systems showed a substantial relationship to plant size, with smaller plants tending to use public facilities to a much greater extent than larger plants, principally because of the costs involved in building, operating, and maintaining on-site treatment facilities.

- Canadian industries paid less than 1% of their gross value of shipments for water and wastewater conveyancing. As noted at several places in the paper, the fact that water is "cheaper than dirt" is thought to explain why Canadian industries are relatively primitive in their water using practices.

- Industrial water use has grown consistently through the entire 1972–1991 period covered by the series of industrial water use surveys by Environment Canada and Statistics Canada. Growth in the thermal power sector, the largest water-using sector, was the chief contributing factor in this growth, dwarfing all of the other sectors. Manufacturing water use grew during the 1972–1981 period, but has fallen substantially since 1981. Because this decline in manufacturing water use was accompanied by falling recirculation rates, increasing water use efficiency is not the explanation for decreased manufacturing water use. Rather, the authors believe that structural changes in the Canadian manufacturing base are largely responsible for this trend in manufacturing water use, but this will remain hypothetical until the required research is conducted to show this structural change effect.

- Total water use was dominated by the thermal power generation industry, which accounts for over two-thirds of total gross water use by the industries surveyed. Almost exclusively, plants in this industy, which are located adjacent to large water bodies, employ once-through cooling systems and recirculate no water. One exception is a thermal power plant in Alberta. In terms of current economic conditions and relatively narrow private or quasi-private interest, once-through cooling is justified to maximize returns on investment. On the other hand, it is antithetical to sustainability principles, especially should increased water rents be implemented in the interests of encouraging more efficient water use.

- The explanation for the water use inefficiencies observed in this paper resides to a large degree in the lack of economic incentives to adopt better methods. In spite of a number of unjustified "myths" that have developed concerning the use of economic principles for improved water use, the authors believe that economic reform holds the key to increased efficiency. The principal mechanisms through which this will occur are the adoption of existing improved management practices, such as recirculation technology, and the future occurrence of technological changes to alter production processes and/or products themselves. Such changes are highly unlikely without basic economic reforms, such as realistic pricing, rent capture, and effluent discharge fees.

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1. INTRODUCTION

1.1 Background and Purpose of the Report

Industry forms an important part of the life blood of Canada's economy. The advanced and sophisticated nature of the country's industrial base indicates membership in the small group of the world's most developed nations. In 1994, Canada's income per capita averaged around $20 000. Based on the United Nation's Human Development Index (World Bank, 1992), in 1992, Canada was rated as the world's most favourable nation in which to live. The economic power that underlies this measure is attributable in large part to the county's industrial base. Thus, in considering water resources in the industrial context, we are examining a basic and very important part of Canada's economic fabric.

Until the issue of sustainable development was raised by the U. N. Commission on Environment and Development (UNCED, 1987), relatively little attention was paid to the use of enviromental resources by industry. Traditionally, it was acknowleged that industry used prodigious amounts of water, air, and land resources to carry out its functions. Many persons concerned with environmental studies acknowledged that industry was a major source of materials damaging to environmental quality, and it was commonly believed that this pollution problem could be dealt with by "end-of-pipe" treatment measures mandated by regulation and enforced though legal sanction. Seldom was an analytical connection made between processes that curtailed water use (commonly termed water conservation) and decreases in pollutant loadings.

This report will present an alternative way of viewing the industrial use of water resources. Although the primary focus of the report is to summarize the findings of a recent industrial water use survey, the framework within which the discussion takes place is that of water demand management (Tate, 1990). This framework suggests that water is a "demand" imposed by industrial firms on the environment, as opposed to a "requirement" that must be met. Water demand is neither fixed nor static, but rather can be altered very substantially by policy, research, economic forces, education, and the like. Further, throughout the paper, water use is viewed, in all of its dimensions, as a vital <u>input</u> to the industrial process. Even the act of discharging wastes can, and should be viewed, in the first instance, as an input to production, rather than merely as a means of discarding waste materials. This nontraditional perspective, dealt with in Section 6, offers some significant insights into the ways in which economy and environment can be "integrated," as called for by the sustainable development approach advocated by UNCED, and as adopted by the federal and provincial governments in Canada.

Inventories of resource usage chronicle many important transactions between humans and their environment. In the case of land use planning, inventories have formed the basis for the planning process itself. In Canada, studies as diverse as the Royal Commission on the Future of the Toronto Harbourfront (1990) and the Environment Canada study entitled *Stress on Land* (Simpson-Lewis et al., 1983) have used basic resource inventories as their fundamental source of information. Similarly, to be effective, water management studies must have an objective, neutral source of data on basic resource usage in order to carry out their respective mandates. Although usage information can be compiled at the time of any particular study, researchers, planners, and managers are in a much more favourable position if they have available a time series of relevant information.

Researchers in the past 25 years have built a rich literature in industrial water use (see, for example, Bower, 1966; de Rooy, 1970; Kindler and Russell, 1984; Tate, 1984, 1986; Renzetti, 1987). Several general observations have emerged. First, water use is multivariate in nature, with physical, technologic, economic, and policy factors all contributing to the level of water usage. Second, the studies have shown that water use is actually a "demand" in the economic sense in that as price rises, usage or demand falls in a predictable and statistically significant fashion. Third, the level of water use can be influenced heavily by action to control water pollution. Fourth, industries can adapt their water use to conditions of availablity, such that regional patterns are definitely discernable. Finally, with sufficient information, water managers can influence the industrial location decision. These factors have all influenced the design of the Canadian industrial water use surveys.

The foregoing background has been used to build a small continuing program of surveys and analysis on Canadian industrial water use. This paper describes the results of the 1991 version of this program. It updates similar surveys, carried out in 1972 (Tate, 1977); 1976 (Tate, 1983) ; 1981 (Tate and Scharf, 1985) and 1986 (Tate and Scharf, 1992). Data collected during the 1991 survey have already been used in a variety of federal, provincial, and private sector studies, and publication of this statistical summary represents the final stage of the survey process. Although presentation of the survey results forms the principal aim of the paper, the paper also provides the opportunity to discuss some fundamental issues of importance for future environmental management. In this way, the survey results can contribute to a discussion of the sustainable use of water resources.

1.2 Purpose and Scope of the Survey

The 1991 Industrial Water Use Survey comprised a mailed survey to just over 5100 industrial establishments conducted under the federal Statistics Act, and administered by Statistics Canada. Several dimensions of industrial water use were of interest, including:

- A basic inventory of the volumes of water being used by industry. Water use parameters for this inventory included water intake, recirculation, gross water use, consumption, and discharge[1].

- An examination of the basic end uses (e.g. cooling, processing) to which the industrial water is put.

- A compilation of a few basic economic parameters (e.g. employment, value of shipments), in order to relate water usage to measures of economic activity.

- Assembly of sufficient information to allow the computation of an approximate price for water to the plants surveyed.

- Collection of basic data on industrial waste treatment.

The survey is limited in a number of ways. It did not survey all Canadian industrial operations, which number between 35 000 and 40 000 establishments. Resource constraints dictated this limitation. Sampling procedures were not used. Instead, the survey was sent to a pre-selected universe, and results imputed for non-respondents on the basis of results received. No data on physical output were collected, as outputs from large operations can vary widely in type. Collection of this information was beyond the scope of the survey. Finally, no data were compiled on the quality of effluent streams, due both to the survey method and to the complexity of sampling industrial effluents.

1.3 Report Outline

This report describes and discusses the quantitative results of the survey. It draws descriptive observations about water use patterns in the various subcomponent industries, but does not attempt to provide an in-depth analysis of these patterns. In other words, the report presents basic survey results, which can then be used for many types of analyses by a wide variety of researchers.

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[1] Section 1.4.1 defines these water use terms in detail.

The remainder of section 1 details various aspects of the methodology used to carry out the project. Section 2 begins the substantive part of the report, with a detailed outline of water use in manufacturing, organized by sector and province. The focus is on the five main parameters of water use described in section 1.4.1. The discussion includes the sources of water for manufacturing; the treatment of this water prior to use; the basic end uses to which water is put; the gross, or total, amount of water used in manufacturing; and various aspects of waste disposal. In addition, it outlines the basic economic data collected, including the costs of water intake (e.g. pumping, licences, etc.), intake treatment, water recirculation, and waste treatment. The sum of these four cost parameters, averaged over a plant's total water intake, can be used as a proxy for the price of water (de Rooy, 1970).

Sections 3 and 4 repeat the coverage of section 2, for the mining and thermal power sectors respectively, but in abbreviated form. Because this survey is the fifth of a series, Section 5 looks very briefly at major trends since 1972. The purpose here is descriptive, not analytical, and, although some possible explanations for these trends are suggested, these are merely working hypotheses, not confirmed results of detailed statistical analyses.

Section 6 extends the water use discussion into the field of resource sustainability and policy, showing how this inventory exercise relates to and can underlie management decisions in the future. This section uses concepts from the field of water demand management and microeconomics to provide what we consider to be the best contextual framework within which to view industrial water use. Section 7 presents the report's conclusions.

1.4 Survey Concepts and Methods

1.4.1 Basic Survey Parameters

In documenting industrial water use, five basic parameters are of interest: water intake, recirculation, gross water use, water consumption, and wastewater discharge. Figure 1 shows the relationships between these parameters, which are further defined in this section. These parameters have been used in all of the Canadian industrial water use surveys, and are consistent with those used in other nations.

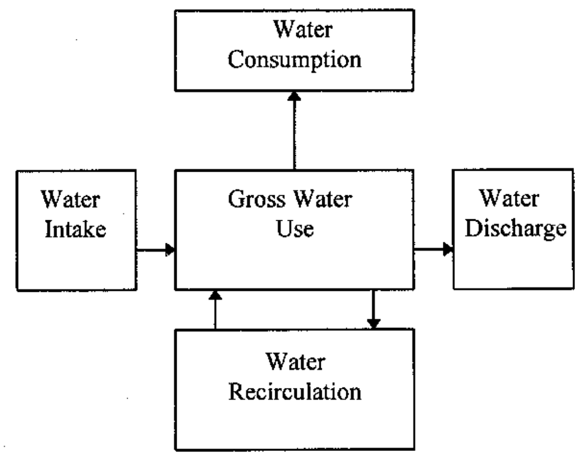
Total water intake refers to the total amount of water added to the water system of the plant to replace water discharged or consumed during production. It may be broken down into the amounts withdrawn from various sources (e.g. surface water, groundwater, etc.) and the amounts used for various purposes, or end uses. The latter refers to the initial use of water in these purposes — cooling, processing, condensing, and steam generation, and sanitary and other purposes. Cooling and condensing water refers to that water used for the production of steam or the dissipation of waste heat. Processing water refers to water that comes in contact with an intermediate or final product of the manufacturing operation. Sanitary water use serves basic human sanitary requirements at the respective industrial plants.

Recirculated water (or recirculation) refers to water used at least twice in an industrial plant, and in Canada applies mainly to manufacturing and mineral extraction activities. Recirculation does not refer to water used a number of times within a particular process subsystem of a plant but only to water that leaves a particular process subsystem and re-enters it or is used in another process. Recirculation and water intake combine to form the water input system of a plant.

Gross water use refers to the total amount of water used in the production of the product. It is the sum of total water intake and water recirculation.

Water consumption (or consumption) refers to water that is lost in the production process. In other words, consumed water is not returned to its original source. The two major portions of consumed water are escaped steam and the incorporation of water into a product, as for example in the production of soft drinks. Water consumption is a strictly "local" concept for the purposes of this paper, and refers to water not returned to the source of abstraction *in the vicinity of the plant in question*. In the broader context, because of the earth's water cycle, water is never really "consumed." For example, evaporated water falls back to the earth in the form of precipitation, and is not "lost" to the environment as a whole. In this paper, "consumption" is an accounting concept used to describe the water balances at single plants only.

Figure 1 A Generalized View of an Industrial Plant Water System



Wastewater discharge (or discharge) refers to water that is returned to the environment in the form of water usually close to the plant. Discharged water may be treated or untreated. Together, water discharge and water consumption form the effluent subsystem of the plant. The sum of these two parameters is approximately equal to the total water intake of the plant.

1.4.2 Questionnaire Design

On the basis of the preceding section, two identities can be used to quantify industrial water use. On the intake side,

$$I + R = G \qquad (1)$$

Where: I = the quantity of water intake
R = the quantity of recirculated water
G = the quantity of gross water use

On the discharge side,

$$I - C = D \qquad (2)$$

Where: C = the quantity of water consumed
D = the quantity of water discharged

This survey collected data on intake, recirculation, and discharge. This allows the other two parameters to be calculated.

The questionnaires used for each of the four industrial sectors — mineral extraction , manufacturing, thermal power, and hydro power — were quite similar in construction (see Appendix). Some variations were made in the two power generation sectors to allow the collection of data peculiar to those sectors. All data were collected on an annual basis. The general description which follows is based on the manufacturing and mineral extraction sectors.

Section 1 of each questionnaire requested basic information on employment, plant operations, and product descriptions. Section 2 collected information on the monthly pattern of water intake and discharge, and their annual totals. The sources of water intake were covered in section 3, and section 4 requested details on the various treatments given to the intake water. Both volume and cost information were requested in sections 3 and 4. Section 5 was concerned with intake water by purpose and section 6, with data on the volume of recirculation, as well as an estimate of the cost of recycling. Section 7 was devoted to the various types of treatment to discharge water prior to discharge. Finally, section 8 concerned data on the discharge of the effluent by discharge point and the cost of waste treatment.

1.4.3 Respondent Selection

The survey included plants in selected categories of the manufacturing, mineral extraction, and electric power sectors of the Canadian economy. The mailing list used has evolved over time, particularly with regard to the manufacturing sector, and, to add perspective, the development of this list is summarized here. During the first survey in 1972, questionnaires had been sent to a relatively large number of respondents who used very little water. To omit these smaller users, the 1976 survey was sent only to members of those industries classified as belonging to the 10 largest water-using two-digit SIC groups[2] within the manufacturing sector. For these 10 groups, only those establishments that had received the long-form questionnaires[3] during the annual Census of Manufacturing were selected. In 1981, the metal fabrication sector was added, because of its potentially high water use. Further revisions occurred for the 1986 survey, due largely to Statistics Canada's revision to the SIC system. For example, the food and beverage industry was split into two components, foods and beverages. Similar revisions lead to the survey of 14 manufacturing groups, again using a "universal" selection of long form respondents. The mailing list for 1991 was compiled on the same basis as that for 1986.

The selection of establishments to be surveyed in the mineral extraction industry was based on the selection used in 1986, except for the deletion of the peat extraction industry and the crude petroleum and natural gas plants (located in Alberta and surveyed in 1986). Basically, an attempt was made to include all significant operating mining establishments. All thermal power plants in operation were included in the 1991 survey. As in 1986, a sub-section of the 1991survey was devoted to the hydroelectric power generating plants.

1.4.4 Response Rates

The number of plants and the response rates obtained varied among the four sectors surveyed (Table 1). The manufacturing sector, with 4477 questionnaires, comprised the largest sector surveyed. Of these questionnaires, 3060 were returned, for an overall response rate of 68%. The remaining 1417 plants surveyed either (1) sent back returns that contained basic information such as employment, operating days, and product descriptions but little or no water use information, or (2) refused to respond. For both types of returns, water use information was estimated from the respondent data to obtain survey totals[4]. For the mineral extraction sector, the response rate was much higher at 89%. In the two electric power sectors, completed questionnaires were received for all plants. The aggregate response rate for the entire survey was 72% (Table 1).

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[2] Standard Industrial Classification (SIC), as defined by Statistics Canada. The two-digit level is the "coarsest" level of the SIC, and includes major industrial groups like the food industry, the paper and allied products industry, and others. The 4-digit level is the "finest" breakdown, which isolates sub-categories of industry (e.g. sugar refineries, pulp mills, and so on). See Statistics Canada, 1980.

[3] Long-form questionnaires are used to collect the most detailed information about characteristics such as employment, output, resource use, value of shipments, etc. They contrast with "short-form" questionnaires, which collect only summary information.

[4] Estimation procedures are described in sub-section 1.4.5.

1.4.5 Estimation Procedures for Non-Respondent Data

As in the previous surveys, estimation procedures provided water use data for non-respondents in the maufacturing and mineral extraction sectors. These estimations used coefficients of water use per employee developed from the respondent data, for each industry at the four-digit SIC industry level on a provincial basis, multiplying each water use coefficient by the employment for the non-respondent plants. The estimates were then added to the respondent data to provide aggregated results for each parameter. Where the provincial set of responses for a particular industry were too small to form reliable coefficients of water use per employee (judged to be fewer than three observations), coefficients from the national level were used to provide the estimates. No estimations were required for the electric power sectors, because the survey in these sectors was complete.

The assumption underlying the non-respondent estimates was that plants in the same industry in the same province use essentially the same processes. Theoretically, this assumption is not wholly acceptable (Whittington, 1978; Tate, 1984), but was used here as an approximate means of obtaining complete estimates of water use by sector and spatial unit. In general, estimations were required only for the smaller plants. However, a much larger proportion of Alberta manufacturing plants and mines had to be estimated, due to several technical problems, such as personnel and budgetary restraints encountered by the provincial staff who had originally agreed to conduct the Alberta portion of the survey.

1.4.6 Survey Responsibilities

The 1991 survey was a collaborative effort by Environment Canada and Statistics Canada. Statistics Canada personnel guided the selection of potential respondents from the Censuses of Manufacturing, Mining and Energy, and undertook to receive the completed questionnaires using their system for "tracking" questionnaire surveys as they progress. Environment Canada staff undertook all other tasks, such as selection of industry (SIC) groups to be surveyed, questionnaire design, editing, data processing, and publication of the survey results.

Table 1 Summary of Responses for the 1991 Industrial Water Use Survey, by Response Parameter and Sector

Sector	Total number of questionnaires	Number of respondents	Number of non-respondents	Response rate (%)
Manufacturing	4477	3060	1417	68
Mineral Extraction	203	180	23	89
Thermal Power	66	66	0	100
Hydro Power	358	358	0	100
Total	5104	3664	1440	72

2. MANUFACTURING WATER USE

Water forms an essential input to the manufacturing process, regardless of industrial sector. Without water to serve cooling and processing purposes, to act as a catalyst and to convey waste materials, industry would be unable to function. The availability of water supplies in sufficient quantity and quality is one of several important considerations in the location of most industrial plants, and it comes as no surprise that the overwhelming majority of Canadian manufacturing plants are located adjacent to large sources of water. Given the huge volume and, for the most part, adequate quality of these sources, as well as the exceptionally low prices of water, it is also no surprise that Canadian manufacturing plants use water *extensively*, with few considerations for conservation, recycling, and reuse. These observations are replete with implications for public resource management policy, as will be shown in section 6 of this paper.

The aim of this section is to document the basic facts about water use in manufacturing, identified by the industrial water use survey. As shown in Table 1, the survey covered just under 4500 individual plants in the manufacturing sector, including all of the largest plants in the country. This section presents the survey results, first on an industry-by-industry and then on a provincial basis.

2.1 Industry-by-Industry Water Use Patterns

2.1.1 General Characteristics

Over 733 000 persons worked in the 4477 manufacturing plants surveyed (Table 2). These plants represented the majority of large water-using manufacturing plants in Canada, and about 43% of the nation's total manufacturing employment. The remaining employment occurred in industries which are relatively small water users that were not surveyed. The surveyed plants withdrew a total of 7282 million cubic metres (MCM) from ambient water bodies in 1991 (Table 3), and had a gross water use totalling 14 088 MCM. Accordingly, water recirculated within the surveyed plants totalled 6806 MCM. In other words, recirculation effectively "stretched" the sector's water intake by a factor of two. The use rate[5] for the manufacturing sector as a whole was 193%, down slightly from 198% in 1986. Water consumption totalled 520 MCM, or approximately 7.1% of total withdrawal, and 6762 MCM were discharged to ambient water bodies adjacent to the plants, or to municipal sewer systems.

Paper and allied products, primary metals, chemicals and chemical products, food, and petroleum and coal products industries were the five largest water-using manufacturing groups covered in the survey. Together they accounted for about 90% (93%)[6] of total intake and 91% (93%) of total discharge and 78% (89%) of total consumption.

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[5] The use rate is an index of water recirculation within a plant or industry. It is calculated as: (Gross water use/Water intake) *100%

[6] 1986 data are in brackets

Table 2 Employment (number of persons) in Surveyed Manufacturing Firms, by Industry Group and Province, 1991

Industry group	Newfoundland	P.E.I.	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskat-chewan	Alberta	British Columbia	Territories	Canada Total
Foods	15 115	2 563	8 805	11 162	23 446	50 688	4 991	3 190	9 249	11 239	43	140 491
Beverages	508	--	625	763	7 014	6 963	791	462	1 438	1 609	--	20 173
Rubber	--	--	3 800	--	4 413	10 469	155	--	390	175	--	19 402
Plastics	30	--	430	152	8 205	19 240	864	173	1 719	2 436	--	33 249
Textiles	--	--	456	90	7 628	7 183	--	--	685	177	--	16 219
Textile products	--	--	250	--	4 117	2 593	--	--	200	--	--	7 160
Wood	230	55	436	2 095	8 889	4 425	97	336	2 108	23 744	4	42 419
Paper & allied	2 271	--	2 832	5 041	31 070	24 551	1 392	816	2 800	15 643	--	86 416
Primary metals	--	--	710	550	23 089	51 922	4 480	1 007	2 658	5 309	--	89 725
Metal fabricating	80	275	343	943	9 023	17 862	1 039	523	2 924	3 107	14	36 133
Transport equipment	606	135	2 507	3 670	29 999	96 112	4 452	40	1 313	2 188	--	141 022
Nonmetal-lic mineral products	276	15	662	686	8 645	17 540	818	389	3 219	2 861	--	35 111
Petroleum	225	--	494	450	1 155	3 644	--	440	1 856	1 108	20	9 392
Chemicals	103	68	480	192	16 242	31 661	561	372	4 323	2 394	--	56 396
Canada total	19 444	3 111	22 830	25 794	182 935	344 853	19 460	7 748	34 882	71 990	81	733 308

-- No employment reported.

1. The industry group names used in this table have been abbreviated because of space considerations. The "standard" names used appear in Table 3, and those subsequent to it.

Table 3 Selected Characteristics of Manufacturing Water Use (MCM/year), by Water Use Parameter and Industry Group, 1991

Industry group	Number of plants	Employment (000s)	Intake	Recirculation	Gross water use	Discharge	Consumption
Food products	1 029	140.5	347.2	192.7	539.9	320.1	27.1
Beverage products	131	20.2	73.4	16.4	89.8	61.6	11.7
Rubber products	69	19.4	20.7	55.7	76.4	18.7	2.0
Plastic products	398	33.2	41.6	267.3	308.9	38.8	2.8
Primary textiles	79	16.2	258.6	170.1	428.6	226.8	31.8
Textile products	46	7.2	13.6	19.6	33.2	12.2	1.4
Wood products	342	42.4	59.2	5.1	64.3	46.8	12.4
Paper and allied	264	86.4	2 911.9	2 181.2	5 093.1	2 732.9	179.0
Primary metals	191	89.7	1 560.6	1 688.5	3 249.1	1 490.7	69.9
Metal fabricating	434	36.1	19.4	29.5	48.9	18.7	0.7
Transportation equipment	378	141.0	81.5	36.2	117.7	74.7	6.8
Non-metallic mineral products	530	35.1	136.6	155.7	292.2	90.1	46.5
Petroleum and coal products	30	9.4	445.2	1 011.6	1 456.8	410.8	34.4
Chemicals and chemical products	556	56.4	1 312.7	976.9	2 289.6	1 218.8	93.8
Canada total	4 477	733.3	7 282.1	6 806.5	14 088.6	6 761.8	520.3

Use rates and consumption rates varied substantially among industry groups (Table 4). The use rate[7] represents an index of recirculation, whose minimum value is 100%, denoting no recirculation. Higher values pertain to firms that recirculate large amounts of water. The average use rate for all manufacturing, as shown earlier, was 193% in 1991, ranging between 109% for the wood industry and 741% for the plastic products industry. Two of the large water–using industrial sectors, refined petroleum and coal products industry at 327% and primary metals industry at 208% were above the national average of 193%. The other three major users, paper and allied products, food products, and chemicals and chemical products industry had use rates significantly below the national average at 175%, 156%, and 174% respectively. These three industries had a significant impact in lowering the national average use rate.

Table 4 Use Rates and Consumption Rates in Manufacturing, by Industry Group, 1991

Industry group	Use rate	Consumption rate
Food products	156	8
Beverage products	122	16
Rubber products	368	10
Plastic products	741	7
Primary textiles	166	12
Textile products	244	10
Wood products	109	20
Paper and allied	175	6
Primary metals	208	4
Metal fabricating	252	3
Transportation equipment	144	8
Non-metallic mineral products	214	34
Petroleum and coal products	327	8
Chemicals and chemical products	174	7
Canada total	193	7

Historically, the trends in use rates are instructive in terms of the ways in which Canadian industries use water. For most of the manufacturing sectors, use rates rose between 1972 and 1976 (Tate, 1977, 1983), indicating a short-term trend toward the increasing use of recirculation technology. In the 1981 survey, the rubber and plastics, non-metallic mineral products, petroleum and coal products, and wood industries showed large increases in use rates, and the major water-using industries remained static or actually fell with respect to their recirculation of water.This trend continued in 1986 and 1991. This pattern reflects decreasing water use efficiency over the 1981 to 1991 period, which is antithetical to the overall public policy aim to improve the sustainable use of environmental resources.

Consumption rates provide an index of the amount of water lost during production at the individual plant level, most commonly through evaporation or incorporation of water into products[8]. As noted earlier, the national average rate of consumption for 1991 was 7.1% of intake. This rate varied from a high of 34.0% for the non-metallic mineral products industry to 3.4% for the fabricated metal products industry.

[7] See supra, footnote 5.
[8] The reader is referred to the discussion on page 4 for the correct interpretation of consumptive use and "water loss".

2.1.2 Water Sources

The manufacturers surveyed obtained over 6100 MCM (83%) of their water supply from self supplied freshwater surface sources (Table 5), similar to 1986 results. An additional 10% derived from public utilities, an increase of about 2% from 1986. Slightly less than 2% of the total came from fresh groundwater sources with the remainder, slightly under 3%, from brackish sources.

A notable, but expected, difference emerged with regard to water source between industries dominated by large establishments and those dominated by relatively small establishments. The latter tend to draw a much larger proportion of their water supplies from public utilities, largely for two reasons: the fact that public supplies are cheaper than the cost of self supplied water systems, and the need for potable water for many of the smaller firms. For example, the beverage industry, composed generally of many relatively small water users, withdrew 58% of its total intake from public sources. This industry was characterized not only by small plants but by a requirement for high quality intake water. Thus, it relied upon public supplies for much of its water. Another industry — fabricated metal products — was dominated by small and mid-sized establishments revealed a similar dependency of 58% on public water supply. In contrast, the four largest water withdrawing industries — paper and allied products, primary metals, petroleum and coal products, and chemicals and chemical products — withdrew relatively small quantities from public sources. These industries were characterized by fewer and generally larger plants than those of the beverage and fabricated metal products industries. (In 1991, the transportation equipment industry revealed the largest dependency on public sources, 94%, up dramatically from 51% in 1986. The reason for this increase is unknown, but it may be due to a survey anomaly, arising from a somewhat different composition of the set of firms surveyed).

2.1.3 Water Intake Treatment

Manufacturers treat large volumes of intake water prior to use (Table 6). Since many plants employ two or more treatment processes prior to use, the total amount of water reported in this table substantially exceeded the total water intake reported in Table 3. On the other hand, many plants reported little treatment prior to the initial use of water. The volume of water treated by the manufacturing firms surveyed totalled 9180 MCM in 1991. Screening, followed by chlorination and disinfection, and filtration comprised the most frequently used pre-treatment types, together accounting for about 78% of the total amount treated. The "other" category included processes like dechlorination and distillation, which were not easily classified to other groups. Treatment of intake water is tailored to the quality needs at the respective plants.

2.1.4 Initial Purpose of Water Use

Data on the inital use of water in manufacturing (Table 7) are surrogates for the end uses of water in the sector. Cooling, condensing, and steam generation was the largest initial use of new water taken into plants, accounting for 49% of total intake. Processing water accounted for 47% of intake, with sanitary and other uses accounting for the remaining 4%. Cooling, condensing and steam generation accounted for the largest proportion of initial use in 11 of the 14 industries surveyed. The largest water-using industry, paper and allied, however, used most of its new water intake for processing, thereby having a significant impact on the total amount of processing water reported in Table 7. The other three major water users reported more of their intake used in cooling and condensing than in processing .

Table 5 Water Intake in Manufacturing (MCM/year), by Source and Industry Group, 1991

Industry group	Fresh water				Brackish water			Total intake
	Public/	Self supplied			Self supplied			
	municipal	Surface	Ground	Other	Ground	Tidewater	Other	
Food products	156.0	72.9	43.9	6.7	1.1	65.1	1.3	347.2
Beverage products	42.1	18.8	12.2	0.3	0.0	0.0	0.0	73.4
Rubber products	6.8	4.7	8.7	0.5	0.0	0.0	0.0	20.7
Plastic products	38.2	2.4	0.9	0.1	0.0	0.0	0.0	41.6
Primary textiles	8.3	249.2	0.5	0.0	0.7	0.0	0.0	258.6
Textile products	13.6	0.0	0.0	0.0	0.0	0.0	0.0	13.6
Wood products	9.7	39.8	2.1	0.0	0.1	7.3	0.0	59.2
Paper and allied	143.4	2698.2	31.1	36.4	0.0	2.9	0.0	2911.9
Primary metals	82.2	1446.1	1.6	26.2	0.0	4.2	0.3	1560.6
Metal fabricating	11.3	7.2	0.9	0.0	0.0	0.0	0.0	19.4
Transportation equipment	77.4	3.6	0.4	0.1	0.0	0.0	0.3	81.5
Non-metallic mineral products	43.3	43.4	27.4	17.1	5.1	0.3	0.0	136.6
Petroleum and coal products	20.3	323.8	0.1	1.4	1.5	93.1	5.1	445.2
Chemicals and chemical products	59.8	1222.7	21.2	27.1	0.0	0.6	0.4	1312.7
Canada total	712.5	6132.7	131.9	115.9	8.4	173.5	7.1	7282.1

Table 6 Water Intake Treatment (MCM/year), by Type of Treatment and Industry Group, 1991

Industry group	Filtration	Chlorination and disinfection	Corrosion and slime control	Screening	Hardness and alkalinity control	Other	Total intake treated	Total intake
Food products	27.7	97.4	5.8	30.7	14.3	1.9	177.8	347.2
Beverage products	41.9	17.3	1.4	10.0	15.1	9.2	95.0	73.4
Rubber products	1.2	0.7	1.3	0.0	1.2	0.6	5.1	20.7
Plastic products	1.8	19.3	24.6	3.1	188.3	1.0	238.2	41.6
Primary textiles	6.9	150.0	0.3	207.9	5.5	0.1	370.7	258.6
Textile products	0.0	0.0	0.0	0.0	1.8	0.6	2.5	13.6
Paper and allied	1096.2	778.0	152.0	1397.1	341.2	73.0	3837.6	2911.9
Primary metals	325.6	266.4	458.0	758.1	53.6	36.6	1898.3	1560.6
Metal fabricating	3.2	0.1	0.2	1.9	0.4	0.1	5.8	19.4
Transportation equipment	0.9	0.1	0.7	3.7	5.2	0.7	11.3	81.5
Non-metallic mineral products	3.1	3.2	0.9	18.0	4.2	1.3	30.8	136.6
Petroleum and coal products	28.6	296.0	189.4	263.7	56.7	10.7	845.1	445.2
Chemicals and chemical products	87.6	345.1	310.0	799.9	33.7	38.3	1614.5	1312.7
Canada total	1629.7	1983.5	1148.2	3513.7	725.3	176.4	9179.7	7282.1

2.1.5 Monthly Water Use Patterns

The monthly distribution of annual water intake was consistent with that of water discharge. Thus, only the intake pattern has been tabulated (Table 8). The data were converted to percentage terms (i.e. of annual intake) for the purposes of this table, to facilitate inter-industry comparisons by removing the effect of industry group size. If an even monthly distribution of the data occurred, each month would account for 8.3% of annual intake. Table 8 demonstrates that some seasonality was experienced, with total intake tending to be higher in the summer and fall months. This pattern was expected in view of higher cooling requirements in the summer and the effects of fall processing in the food industry.

Inter-industry patterns varied. The foods, beverages, and non-metallic mineral products industries exhibited the most significant trends toward summer peaking, with differences of over 2% between the lowest and highest pumpage months. The other industries showed a more uniform pattern throughout the year.

2.1.6 Water Discharge Points

Wastewater from manufacting plants totalled 6762 MCM in 1991 (Table 9), and discharged to the following points: public sewers (10%), private surface water disposal (74%), tidewater (14%), and slightly more than 1% to ground water and other uses. The transportation equipment industry discharged about 95% of its effluent to the public sewer, just slightly larger than its withdrawal of 90% from the public water supply. Similarily, the plastic products industry discharged 92% of its effluent to the public sewer, and withdrew 90% from the public water supply. However, the beverage industry discharged 71% of its effluent to the public sewer, a proportion larger than its withdrawal (57%) from the public water supply system. In contrast, the four largest water-using industries discharged relatively small amounts of water to public sewers (i.e., chemicals and chemical products (2%), petroleum and coal products (3%), primary metals (6%), and paper and allied products (8%). Wastes in these industries were of sufficient quantities and complexity to demand individual treatment.

Table 7 Manufacturing Water Intake (MCM/year) by Purpose of Initial Use and Industry Group, 1991

Industry Group	Processing	Cooling, condensing and steam	Sanitary services	Other	Total intake
Food products	147.5	139.0	49.3	11.4	347.2
Beverage products	33.9	29.2	9.0	1.3	73.4
Rubber products	2.3	16.8	1.4	0.2	20.7
Plastic products	6.0	13.5	21.8	0.3	41.6
Primary textiles	47.7	201.4	9.5	0.0	258.6
Textile products	10.6	2.7	0.3	0.0	13.6
Wood products	24.8	29.5	3.8	1.1	59.2
Paper and allied	2214.3	626.1	47.5	24.0	2911.9
Primary metals	631.5	893.3	23.7	12.0	1560.6
Metal fabricating	9.8	7.7	1.5	0.3	19.4
Transportation equipment	23.0	44.8	13.2	0.6	81.5
Non-metallic mineral products	55.6	50.7	4.9	25.4	136.6
Petroleum and coal products	44.0	391.5	3.8	5.9	445.2
Chemicals and chemical products	183.9	1106.7	6.8	15.4	1312.7
Canada total	3434.7	3552.8	196.6	98.0	7282.1

Table 8 Monthly Distribution of Water Intake (%) in Manufacturing, by Month and Industry Group, 1991

Industry group	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Food products	7.2	6.9	7.0	7.3	8.8	9.0	9.1	10.1	9.6	9.0	8.2	7.8
Beverage products	7.7	7.4	8.3	8.4	9.8	11.7	8.1	7.9	7.5	8.4	7.8	7.0
Rubber products	8.1	8.0	7.8	8.4	8.8	9.2	8.3	9.2	8.7	8.1	7.7	7.6
Plastic products	7.6	8.8	7.4	7.6	7.7	9.3	8.9	9.3	8.1	8.4	9.4	7.3
Primary textiles	7.9	7.0	6.9	7.0	8.1	9.3	9.8	8.8	10.5	9.7	7.7	7.6
Textile products	6.9	7.4	7.2	8.7	9.0	9.2	7.3	9.4	9.3	9.5	8.7	7.1
Wood products	8.3	8.2	8.4	8.3	8.0	8.0	9.1	7.8	7.8	8.9	8.3	8.8
Paper and allied	8.5	8.0	8.4	8.2	8.7	8.7	8.7	9.1	7.8	8.4	8.2	7.4
Primary metals	7.7	7.5	7.9	7.8	8.3	8.6	8.7	8.8	8.8	8.8	8.6	8.5
Metal fabricating	7.8	7.6	8.3	8.1	8.1	8.3	9.0	8.7	8.9	8.8	8.6	8.5
Transportation equipment	7.5	7.5	7.5	7.4	8.0	8.1	8.2	8.2	7.9	7.8	12.7	9.0
Non-metallic mineral products	7.4	7.0	7.4	7.6	9.4	9.5	9.2	9.3	8.9	8.7	8.3	7.2
Petroleum and coal products	8.5	7.8	8.3	7.3	7.9	8.5	9.1	8.8	8.6	8.7	8.3	8.1
Chemicals and chemical products	8.1	7.8	8.6	8.2	7.9	8.2	9.0	9.5	8.7	7.1	8.4	8.3
Canada total	8.1	7.7	8.2	7.9	8.4	8.7	8.8	9.1	8.5	8.3	8.4	7.9

The use of various discharge points was related directly to the magnitude of the waste water discharged, the location of the plant, and also the characteristics of the pollutants in the waste water. The food and beverage industries, being composed of relatively small water users, usually do not have sufficient water discharges to justify building and operating individual waste treatment facilities. There were, of course, exceptions to this general point, and many plants in the industry pre-treated their waste before discharging it to public sewers. Also, wastes from food and beverage plants, being composed mainly of biochemical oxygen demand (BOD) and suspended solids (SS), tend to be compatible with municipal waste treatment processes. On the other hand, the larger plants of other industrial groups generate large volumes of waste. Often, these volumes are too large to be treated by municipal treatment plants, or some of the pollutants generated by large industries are incompatible with municipal waste treatment processes, resulting in the need for internal treatment and subsequent direct discharge to receiving waters.

2.1.7. Wastewater Treatment

Many of the firms surveyed provided some type of treatment to their waste water prior to discharge. The quantities of waste involved (Table 10) are classified by the generic type of treatment. Primary treatment refers to the use of mechanical methods of treating wastes, such as screening, coagulation, and filtration. Secondary treatment refers to the use of processes depending upon some form of biological treatment to reduce the biochemical oxygen demand of the effluent. Activated sludge and trickling filter methods are common forms of secondary treatment. Tertiary treatment refers to the use of methods to "polish" the effluent subsequent to secondary treatment. One common form of tertiary treatment is phosphorus removal.

Table 9 Water Discharge in Manufacturing, by Point of Discharge and Industry Group, 1991

Industry group	Public sewer	Freshwater body	Tidewater body	Ground-water body	Transferred to other uses	Total discharge
Food products	136.6	89.0	83.5	5.1	6.0	320.1
Beverage products	43.8	11.1	0.0	6.6	0.1	61.6
Rubber products	4.1	14.4	0.0	0.1	0.0	18.7
Plastic products	35.7	2.7	0.0	0.4	0.0	38.8
Primary textiles	9.1	209.2	0.0	8.4	0.0	226.8
Textile products	12.2	0.0	0.0	0.0	0.0	12.2
Wood products	3.4	40.0	0.8	2.5	0.1	46.9
Paper and allied	215.0	1762.0	737.7	18.1	0.1	2732.9
Primary metals	96.5	1342.4	29.7	21.7	0.4	1490.7
Metal fabricating	13.0	4.8	0.0	0.8	0.0	18.7
Transportation equipment	64.5	9.0	0.9	0.3	0.0	74.7
Non-metallic mineral products	28.9	53.0	0.0	7.2	1.1	90.1
Petroleum and coal	11.7	300.6	96.7	1.5	0.2	410.8
Chemicals and chemical products	25.3	1185.9	4.4	2.5	0.7	1218.8
Canada total	699.8	5024.1	953.9	75.3	8.7	6761.8

As in the case of water intake treatment, the same physical volume of water may be processed by more than one level of treatment. For example, it is common for a plant to treat its wastes by primary methods initially and then by secondary methods prior to final discharge. Thus, the amounts recorded in the "total treatment" column of Table 10 will contain a substantial degree of double counting. The brief discussion below examines the data within each column in an attempt to avoid the double counting as much as possible.

A total of 4717 MCM of effluent was treated by Canadian manufacturers in 1991. This volume comprised about 70% of total discharge. However, there was substantial double counting in compiling these data, meaning that the proportion of waste treated was probably much smaller than this. At a minimum, wastes treated at the two "advanced" levels underwent primary treatment initially. Thus, we can state with some confidence that just under 3000 MCM of discharge (i.e. about 44% of manufacturing discharge) was treated. Because the figures for secondary and tertiary treatment were significantly under the primary treatment volume, it is likely that the former volumes are "cascaded" through the "advanced" levels of treatment. Therefore, the best estimate is that over 50% of discharge from manufacturing plants is given no treatment. The amounts of water treated under each category of treatment were distributed among the industrial groups in roughly the same way as other characteristics of water use. The largest amount treated in all categories was accounted for by the paper and allied products industry, with 59% (1754 MCM) of the total amount treated by primary methods (2988 MCM), 79% of the a volume treated by secondary treatment, and 52% of the volume treated by tertiary treatment. This dominance reflects efforts made by the paper and allied products industry during the 1970s and the 1980s to install pollution control devices. The proportion of discharge treated with primary methods reflects this fact. The primary metals, petroleum and coal products, and chemicals and chemical products groups accounted for the next most significant amounts in terms of the quantities of wastes treated.

Table 10 Treatment of Manufacturing Water Discharge (MCM/year) by Treatment Type and Industry Group, 1991

Industry group	Primary treatment	Secondary treatment	Tertiary treatment	Total treated discharge	Total discharge
Food products	61.2	26.2	11.9	99.4	320.1
Beverage products	10.3	7.7	1.2	19.4	61.6
Rubber products	0.5	0.2	0.6	1.3	18.7
Plastic products	0.8	0.0	0.1	0.9	38.8
Primary textiles	153.2	12.2	0.0	165.4	226.8
Textile products	5.6	0.0	0.0	5.6	12.2
Wood products	51.1	48.0	0.0	99.1	46.8
Paper and allied	1754.6	1000.9	236.5	2992.0	2732.9
Primary metals	435.1	55.4	183.0	673.6	1490.7
Metal fabricating	6.2	0.8	0.5	7.5	18.7
Transportation equipment	4.3	2.9	1.8	9.0	74.7
Non-metallic mineral products	27.8	4.3	0.0	32.1	90.1
Petroleum and coal	370.7	93.6	9.8	474.2	410.8
Chemicals and chemical products	106.7	21.2	8.6	136.5	1218.8
Canada total	2988.3	1273.8	454.1	4716.1	6761.8

2.1.8 Water Recirculation

The data on water recirculation (Table 11) highlight the importance of recycling or reuse to the four major water-using industries. These industries accounted for over 88% of total recirculation by all manufacturers (6806 MCM or over 93% of total intake). The paper and allied group alone recycled about 32% of the total, much of it for processing purposes. Most recycled water was used for cooling and condensing purposes by the petroleum and coal products, chemicals and chemical products, primary metals, and food and beverage industries. In total, about 59% of recirculation was used for cooling, condensing, and steam generation.

2.1.9 Cost of Water

As in previous surveys, the 1991 survey collected data on the costs of water acquisition, intake treatment, waste water treatment, and water recirculation (Tables 12 and 13). The costs of water acquisition consisted mainly of the amounts paid by firms to water suppliers, normally local public utilities, for water services or in many cases, the cost of the plant intake licence (paid to provincial water agencies). These data constitute only part of the total cost of water to the industries surveyed. Not included in Table 12, for example, were data on the capital costs or depreciation of self-supplied water acquisition facilities, although most of these firms did include their operation and maintenance costs. The cost of waste treatment referred usually to annual operation and maintenance costs of at-plant treatment, but may also have included sewer surcharges levied by municipalities. No attempt was made to estimate costs for non-respondents for any of the cost categories.

The cost of water acquisition totalled just over $812 million ($228M in 1986). The primary metals industry accounted for the largest portion of this cost (50%), with paper and allied products industry the second contributor (at 26%), followed by chemicals and chemical products(9%), and the foods industry (about 6%). The amount paid for water licences was under 1% of this total, making it a negligible factor in industrial water costs. Data in Table 12 also reveal that about 85% of the costs reported were for in-house operation and maintenance costs, (up substantially more from 59% in 1986), with payments to the public utilities category now at about 15% (down from 40% in 1986). Of the amount paid to public utilities the leading contributors are the food, beverage, paper and allied, and primary metals industries. In the case of the food and beverage industries, this finding

Table 11 Water Recirculation in Manufacturing (MCM/year), by Purpose and Industry Group, 1991

Industry group	Processing	Cooling, condensing and steam	Other	Total recirculation
Food products	45.9	138.4	8.4	192.8
Beverage Products	5.9	6.2	3.4	16.4
Rubber Products	7.2	39.0	9.5	55.7
Plastic products	46.2	183.7	37.2	267.3
Primary textiles	128.5	41.6	0.0	170.1
Textile products	1.9	15.9	1.7	19.6
Wood products	1.7	3.0	0.3	5.1
Paper and allied	1549.5	583.3	48.4	2181.2
Primary metals	808.8	876.5	3.2	1688.5
Metal fabricating	2.9	26.4	0.2	29.5
Transportation equipment	6.5	29.7	0.0	36.2
Non-metallic mineral products	20.3	131.2	4.2	155.7
Petroleum and coal products	4.7	978.2	28.7	1011.6
Chemicals and chemical products	17.3	959.0	0.6	976.9
Canada total	2647.6	4012.2	146.7	6806.4

Table 12	Water Acquisition Costs ($million) in Manufacturing, by Cost Component and Industry Group, 1991			
Industry group	Paid to public utilities	At-plant O&M	Provincial licence fees	Total
Food products	28.2	17.9	0.6	46.8
Beverage products	10.5	0.7	0.0	11.3
Rubber products	1.7	0.6	0.0	2.3
Plastic products	2.4	5.3	0.0	7.7
Primary textiles	1.8	2.2	0.0	4.1
Textile products	1.6	0.0	0.0	1.7
Wood products	0.9	3.4	0.0	4.3
Paper and allied	10.4	197.7	2.7	210.8
Primary metals	26.5	383.4	0.1	410.1
Metal fabricating	2.7	0.5	0.0	3.2
Transportation equipment	9.0	0.6	0.3	9.9
Non-metallic mineral products	5.0	1.9	0.0	6.9
Petroleum and coal products	3.5	17.8	0.1	21.4
Chemicals and chemical products	14.1	57.6	0.1	71.9
Canada total	118.5	689.8	4.1	812.4

Table 13	Total Water Costs ($million) in Manufacturing, by Cost Component and Industry Group, 1991				
Industry Group	Acquisition	Intake treatment	Recirculation	Discharge treatment	Total
Food products	46.8	5.6	2.9	14.8	70.0
Beverage products	11.3	2.7	0.4	1.1	15.5
Rubber products	2.3	0.8	0.7	0.0	3.8
Plastic products	7.7	0.6	1.6	0.1	10.0
Primary textiles	4.1	1.7	1.5	1.9	9.2
Textile products	1.7	0.2	0.3	0.3	2.5
Wood products	4.3	1.0	0.2	0.8	6.3
Paper and allied	210.8	36.3	20.7	100.3	368.1
Primary metals	410.1	22.0	41.0	49.2	522.3
Metal fabricating	3.2	0.7	0.6	5.2	9.7
Transportation equipment	9.9	1.1	1.8	6.5	19.3
Non-metallic mineral products	6.9	1.2	0.8	0.8	9.7
Petroleum and coal products	21.4	28.6	13.1	24.6	87.7
Chemicals and chemical products	71.9	18.9	11.2	16.0	118.0
Canada total	812.4	121.5	96.7	221.7	1252.2

denotes the reliance of the small to middle-size plants of these industries on potable water largely supplied by municipalities. A large increase in the costs was reported in the in-house operation and maintenance costs category over the 1986 figure. This may reveal an increased effort within many plants to determine their costs of water acquistion.

The data on intake treatment costs also reflected the dominance of the four major water-using industries (Table 13). These four water users plus the food and beverage industries spent approximately 94% of the total cost reported for intake treatment.

The cost of discharge or waste treatment was reported at just over $221 million. Of this total, the paper and allied group spent just over $100 million, or 45%. The combined costs of the other three large water users, primary metals, chemicals and chemical products, and petroleum and coal products followed the paper and allied group at about $90 million. The other significant costs for waste treatment were incurred by the food, transportation equipment, and fabricated metal products industries.

The costs of water recirculation reflected the relative importance of recirculation to the four major water-using industries, which account for over 88% of the total cost. The primary metals group alone spent almost $41 million, or about 42% of these costs. Other significant contributors to recirculation costs were the paper and allied products, petroleum and coal products, and chemicals and chemical products industries.

Through the extensive telephone follow-up undertaken to complete returns for some of the survey respondents, additional information was obtained on the costs of water acquisition and treatment. Hence the values obtained for the 1991 survey are more representative than those of the 1986 survey, where only a minimum amount of time was available for the follow-up inquiries.

The response to these cost items also reflects several interesting points about current water management practices. First, there has been an increase in the use of meters by both the municipalities and the larger industries, resulting in improved records of the amounts of money spent on water use. Second, owing to the greater concentration of effort in the area of treatment, especially waste treatment, companies are monitoring the costs of each treatment method and its efficiency in terms of dollars as well as water quality. The data also reflect the greater emphasis being placed in all industrial sectors on the recirculation and reuse of the water used in their plant processes. Finally, and perhaps most importantly, the data on waste treatment reflect the construction and commencement of operation of a new paper mill in Western Canada, which incorporates the latest technology for pollution prevention.

2.2 Provincial Water Use Patterns

2.2.1 General Observations

Tables 14 through 21 focus upon patterns of water use in the provinces, but the description and interpretation of these tables are done only in summary form. In the following tables, data for the Yukon and Northwest Territories have been combined under the heading "Territories." Ontario accounted for over 47% of the total Canadian manufacturing water intake, followed by Quebec with 22% of the total, and British Columbia with 16% (Table 14). In contrast, Prince Edward Island and the territories accounted for an insignificant proportion of the total. This distribution of water intake among the provinces reflected provincial industrial structures.

Use and consumption rates by province are given in Table 15. In general, the use rates in the Atlantic region (i.e. the four eastern provinces) were among the lowest in Canada. These lower use rates resulted from several factors. First, water is more readily available in the Atlantic region than in many other areas, reducing the need for recirculation. Also, the industrial mix of the region was such that industry groups with higher use rates, such as petroleum and coal products and chemicals and chemical products, were not predominant. Finally, the industrial base of the Atlantic region tended to be older than that of the rest of Canada and thus employed older technological methods that did not recirculate large amounts of water.

The use rates for the three Prairie provinces were substantially higher than those in the rest of Canada. This reflects the need for greater water recirculation by plants in the Prairie region, due in part to a semi-arid climate that requires enhanced water conservation efforts. The use rate for British Columbia was lower than that for any of the Prairie provinces, but slightly above the national average, reflecting the industrial mix and location patterns of industry in this province.

Consumption rates varied substantially among the provinces, ranging from 4% in Newfoundland to 19% in Alberta. The consumption rates for New Brunswick, Alberta, and British Columbia were the highest of the Canadian provinces and substantially above the national average. The higher rates in Alberta reflected relatively high evaporation rates during the summer because of greater use of recirculation practices. However, Manitoba and Saskatchewan, the other two Prairie provinces, actually had lower consumption rates than several other provinces. Additional explanatory factors are the provincial industrial mixes and the ages of the plants.

2.2.2 Water Sources

The distribution of the total water intake by source among the various provinces (Table 16) shows some interesting geographical patterns. In the Atlantic provinces, about 26% of industrial water derived from public systems, as opposed to a national average of 10% and a low of 4% in British Columbia. Atlantic firms withdrew much less water from their own freshwater sources (39%) than the national average of 84%, and much less than Ontario (89%) and British Columbia (90%).

Table 14 Selected Characteristics of Manufacturing Water Use (MCM/year), by Water Use Parameter and Province, 1991

Province	Intake	Recirculation	Gross water use	Discharge	Consumption
Newfoundland	100.4	5.0	105.4	96.0	4.4
P.E.I.	10.7	4.3	15.0	10.2	0.5
Nova Scotia	251.4	203.0	454.3	237.1	14.2
New Brunswick	238.4	206.0	444.4	205.7	32.7
Quebec	1615.9	1372.9	2988.8	1513.4	102.5
Ontario	3457.4	3021.1	6478.6	3278.6	178.8
Manitoba	125.1	134.2	259.3	120.7	4.4
Saskatchewan	47.3	173.5	220.9	44.6	2.8
Alberta	273.6	565.8	839.4	221.4	52.3
British Columbia	1161.2	1120.7	2281.9	1033.4	127.8
Territories	1	0	1	1	0
Canada total	7282.1	6806.6	14088.6	6761.7	520.3

Table 15 Use Rates and Consumption Rates, by Province, 1991		
Province	Use rate	Consumption rate
Newfoundland	105	4.4
P.E.I.	140	4.6
Nova Scotia	181	5.7
New Brunswick	186	13.7
Quebec	185	6.5
Ontario	187	5.1
Manitoba	207	3.5
Saskatchewan	467	5.9
Alberta	307	19.1
British Columbia	196	11.0
Territories	100	---
Canada total	193	7.1

Table 16 Water Intake in Manufacturing (MCM/year) by Source and Province, 1991								
Industry group	Fresh water				Brackish water			Total intake
		Self supplied			Self supplied			
	Public/ municipal	Surface	Ground-water	Other	Ground-water	Tidewater	Other	
Newfoundland	20.3	37.5	6.2	0.1	0.0	33.2	3.1	100.4
PEI	8.3	0.0	2.3	0.0	0.0	0.0	0.0	10.7
Nova Scotia	55.6	69.8	4.8	0.9	0.0	120.1	0.0	251.3
New Brunswick	71.9	129.4	24.3	0.0	0.8	10.0	2.0	238.4
Quebec	142.8	1402.5	14.2	54.7	0.7	0.3	0.6	1615.9
Ontario	307.7	3075.1	19.0	52.9	1.7	0.0	1.0	3457.4
Manitoba	22.6	95.7	6.4	0.3	0.1	0.0	0.0	125.1
Saskatchewan	6.8	38.9	0.2	0.0	1.4	0.0	0.0	47.3
Alberta	26.3	235.5	4.8	6.0	0.7	0.0	0.0	273.4
British Columbia	50.2	1047.8	49.8	0.9	2.8	9.7	0.0	1161.2
Territories	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.6
Canada total	712.5	6132.7	132.0	115.9	8.4	173.5	7.1	7282.1

These findings illustrate that the smaller plants in the Atlantic region relied less heavily upon the surface systems than do the larger plants in Ontario, Quebec, and British Columbia. Although the national average for withdrawals from ground water sources was less than 2% of the total withdrawals, the ground water withdrawals in the four Atlantic provinces and British Columbia were above this average, with a high of 4% in British Columbia.

Tables 17 and 18 examine water intake from the viewpoints of initial use and treatment prior to use respectively. Processing water is used in roughly the same volumes in both Quebec and Ontario, the two provinces that dominate Table 17. Ontario, however, dominates the cooling, condensing and steam category, using about four times the amount of water as plants in Quebec. The geographic patterns displayed reflect the industrial structures and the corresponding water use patterns among the respective provinces.

For the most part, the geographic patterns displayed in Table 18 show little that does not follow from basic industrial distributions. The only slightly unusual observation is that three treatment methods, (chlorination and disinfection, corrosion and slime control, and screening) appear to be used relatively less in Quebec than in Ontario. No explanation of these two anomalies is offered here.

2.2.3 Water Discharge Points and Treatment

The four Atlantic provinces and British Columbia relied heavily upon discharge to tidewater (about 14% of the national total) (Table 19). The plants in the inland provinces principally used surface water bodies (about 74% of the national total). It is notewothy, for the discussion in Section 6, that this discharge to surface water occurs free of charge, regardless of effluent quality. In all provinces, a small proportion of waste water was discharged to public systems usually by the smaller plants (about 10% of the national total). As in the intake treatment, the distribution of discharge to ground water and other sources was small, contributing less than 1% of the national total. Table 20 shows the quantities of wastewater treated by various types of treatment. As in the corresponding table by industry group, there is substantial double counting in Table 20, and the reader is referred back to section 2.1.7 for a correct interpretation of these data.

Table 17 Manufacturing Water Intake (MCM/year) by Purpose of Initial Use and Province, 1991

Industry Group	Processing	Cooling, condensing and steam	Sanitary services	Other	Total intake
Newfoundland	73.1	20.7	6.2	0.3	100.4
Prince Edward Island	2.7	5.0	2.9	0.0	10.7
Nova Scotia	114.1	126.3	6.2	4.8	251.4
New Brunswick	173.6	49.1	10.1	5.5	238.4
Quebec	1026.6	526.1	39.6	23.6	1615.9
Ontario	1099.1	2235.5	88.9	33.9	3457.4
Manitoba	93.1	25.3	6.4	0.4	125.1
Saskatchewan	31.6	14.0	1.5	0.3	47.3
Alberta	107.4	155.1	7.9	3.2	273.6
British Columbia	713.4	395.0	26.9	26.0	1161.2
Territories	0.0	0.6	0.0	0.0	0.6
Canada total	3434.7	3552.8	196.6	98.0	7282.1

Table 18 Intake Water Treatment (MCM/year), by Type of Treatment and Province, 1991								
Industry group	Filtration	Chlorination and disinfection	Corrosion and slime control	Screening	Hardness and alkalinity control	Other	Total intake treated	Total intake
Newfoundland	2.7	40.3	4.0	56.1	1.5	0.7	105.4	100.4
P.E.I.	0.1	6.0	0.0	0.0	0.3	0.0	6.5	10.7
Nova Scotia	23.1	168.2	17.9	62.4	47.4	39.2	358.2	251.3
New Brunswick	79.6	70.8	59.1	88.8	12.6	2.4	313.2	238.4
Quebec	405.4	287.0	183.3	538.7	248.1	22.7	1685.1	1615.9
Ontario	528.1	1058.6	801.4	2207.4	282.8	69.9	4948.2	3457.4
Manitoba	20.3	21.7	0.3	27.0	2.1	0.3	71.7	125.1
Saskatchewan	37.4	36.2	0.8	0.3	41.4	0.0	116.1	47.3
Alberta	137.7	71.5	34.4	123.5	61.6	35.0	463.7	273.6
British Columbia	395.2	223.3	47.0	412.4	27.4	6.2	1111.5	1161.2
Territories	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.6
Canada total	1629.6	1983.5	1148.2	3516.7	725.3	176.4	9179.7	7282.1

Table 19 Wastewater Discharge in Manufacturing (MCM/year), by Point of Discharge and Province, 1991						
Industry group	Public sewer	Freshwater body	Tidewater body	Groundwater body	Transferred to other uses	Total discharge
Newfoundland	8.2	2.1	84.4	1.3	0.0	96.0
P.E.I.	4.1	4.1	2.0	0.2	0.0	10.3
Nova Scotia	41.4	13.1	181.5	1.0	0.0	237.1
New Brunswick	18.3	106.2	80.4	0.7	0.0	205.7
Quebec	187.6	1224.4	89.7	10.7	1.0	1513.4
Ontario	297.6	2964.9	0.0	12.7	3.4	3278.6
Manitoba	74.3	28.5	0.0	16.4	1.4	120.7
Saskatchewan	5.3	39.1	0.0	0.1	0.0	44.6
Alberta	21.7	193.8	0.0	3.9	1.9	221.4
British Columbia	41.3	447.2	515.8	28.2	0.9	1033.4
Territories	0.0	0.7	0.0	0.0	0.0	0.7
Canada total	699.8	5024.1	953.9	75.3	8.7	6761.8

2.2.4 The Cost of Water

The provincial distribution of water cost data (water acquistion, intake and waste water treatment, and water recirculation) show that Alberta dominates all cost categories (Tables 21 and 22), followed by Ontario. In the acquistion cost total ($812) million, Alberta was the largest contributor followed by Ontario, Quebec, Alberta, and British Columbia. The at-plant O&M cost category dominates the water acquistion costs, accounting for over 85% of the total. The high total water acquisition cost in Alberta was due to the commencement of a major new plant, as noted in section 2. Of the remaining cost questions, the cost of discharge or waste treatment was reported at over $116 million with Ontario dominating (59%).This province also led the recirculation costs reported with about 62% of the $97 million (Table 22).

Table 20 Treatment of Manufacturing Water Discharge (MCM/year) by Treatment and Province, 1991

Industry group	Primary treatment	Secondary treatment	Tertiary treatment	Total treated discharge	Total discharge
Newfoundland	10.5	8.4	0.1	19.0	96.0
P.E.I.	2.6	0.2	0.0	2.8	10.2
Nova Scotia	127.4	12.7	1.3	141.4	237.1
New Brunswick	102.2	54.1	31.6	187.8	205.7
Quebec	819.8	158.9	150.8	1129.5	1513.4
Ontario	1203.1	376.5	234.8	1814.4	3276.8
Manitoba	42.0	16.3	0.4	58.7	120.7
Saskatchewan	41.8	40.0	15.8	81.8	44.6
Alberta	108.8	101.8	2.9	213.4	221.4
British Columbia	529.5	504.8	32.3	1066.6	1033.4
Territories	0.7	0.0	0.0	0.7	0.7
Canada total	2988.3	1273.8	454.1	4716.1	6761.8

Table 21 Water Acquisition Costs ($million) in Manufacturing, by Cost Component and Province, 1991

Province	Paid to public utilities	At-plant O&M	Provincial licence fees	Total
Newfoundland	0.7	0.9	0.0	1.6
P.E.I.	0.1	0.0	0.0	0.1
Nova Scotia	1.1	1.0	0.0	2.2
New Brunswick	1.3	9.2	0.2	10.7
Quebec	16.5	27.0	0.5	44.0
Ontario	79.1	95.4	0.5	175.1
Manitoba	4.2	1.1	0.0	5.3
Saskatchewan	4.2	0.3	0.1	4.6
Alberta	5.7	534.0	0.2	539.9
British Columbia	5.4	20.9	2.5	28.9
Territories	0.0	0.0	0.0	0.0
Canada total	118.5	689.8	4.1	812.4

Table 22 Total Water Costs ($million) in Manufacturing, by Cost Component and Province, 1991					
Province	Acquisition cost	Intake treatment	Recirculation	Discharge treatment	Total water cost
Newfoundland	1.6	0.4	0.0	0.8	2.8
P.E.I..	0.1	0.4	0.0	0.0	0.5
Nova Scotia	2.2	2.8	0.5	2.3	7.8
New Brunswick	10.7	3.2	0.6	5.6	20.1
Quebec	44.0	36.9	25.0	50.7	156.6
Ontario	175.1	32.7	55.3	115.3	378.5
Manitoba	5.3	2.8	1.4	2.3	11.8
Saskatchewan	4.6	7.9	3.6	1.3	17.4
Alberta	539.9	19.7	6.6	8.7	575.0
British Columbia	28.9	14.4	3.5	34.7	81.5
Territories	0.0	0.0	0.0	0.0	0.1
Canada total	812.4	121.5	96.7	221.7	1252.2

3. MINERAL EXTRACTION WATER USE

For the purposes of this survey, the mineral extraction industry consisted of metal mining, non-metal mining, and coal mining. Technical difficulties prevented the inclusion of crude petroleum and natural gas plants, which had been surveyed in previous years. Due to confidentiality restrictions under the federal Statistics Act, the summary results contained in this paper are reported at the regional level, as opposed to the more detailed provincial level of section 2. For the same reason, the northern territories are included with the British Columbia data. Also, the discussion is much shorter, because the basic concepts used are similar to those employed in section 2.

The mineral extraction plants surveyed employed just over 55 000 persons in 1991. They had a combined water intake totalling 364 MCM , which, combined with recirculation of 1223 MCM, yielded a gross water use of 1587 MCM (Table 23). The metal mines, the largest group surveyed, were the largest water users in all parameters. The use rate for the three mining sectors was calculated at 436%, much higher than that for manufacturing, primarily because of water recirculation from tailings ponds. Because the question pertaining to wastewater discharge included drainage of groundwater from many of the mines, discharge totals often exceeded intake, causing consumption to be mathematically negative. To circumvent this problem, discharge was calculated to exclude mine water in Table 23.

The mineral extraction industries abstracted most of their water intake (Table 24) from surface water bodies (78%), with the second source of supply being groundwater sources (8%). Processing uses (75%) accounted for the largest amount of intake water in this sector, followed by cooling and condensing (16%), and sanitary and other purposes (8%) (Table 25). Screening dominated the methods of intake treatment (Table 26) followed by chlorination and disinfection, other treatment, category and filtration.

Freshwater bodies accounted for the largest proportion (59%) of water discharge from plants in this sector. (Table 27). The amounts of water transferred to tailings ponds (20%) reflected the importance of tailings recovery processes in the metal mines. As noted above, much of the water recirculated by metal mines derives from tailings ponds. To a lesser degree, the tailings ponds were used in potash mining, but the Saskatchewan potash plants injected most of their salty wastewater to disposal wells for permanent ground storage.

Much of the effluent from all three mining sectors received at least primary treatment (Table 28). Metal mines provided all three levels of treatment to cleanse their effluent before discharge. As is common with the manufacturing sector, the primary (mechanical) waste treatment type predominated in the mining sector. Much of the settleable waste from ore processing remains in tailings ponds adjacent to most mine sites. However, settling will not remove substances requiring more advanced forms of treatment. Thus, mining may generate a wide variety of pollutants that can damage the quality of streams and lakes. The offsetting factor to this point is that mines are generally in remote locations, away from major concentrations of population. However, this fails to take account of harm done to the environment, and to fish and wildlife dependent on it. Therefore, the lack of advanced waste treatment is an unsustainable practice that needs to be addressed.

The reliance on self-supplied intake sources in all three groups is reflected in the water acquistion costs. The in-house operating and maintenance costs reported by the metal mines accounted for approximately 93 % of these expenditures (Table 29). Only the non-metals group paid slightly more to the public utilities for their withdrawals (53%) than on in-house operating and maintenance costs. As in all other parameters, the metals group incurred the largest costs.

Tables 30 through 36 examine the mineral extraction water use data on a regional basis. The spatial distributions indicated reflect the distribution of mining activity in Canada. These data are not discussed further here.

Table 23 Selected Characteristics of Water Use (MCM/year) in Mineral Extraction, by Parameter and Industry Group, 1991

Industry Group	Number of plants	Employment	Intake	Recirculation	Gross water use	Discharge	Consumption*
Metal mining	118	37807	307.5	1094.0	1401.5	424.2	89.2
Non-metal mining	55	8705	43.3	81.7	125.0	57.6	7.9
Coal mining	30	8556	13.0	48.0	60.9	17.4	3.9
Canada total	203	55068	363.8	1223.6	1587.4	499.1	101.0

* In the mineral industry context, water "consumption" is negative in many cases because of groundwater intrusion. For this table, consumption was calculated excluding mine water.

Table 24	Water Intake (MCM/year) in Mineral Extraction, by Source and Industry Group, 1991							
Industry Group	Fresh water				Brackish water			
	Public utilities	Self-supplied surface	Self supplied ground	Other	Self-supplied ground	Self-supplied tidewater	Other	Canada total
Metal Mining	15.9	255.9	13.3	13.0	3.0	0.0	6.3	307.5
Non-metal mining	3.6	25.3	7.0	0.4	0.7	5.7	0.6	43.3
Coal mining	0.7	2.6	7.3	2.3	0.0	0.0	0.0	13.0
Canada total	20.2	283.9	27.6	15.7	3.7	5.7	6.9	363.8

Table 25	Water Intake (MCM/year) in Mineral Extraction by Purpose of Initial Use and Industry Group, 1991				
Industry Group	Processing	Cooling, condensing and steam	Sanitary services	Other	Total intake
Metal Mining	236.9	46.6	13.6	10.4	307.5
Non-metal mining	28.1	12.1	1.8	1.4	43.3
Coal Mining	9.3	0.8	2.3	0.6	13.0
Canada total	274.3	59.4	17.7	12.3	363.8

Table 26	Water Intake Treatment (MCM/year) in Mineral Extraction, by Type of Treatment and Industry Group, 1991						
Industry Group	Filtration	Chlorination and Disinfection	Corrosion and slime control	Screening	Hardness and alkalinity control	Other	Canada total
Metal mining	24.7	94.7	15.1	97.0	13.1	95.3	339.9
Non-metal mining	1.3	3.8	1.2	7.5	1.6	4.3	19.7
Coal mining	0.0	0.2	0.0	0.0	0.2	0.3	0.8
Canada total	26.0	98.7	16.4	104.5	15.0	99.9	360.4

Table 27 Wastewater Discharge (MCM/year) in Mineral Extraction, by Point of Discharge and Industry Group, 1991							
Industry group	Public sewers	Freshwater body	Tidewater body	Ground water	Tailings pond	Transferred to other uses	Total
Metal mining	2.2	260.4	26.6	40.2	94.5	0.3	424.2
Non-metal mining	0.1	28.1	7.8	17.1	2.8	1.7	57.5
Coal mining	3.9	4.6	3.3	0.9	4.7	0.1	17.4
Canada total	6.2	293.1	37.7	58.2	101.9	2.0	499.1

Table 28 Wastewater Treatment (MCM/year) in Mineral Extraction, by type of Treatment and Industry Group, 1991				
Industry Group	Primary	Secondary	Tertiary	Total
Metal mining	293.0	14.9	46.9	354.8
Non-metal mining	10.9	1.1	0.0	12.0
Coal mining	12.3	0.5	0.0	12.8
Canada total	316.2	16.5	46.9	379.6

Table 29 Water Acquisition Costs ($000) in Mineral Extraction, by Cost Component, Industry Group, and Region, 1991				
Industry Group and Region	Paid to public utilities	Operation and maintenance	Provincial water licences	Total acquisition cost
(a) Industry group				
Metal mining	1 679.1	47 860.3	269.2	49 808.4
Non-metal mining	1 568.0	1 371.0	8.0	2 946.0
Coal mining	83.0	1 144.0	2.0	1 229.0
(b) Region				
Atlantic	284.1	655.2	0.7	939.9
Quebec	366.6	1 952.9	0.0	2 319.5
Ontario	277.1	39 807.6	0.0	40 804.7
Prairie	1 391.9	5 125.5	8.3	6 525.8
British Columbia/territories	1 010.9	2 832.8	270.5	4 114.2
Canada total	3 330.6	50 374.1	279.5	53 984.1

Table 30 Selected Characteristics of Water Use (MCM/year) in Mineral Extraction, by Parameter and Region, 1991							
Region	Number of plants	Employment	Intake	Recirculation	Gross water use	Discharge	Consumption*
Atlantic	26	8 288	76.7	549.2	625.9	113.1	39.8
Quebec	40	9 082	74.1	259.9	334.0	112.3	21.1
Ontario	56	14 843	87.2	122.4	209.6	106.9	13.2
Prairie	46	11 720	50.2	116.4	166.6	78.8	10.6
British Columbia/ territories	35	11 135	75.6	175.7	251.3	88.0	16.3
Canada total	203	55 068	363.8	1 223.6	1 587.4	499.1	101.0

* In the mineral in industry context, water " consumption" is negative in many cases because of groundwater intrusion. For this table, consumption was calculated excluding mine water.

Table 31 Water Intake (MCM/year) in Mineral Extraction, by Source and Region, 1991								
Region	Fresh water				Brackish water			Total
	Public	Self supplied surface	Self supplied ground	Other	Self supplied ground	Self supplied tidewater	Other	
Atlantic	4.8	61.8	2.8	1.6	0.0	5.8	0.0	76.7
Quebec	2.5	69.3	1.9	0.4	0.0	0.0	0.0	74.1
Ontario	2.5	68.1	7.7	3.1	1.8	0.0	4.0	87.2
Prairie	3.3	36.3	4.5	3.7	1.8	0.0	0.6	50.2
British Columbia/ territories	7.1	48.4	10.8	7.0	0.0	0.0	2.7	75.6
Canada total	20.2	283.9	27.6	15.7	3.7	5.8	6.9	363.8

Table 32 Water Intake Treatment (MCM/year) in Mineral Extraction, by Type of Treatment and Region, 1991							
Region	Filtration	Chlorination and disinfection	Corrosion and slime control	Screening	Hardness and alkalinity control	Other	Total
Atlantic	14.9	40.0	0.2	57.9	1.2	0.0	114.2
Quebec	6.1	14.6	2.6	13.4	4.4	1.4	42.5
Ontario	3.1	20.2	12.3	15.6	8.7	4.3	64.2
Prairie	1.5	14.9	1.2	9.9	0.6	4.6	32.7
British Columbia/ territories	0.4	9.1	0.0	7.7	0.0	89.6	106.8
Canada total	26.0	98.7	16.3	104.5	14.9	99.9	360.4

Table 33	Water Intake (MCM/year) in Mineral Extraction, by Purpose and Region, 1991				
Region	Processing	Cooling, condensing and steam	Sanitary service	Other	Total
Atlantic	56.5	15.8	4.3	0.1	76.7
Quebec	61.3	9.9	2.1	0.8	74.1
Ontario	59.7	13.1	5.4	8.9	87.2
Prairie	29.0	16.1	3.4	1.8	50.2
British Columbia/ territories	67.9	4.5	2.5	0.7	75.6
Canada total	274.4	59.4	17.7	12.3	363.8

Table 34	Water Recirculation (MCM/year) in Mineral Extraction, by Purpose and Region, 1991			
Region	Processing	Cooling, condensing and steam	Other	Total
Atlantic	535.7	13.5	0.0	549.2
Quebec	255.5	4.0	0.4	259.9
Ontario	34.7	77.8	9.9	122.4
Prairie	85.8	24.1	6.6	116.4
British Columbia/territories	168.0	3.6	4.2	175.7
Canada total	1079.6	123.0	21.0	1223.6

Table 35	Water Discharge (MCM/year) in Mineral Extraction, by Discharge Point and Region, 1991						
Region	Public sewers	Freshwater bodies	Tide-water bodies	Ground water	Tailings ponds	Transferred to other uses	Total discharge
Atlantic	0.0	74.1	10.3	11.5	17.1	0.0	113.1
Quebec	1.8	90.5	0.6	12.6	6.4	0.5	112.3
Ontario	0.3	67.7	0.0	0.2	37.3	1.4	106.9
Prairie	3.9	41.1	0.7	25.0	8.0	0.1	78.8
British Columbia/ territories	0.2	19.8	26.0	8.9	33.1	0.1	88.0
Canada total	6.2	293.1	37.7	58.2	101.9	2.0	499.1

Table 36	Wastewater Treatment (MCM/year) in Mineral Extraction, by Treatment Type and Region, 1991			
Region	Primary	Secondary	Tertiary	Total
Atlantic	90.8	0.2	0.0	91.0
Quebec	81.9	2.3	4.3	88.6
Ontario	50.3	10.2	37.9	98.4
Prairie	39.1	1.0	0.4	40.5
British Columbia/territories	54.0	2.8	4.2	61.0
Canada total	316.1	16.5	46.9	379.6

4. THERMAL POWER PLANT WATER USE

Water use for thermal power generation was the largest of the industrial sectors surveyed. Electric power plants accounted for approximately 99% of intake in the sector, over 28 000 MCM in 1991 (Table 37), with the industrial establishments producing electricity and steam for their processes accounting for the rest. Of these industries, the three major water users accounted for almost the entire remainder of this category, primary metals being largest, followed by paper and allied products and chemicals and chemical products. (No overlap in statistics occurs with the manufacturing and mineral extraction sectors, as the thermal power survey identified separately co-generation plants.)

Surface water bodies made up the principal sources of water for thermal power generators (approximately 92%), with the secondary source being tidewater, especially for the electrical utilities (Table 38). The discharge data show that the most of the effluent (about 92%) was discharged to these same bodies, with tidewater and cooling ponds being minor discharge points (Table 39).

Because of the volumes of water involved, most of the discharge from themal power plants flowed to independent surface water sinks, principally freshwater lakes (Table 39). Very small portions of the water (mainly that from sanitary uses) went to public sewers. One plant in the Prairie region used a surface water basin as part of its recycling system. With this exception, the thermal power industry has a dismal record of water re-use, a finding reinforced by Table 37. Plants generally use their cooling water only once before discharging it back to its source.

The most frequently used process to treat intake water was screening, followed by filtration, chlorination and disinfection, and corrosion and slime control (Table 40). These four treatment methods accounted for about 99% of treatment. The electrical utilities dominated all categories, with primary metals, paper and allied products, and chemicals and chemical products industries ranked by decreasing treatment volumes.

The survey data on costs for water acquisition and intake treatment (Table 41) again reveal the dominance of the electric power utilities, which emerged from the analysis of the water use data. The electrical power industry accounted for over 60 % of the cost of water acquisition, and the paper and allied products industry led the manufacturing industries with about 37 % of the total. The expenditures on intake treatment revealed that approximately 74% were by the electrical utilities, while the paper and allied products industry spent about 13%, slightly more than the chemicals and chemical products industry at 12% (Table 41).

Water use in thermal power generation is distributed among regions exactly as the distribution of plants. Accordingly, most of the usage occurred in Ontario. The regional data are summarized in Tables 42 through 45, for interested readers. They are not described further here.

Table 37 Characteristics of Water Use (MCM/year) in Thermal Power Generation, by Parameter and Industry group, 1991

Industry group	Number of plants	Employment	Intake	Recirculation	Gross water use	Discharge	Consumption
Metal mining	1	16	0.1	1 409.2	1 409.3	0.0	0.0
Primary textiles	1	17	0.1	0.0	0.1	0.1	0.0
Paper and allied	16	594	26.5	24.8	51.3	21.1	5.4
Primary metals	2	46	41.9	0.0	41.9	20.4	21.4
Chemicals and chemical products	2	50	0.8	1.6	2.4	0.5	0.3
Electric power	44	9 440	28 288.1	3 374.3	31 662.4	28 183.0	105.1
Canada total	66	10 163	28 357.5	4 809.9	33 167.4	28 225.2	132.2

Table 38 Water Intake (MCM/year) in Thermal Power Generation, by Source and Industry Group, 1991

Industry group	Fresh water				Brackish water			Total
	Public/municipal	Surface	Ground	Other	Ground	Tidewater	Other	
Metal mining	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Primary textiles	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Paper and allied	6.8	19.8	0.0	0.0	0.0	0.0	0.0	26.5
Primary metals	0.1	41.8	0.0	0.0	0.0	0.0	0.0	41.9
Chemicals and chemical products	0.1	0.7	0.0	0.0	0.0	0.0	0.0	0.8
Electric power	158.1	25 972.7	8.8	0.0	0.0	2 148.4	0.0	28 288.1
Canada total	165.1	26 035.1	8.8	0.0	0.0	2 148.4	0.0	28 357.5

Table 39 Water Discharge (MCM/year) in Thermal Power Generation, by Discharge Point and Industry Group, 1991

Industry group	Public sewers	Freshwater	Tidewater	Groundwater	Artificial surface basin	Transferred to other uses	Total
Metal mining	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Primary textiles	0.1	0.0	0.0	0.0	0.0	0.0	0.1
Paper and allied	0.1	18.1	3.0	0.0	0.0	0.0	21.1
Primary metals	0.0	20.4	0.0	0.0	0.0	0.0	20.4
Chemicals and chemical products	0.0	0.5	0.0	0.0	0.0	0.0	0.5
Electric power	54.4	25 890.0	2 085.8	37.6	37.7	77.5	28 183.0
Canada total	54.6	25 929.0	2 088.8	37.6	37.7	77.5	28 225.2

Table 40 Intake Water Treatment (MCM/year) in Thermal Power Generation, by Type of Treatment and Industry Group, 1991

Industry group	Filtration	Chlorination and disinfection	Corrosion and slime control	Screening	Hardness and akalinity control	Other	Total
Metal mining	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Primary textiles	0.2	0.0	0.0	0.0	0.1	0.0	0.3
Paper and allied	12.8	4.0	2.3	11.4	6.3	0.0	36.7
Primary metals	0.0	0.0	0.0	0.0	0.6	0.0	0.6
Chemicals and chemical products	1.9	0.7	6.9	1.9	0.0	0.0	11.4
Electric power	894.2	749.4	319.3	24 331.3	156.9	89.5	26 540.7
Canada total	909.0	754.0	328.5	24 344.6	164.0	89.6	26 589.8

Table 41 Water Acquisition and Intake Treatment Costs ($ million) in Thermal Power Generation, by Cost Component, Industry Group, and Region, 1991

Industry group	Water acquisition			Intake treatment	Total
	Public utilities	Operation and maintenance	Provincial licence fees		
(a) Industry groups					
Metal mining	0.0	0.0	0.0	0.0	0.0
Primary textiles	0.0	0.0	0.0	0.0	0.0
Paper and allied	0.0	2.4	0.0	2.2	4.6
Primary metals	0.0	0.0	0.0	0.0	0.0
Chemicals and chemical products	0.0	0.1	0.0	1.9	2.0
Electric power	0.9	3.0	0.1	12.3	16.3
(b) Regions					
Atlantic	0.6	0.2	0.0	2.8	3.6
Quebec	0.0	0.0	0.0	0.0	0.0
Ontario	0.2	2.0	0.0	9.7	11.9
Prairie	0.1	0.7	0.1	3.0	3.9
British Columbia/territories	0.0	2.5	0.0	0.7	3.2
Canada total	0.9	5.5	0.1	16.4	23.0

Table 42 Selected Parameters of Water Use (MCM/year) and Economic Activity in Thermal Power Generation, by Water Use Parameter and Region, 1991

Region	Number of plants	Employment (# persons)	Power generated (Gwh)	Intake	Recirculation	Gross use	Discharge	Consumption
Atlantic	20	1 802	17 213.8	2 126.0	18.6	2 144.6	2 106.8	19.1
Quebec	4	743	4 350.9	1 004.6	1 409.2	2 413.8	972.0	32.6
Ontario	17	5 652	105 269.3	23 095.2	16.5	23 111.6	23 072.5	22.7
Prairie	17	1 671	45 888.6	2 025.2	3 355.0	5 380.3	1 971.0	54.3
British Columbia/territories	8	295	1 921.0	106.5	10.6	117.1	103.0	3.5
Canada total	66	10 163	174 643.5	28 357.5	4 809.9	33 167.4	28 225.2	132.2

Table 43 Water Intake Treatment (MCM/year) in Thermal Power Generation, by Type of Treatment and Region, 1991

Region	Filtration	Chlorination and disinfection	Corrosion and slime control	Screening	Hardness and alkalinity control	Other	Total
Atlantic	11.9	6.9	300.1	1 769.2	32.6	2.9	2 123.6
Quebec	869.1	67.0	5.7	5.0	0.8	81.1	1 028.6
Ontario	21.8	585.3	15.5	21 548.2	108.9	3.8	22 283.5
Prairie	3.9	1.1	1.9	922.5	19.0	1.5	950.0
British Columbia/ territories	2.4	93.6	5.3	99.8	2.7	0.3	204.0
Canada total	909.0	754.0	328.5	24 344.6	164.0	89.6	26 589.8

Table 44 Water Intake (MCM/year) in Thermal Power Generation, by Source and Region, 1991

Region	Fresh water				Brackish water			Total
	Public/ Municipal	Surface	Ground	Other	Ground	Tidewater	Other	
Atlantic	10.1	57.7	0.0	0.0	0.0	2 058.1	0.0	2 126.0
Quebec	0.1	1 004.5	0.0	0.0	0.0	0.0	0.0	1 004.6
Ontario	0.7	23 094.4	0.0	0.0	0.0	0.0	0.0	23 095.2
Prairie	154.2	1 862.2	8.8	0.0	0.0	0.0	0.0	2 025.2
British Columbia/territories	0.0	16.2	0.0	0.0	0.0	90.3	0.0	106.5
Canada total	165.1	26 035.1	8.8	0.0	0.0	2 148.4	0.0	28 357.5

Table 45 Water Discharge (MCM/year) in Thermal Power Generation, by Discharge Point and Region, 1991

Region	Public sewers	Fresh water	Tidewater	Groundwater	Artificial surface basin	Transferred to other uses	Total
Atlantic	54.0	8.6	1 994.0	0.2	0.0	50.0	2 106.8
Quebec	0.1	897.2	0.0	37.3	37.3	0.0	972.0
Ontario	0.5	23 072.0	0.0	0.0	0.0	0.0	23 072.5
Prairie	0.0	1 943.0	0.0	0.0	0.4	27.5	1 971.0
British Columbia/territories	0.0	8.2	94.8	0.0	0.0	0.0	103.0
Canada total	54.6	25 929.0	2 088.8	37.6	37.7	77.5	28 225.2

5. WATER USE TRENDS, 1972–1991

During the period 1972 to 1991, five industrial water use surveys were conducted. Using these accumulated data, a few trends can be described (see Table 46 and Figure 2). Detailed analysis of the reasons underlying these trends is beyond the scope of this paper, but will be presented at a later date. Also, no comparison is included here of the outcome of the 1991 industrial water use survey and the forecasts made for the Inquiry in Federal Water Policy of 1985 (Pearse et al., 1985; Tate, 1985).

Industrial water withdrawals in the aggregate experienced increases both nationally and regionally, with national withdrawals growing from 18 045 MCM in 1972 to 36 003 MCM in 1991. Regionally, Ontario and Quebec contained the majority of the industrial water use, and determined this trend of continous growth; British Columbia withdrawals increased from 1972 to 1981 but experienced a decline in 1986 and a further decrease in 1991. The Prairie region began with increased withdrawals between 1972 and 1976, but withdrawals during the 1976 –1986 period underwent a slight reduction which now has been reversed with increased withdrawals in 1991. The withdrawals in the Atlantic region have fluctuated by increasing from 1972 to 1976, declining in 1981, and then increasing again in 1986 and declining in 1991. We suspect that these trends follow the ebb and flow of the national and respective provincial and regional economies, although structural changes and environmental policies also have an (as yet undetermined) effect.

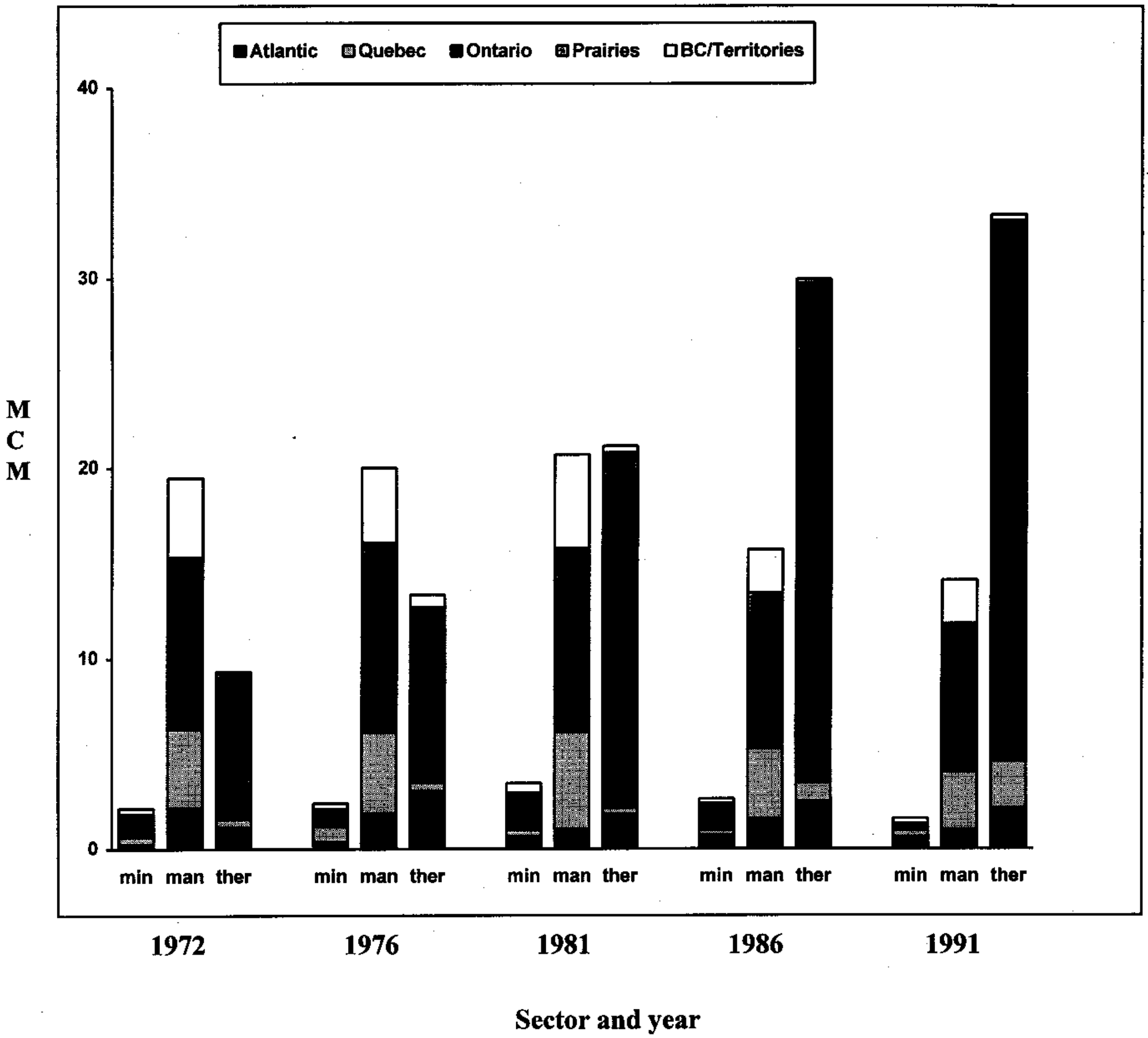
Ontario was the major user accounting for 54% of all withdrawals in 1972, increasing to 74% in 1991. The second largest regional user has changed in almost every survey, with the Prairie region ranking second in withdrawals in 1972, being surpassed by the Atlantic region in 1976, by British Columbia in 1981, and by the Atlantic region again in 1986 and 1991. The regional use of water as a portion of the national use also decreased between 1972 and 1991 in the Atlantic and Quebec regions, though both showed an absolute increase in use. This pattern of growth relates largely to major increases in water withdrawals for thermal generation in Ontario, which overshadowed the increases in all other uses.

Over the 1972–1991 period, the trends in the gross water use for the sectors which practice recirculation increased both nationally and regionally from 30 954 MCM in 1972 to 48 842 MCM in 1991. Regionally, the trends in gross use over the period mirrored those experienced in the water withdrawals previously outlined.

In terms of gross water use over the 1972–1991 period, manufacturing was the largest water user in the 1972 and 1976 surveys, but since 1981 it has lost its dominance to the thermal power generation sector. The mineral extraction sector has remained third among the three throughout the period. The trends among these three sectors will now be discussed individually.

Sectoral Water Use in Canada, 1972–91

Figure 2



min = mineral extraction
man = manufacturing
ther = thermal power generation

5.1. Manufacturing

Manufacturing was the second largest water user among the three sectors surveyed. Over the 1972–1981 period, its total withdrawals increased from 8362 MCM in 1972 to 9937 MCM in 1981. However, in both 1986 and 1991, total withdrawals decreased significantly to 7984 MCM and 7282 MCM respectively. Mirroring the withdrawal trends, the gross use grew from 19 480 MCM in 1972 to a peak of 20 684 MCM in 1981 and decreased significantly to 15 796 MCM in 1986 and down further to 15 088 MCM in 1991.

This pattern of growth and decline is interesting and somewhat paradoxical because it was accompanied by a decline in the use rate in almost all industries. Thus, a fall in usage accompanying a rise in water use efficiency is not a plausible explanation for this pattern of growth and decline. One possible explanation relates to the wholesale decline in manufacturing activity, as suggested by the corresponding decline in gross water use. The decline may have been accompanied by structural changes in the manufacturing sector. To determine the precise causes must await further research.

Table 46 Selected Characteristics of Industrial Water Use (MCM/year) for Canada (1972–1991), by Year, Sector, and Water Use Parameter

Sector and parameter	1972	1976	1981	1986	1991
Manufacturing					
Intake	8 362	8 672	9 937	7 984	7 282
Recirculation	11 118	11 362	10 747	7 813	6 806
Gross water use	19 480	20 034	20 684	15 797	14 088
Discharge	8 023	8 217	9 443	7 579	6 762
Consumption	339	455	494	405	520
Mineral extraction					
Intake	362	637	648	593	364
Recirculation	1 791	1 761	2 792	2 038	1 223
Gross water use	2 153	2 398	3 440	2 631	1 587
Discharge	275	563	470	429	263
Consumption	87	74	178	164	101
Thermal power generation					
Intake	9 321	13 164	19 281	25 364	28 357
Recirculation	0	199	1 868	4 480	4 810
Gross water use	9 321	13 363	21 149	29 844	33 167
Discharge	9 219	13 003	19 213	25 093	28 225
Consumption	102	161	168	271	132

Source: Environment Canada industrial water use surveys.
Note: Data may not add due to rounding.

In each of the five survey years, the paper and allied products industry ranked first as the largest water user among the five major water-using industries surveyed. This industry reported the largest gross water use based on the largest intake combined with the largest level of recirculation. The primary metals industry has been consistently ranked second to paper and allied products throughout the survey period, except in 1986. In the 1986 survey, the chemicals and chemical products industry , which had been third in all other water surveys, moved past primary metals. This anomaly was due to a slightly higher level of recirculation reported and hence a greater gross use. The refined petroleum products industry has consistently ranked fourth during the 1972–1991 period. Finally, the fifth major water-using industry has been the combined foods and beverages industries[9], with the exception of 1976.

Over the five surveys, the refined petroleum products industry, as an individual industry group has consistently practised among the highest levels of recirculation in terms of its withdrawals. During the 1972–1991 period, Ontario led all provinces as the largest water user in manufacturing, followed by Québec and British Columbia.

5.2. Mineral Extraction

The mineral extraction industry ranked last in terms of total intake in all five surveys. Its withdrawals have fluctuated over the study period, increasing from 362 MCM in 1972 to 667 MCM in 1976, but declining slightly to 648 MCM in 1981 and decreasing even more to 593 MCM in 1986 and still further to 364 MCM in 1991.This significant decrease in 1991 reflects the deletion of the crude petroleum and natural gas group from the survey results, due to the poor survey response in Alberta.

Over the five surveys, the mineral extraction sector has employed recirculation to a greater extent than the other sectors, with its withdrawals being reused more than four times on average to meet its gross use. The consumptive use in this sector has slowly increased over the study period.

5.3. Thermal Power Generation

The thermal power generation sector was responsible for the largest withdrawals in all years surveyed. This industrial sector, which includes both conventional and nuclear power generation plants, increased its proportion of total water use significantly from 38.7 % in 1972 to 62.9 % in 1991. This large percentage growth represented the combined effects of rapid growth in demand for electricity, a gradual increase in the proportion of generating capacity accounted for by nuclear power plants, which use relatively more cooling water than conventional thermal plants, and a decline in water use in manufacturing.

Recirculation has increased considerably in recent years from 1868 MCM in 1981 to 4810 MCM in 1991, up from 4480 MCM in 1986. In fact, the gross use, which was reported at 13 363 MCM in 1976, has increased dramatically and has more than doubled to 28 357 MCM in 1991. Compared to the large water withdrawal, this sector's water consumption remains relatively low, owing to the fact that most older plants used a once-through system of cooling and that the highly consumptive cooling towers or cooling ponds were used only in the newer, larger conventional and nuclear power plants. In fact, the consumption has increased slowly from 102 MCM in 1972 to 132 MCM in 1991.

[9] Prior to 1986, these two industrial groups were combined; for the 1986 and 1991 survey years, they were separated because of modifications in the SIC industrial groupings.

6. INDUSTRIAL WATER USE AND THE ENVIRONMENT[10]

As noted in the introduction, industry forms a tremendously important part of the Canadian economy. It provides raw materials, many producer and consumer goods, and the power needed to operate a modern, complex economy. It is subject to competitive pressures, both domestic and, increasingly, international. It also provides employment and incomes to many Canadians. Thus, any public policy actions which have impacts on industry must be undertaken with great care and with lead times sufficient to allow appropriate and non-disruptive adjustments.

It is also true that industry is the source of many environmental problems, some of which have been described in this paper. To recapitulate briefly, the paper has shown that industry uses very large amounts of water each year. This is the outcome of a large and complex industrial base, and, to a certain extent reflects the country's advanced state of economic development. However, the statistics show that industry is quite inefficient with regard to its industrial water use, as reflected by low and falling water use rates. Kollar and MacAuley (1980) showed, for example, that use rates were much higher in U.S. plants practicing best available technologies (Table 47). There is no reason to expect a different outcome for Canada, because general technological conditions do not vary substantially between the two countries. This paper has also shown that, for many industries, waste treatment is inadequate, resulting in pollution problems in many areas. The paper has not addressed the latter specifically, but the industrial sector, taken together, is the source of many water quality problems faced by Canada. This is not to say that many firms do not have good environmental records, but, on the whole, the pollution control practices of industry could be substantially improved. For example, the data presented here showed that under 1% of the value of output from industry was devoted to water handling, only a portion of which went to waste treatment. Because the firms surveyed accounted for the majority of industrial water usage, it seems reasonable to conclude that this proportion of expenditure holds true for Canadian industry in general.

Table 47 Observed and Theoretically Possible Use Rates for Selected U.S.Manufacturing Plants

Industry group	Observed use rates	BAT with maximum possible recirculation
Meat packing	166	667
Dairy products	113	671
Textile mills	223	1820
Rubber	838	3330
Pulp and paper	342	1220
Inorganic chemicals	308	3120
Plastics	353	3330
Steel	164	1190
Petroleum refining	638	3330
Primary copper	312	1190
Automobiles	318	1630

Source: Kollar and MacAuley. 1980.
BAT = best available technology (i.e., as of 1980)

[10] This section of the paper presents an interpretation of industrial water use practices in Canada. These interpretations result from the authors' research, experience, and professional opinion. They do not necessarily reflect the approaches to industrial environment issues currently taken by Environment Canada.

The situation in the industrial sector is not unique, but rather reflects the water management "paradigm" that has always dominated in Canada. In this last section, we offer a general interpretation of overall water use patterns and suggest how industrial water usage could be improved.

6.1 The Canadian Water Management Paradigm

Canadian water management has been dominated throughout history by efforts to harness the country's massive water supplies to serve the economy. This approach may be referred to as supply management. This approach involves manipulating the resource base through various types of structural measures, such as damming, dyking, irrigating, and diverting water to meet all perceived requirements at minimal costs to users. This has frequently involved massive subsidies from the general taxpayer to private users. For example, with respect to industrial water supplies, the supply management approach has sought to supply all users regardless of their water using practices. This is reflected by virtually no volume-based charges for water withdrawal from (publicly owned) surface or ground water sources. With respect to water quality, supply management has aimed to overcome industrial waste disposal problems by allowing the discharge of untreated or minimally treated wastewater. This practice has succeeded in minimizing private sector costs, but has created serious water pollution problems, and persists despite very expensive efforts at regulation. Because publicly owned water resources were available in seeming abundance and aquatic ecosystems were unvalued, these discharges have occurred throughout the history of Canada and promise to be very difficult to change. Efforts at regulation have been only marginally successful, and water pollution due to industrial wastewater discharge is still a major environmental problem. Both water overusage and the discharge of often untreated wastes are proven by the data presented in this paper. It is worth a short digression to try to analyze the basic principles involved in both of these excessive use problems.

6.2 The Centrality of Economic Markets

It is a little trite, but nonetheless of central importance here, to emphasize that Canada's economy is a market-oriented one. More particularly, it is a "mixed" economy within which both economic markets and the public sector share responsibility for the allocation of goods and services, including environmental goods and services. There exists a healthy "tension" between which goods and services fall into the realm of market allocation, and which into the realm of public allocative measures. The current "balance" between the public and private allocation reflects the fact that markets, as they are now structured, are not effective in dealing with "public goods," such as environmental resources, or with other types of distributional issues.

Despite the acknowledged shortcomings of the market system, market forces can be very powerful, and one of the main "tricks" for the future will lie in harnessing these forces for improving water and environmental quality. As the American economist Charles Schultze (1977) pointed out, this is a case where "the public use of private interest" can be beneficial in achieving socio-economic ends.

Western societies have thrived on the operation of the market system. Not only has this system allocated resources, goods, and services in a largely economically efficient (i.e. least cost) manner, it has also (and far more importantly) led to enormously important technological changes. Schultze (1977) captured this historical fact in stating:

> Living standards in modern Western countries are, by an order of magnitude, superior to those of the early 17th century. Had the triumph of the market meant only a more efficient use of technology and resources then available, the gains in living standards would have been minuscule by comparison. What made the difference was the stimulation and harnessing of new technologies and resources. (p. 25)

This statement supports strongly the findings of Nobel prize winner Robert Solow (1957), who demonstrated that over 85% of technological advancement in the U.S. economy during a 40-year period could not be explained by linear, cause-and-effect models then in use, or by the action of individual agents in the economy. Rather, he found that it was the result of systemic effects, hidden variables, and relationships that emerged from collective market interactions. Thus, technological change emerges from market system forces that are "synergistic" in nature, in not being attributable to any one specific set of conditions. This market self-organization appears to be the driver of Solow's "disembodied technological change" concept.

The dynamics of this technological change process can be conceptualized partially as follows. The market provides suppliers with the incentive to expand supplies by exploiting resources of lower concentration or alternative composition to meet the demands they face. Alternatively, suppliers may move to meet the need for new products. As conditions currently exist, this type of supply expansion frequently has adverse effects on the environment, because it occurs in the context of free environmental resources. Demanders, at the same time, have the incentive to search for materials to meet their needs at lower costs than they currently pay, or may demand new products. When these two forces collide in the market-place, a significant incentive is established for technological advancement.

Examples are quite common. Fuel-efficient technologies in transportation and home heating resulted directly from energy price shocks. Microcomputer technologies have literally exploded in the face of industrial, business, and consumer demand and realistic, market-determined pricing. As will be discussed in more detail below, such dramatic advances have not occurred in the environmental area because these "market dynamics" have never been employed. Consequently, effective incentives for the efficient use of environmental resources and for environmentally-related technological change do not exist.

The technological changes which have occurred in the water sector have, as already noted, occurred in response to supply management, often subsidized by the public, and by "end-of-pipe" treatment, basically in response to regulations, the water quality component of supply management. Because of the resource overusage implications of supply management, such technologies as have been developed are undoubtedly inefficient in their use of capital assets, both in the private and the broader social senses. In other words, society is not reaping the self-organizing benefits of "disembodied technological change" in environmental resource use and protection, and is consequently probably paying *too high a price* for these "goods." If resources are free, and if effective incentives for change do not exist, technological change will not occur — and that's exactly what has happened with respect to environmental technology.

Three points emerge from this short discussion, which have relevance for the issues being examined here:

- The market-place dynamic is one of the underpinnings of all Western-style capitalist economies. Although there are certain details, such as imperfect markets (e.g., monopolies), which have to be considered, the centrality of the market in economies such as Canada's is *fundamental*, and offers certain features which could be exploited to support improved water and enviromental management.

- Technological change is a response primarily to economic forces. It is not random, it is not serendipitous, it is not initiated, for the most part, by "backyard inventors." It is instead the net result of a very rational, and largely economic, set of forces.

- These forces have never been used seriously in Canada to meet environmental ends. As will be pointed out shortly, they could be used in the environmental context with very significant positive impacts.

The authors want to stress the foregoing points are not meant to imply that an unfettered free market is wholly desirable. As pointed out already, the market can and does cause "external" effects which do not serve society's interest. Indeed the "pollution problem" is one of these. But, it is important not to lose sight of characteristics embedded in the economy, which, if used creatively, can promote the achievement of environmental objectives.

6.3 Production Dynamics and the Environmental Problem

Although section 6.2. demonstrated some of the dynamics at work in making technology advance, a closer look should be taken at production processes to draw a link with environmental conditions. Economists use the concept of a "production function" to generalize the operation of firms in an economy. For current purposes, it is sufficient to state that a production function is a "recipe" which links outputs to their factor inputs. In other words, a production function — for any activity — simply denotes the way in which resource inputs are combined to produce a given output.

The critical point here is that the selected combination of inputs normally reflects relative input costs. The logic behind this is clear — producers want to minimize their costs and do so by selecting the least-cost combination of inputs. The combination process takes place in a dynamic sense, such that if the relative prices of the inputs change, the input quantities, or even the types of inputs, will change. A corollary to this process is that cheap or unpriced resources, such as water, will be used "infinitely" — that is to the degree required, with no consideration for alternatives which might conserve or protect the resource.

This production function approach to viewing the economic process offers a powerful means of diagnosing the water resource problems described in this paper. Environmental resources — principally water and air — serve vital purposes for any type of socio-economic activity, both as inputs and depositories for wastes. Industry, for example, could not operate without these resources. A pulp mill operating without water, or a thermal generating station without access to both water and air, are inconceivable prospects. And yet, with the exception of small, economically irrelevant "water rentals" in some provinces, and the cost of pumping, these environmental resources have a very low or zero cost. In other words, users can gain unlimited access to environmental resources very cheaply. The results are wholly predictable — resource overuse and abuse, examples of which are documented in this paper. It is this overuse and abuse that has created almost all environmental problems.

To summarize, Canadian water management has developed with an almost exclusive orientation toward moving supplies to meet what are perceived to be requirements that are fixed and unchangeable. Although this predominant paradigm has been successful in satisfying these requirements as they arose, the approach has not been without both private and social costs. In the industrial context there is a visible, quantifiable overuse of water, accompanied by a decades-long overcapitalization of water conveyance facilities. In terms of social costs, the problem is even greater. When industries draw water from municipal systems, their non-conserving practices inflate municipal water usage, again overcapitalizing water systems. The more serious problem, and the one at the root of environmental concern, is the pollution problem. As business is now conducted, the cheapest pollution control alternative is untreated discharge to receiving waters, including groundwater, or to municipal systems. Unless prosecuted for contravening quality regulations, which in itself has proven difficult, industries have very little incentive for in-plant treatment. When action is forced, only the minimal levels of treatment are provided, as shown in the relevant portions of sections 2, 3, and 4 of this paper. The authors believe that complementary methods of handling the industrial water use problem are required and are available. It is to a brief description of these that the paper now turns.

6.4 Economic Rent and Its Importance for Environmental Management[11]

Economic rent is an uncommon concept in the water management field, but one which is common to other resource fields, such as mineral extraction and forestry. It is a potentially valuable one in the water resources field, for it can be used to provide an economic dimension to the use of water. In formal terms, Gunton and Richards (1987) described economic rent as follows: "After revenues from natural resources have been disbursed to pay all costs of production — including a return on investment, or normal profit, equivalent to what could be earned in the next best use of capital — any surplus remaining is economic rent"(p. xxxi).

[11] We acknowledge that water resource ownership rests solely with the provinces under the Constitution Act of 1981. We have abstracted from this issue,and are neutral as to which party is entitled to which share of the economic rent from water resources. For present purposes, the use of economic rents in placing a realistic, incentive-generating price on water is the sole concern.

The most outstanding example of economic rent in the recent past related to the monetary "windfalls" that accrued to petroleum resource owners or controllers. The OPEC-induced rises in the price of crude oil raised the market price substantially. Production costs remained essentially unchanged, and, with "normal profits" already monetized into the pre-rise price, a substantial excess profit, or rent, accrued to the owners of the resource. In Canada, the policy response federally was the so-called National Energy Program, an attempt to share the rent amongst the public and private sectors.

In the water resource area, industry benefits from having available sufficient quantities of water to serve their needs. This benefit, theoretically, is the difference between the cost of current water provisioning and the cost of the next-best alternative, for example a recycling system to eliminate the need for much of the water intake. This rent is implicit and elusive because there have been few attempts to measure it. Some provinces levy "water royalties" for licences to withdraw water, but as noted earlier in the paper, the resulting charges are administrative in nature, not the product of analysis. As a result, most of the economic rents accruing from water resources go to the users of the resource, not the (public) owners. This is an additional way of explaining why industrial water is literally "cheaper than dirt" in Canada, with the attendant effects as outlined in section 6.1.

6.5 Methods for Capturing Economic Rent

Many methods exist for calculating and assigning economic rent. The current debate about economic instruments for environmental managment is essentially a debate over the capturing of this rent. We will not join this debate in the present paper, for the final decisions must be analytically based. However, a number of criteria exist as possible bases for rent calculation, a few of which follow:

- Any economic rents charged must be viewed as charges for the use of publicly owned resources. They are not, and must not be envisaged as taxes. They are not unlike service charges for other public utilities, like telephones or cable T.V.

- The level of the charge should be sufficient to act as an incentive to change behavior. Very small, administrative charges will not be effective, and will be more costly to operate than they are worth.

- Charges should cover at least the full cost of public administration of the resource within the respective jurisdictions. Publicly owned resources are being used, and are becoming costly to maintain. Users should pay the full costs of maintaining, and where necessary, improving the quality of these resources.

- Current resource valuation techniques are advancing very rapidly, and will soon have the ability to place economic values on damages from pollution. These values could be used as the basis of rent calculations.

- The noted American economist, Robert Solow (1991) suggested that the key to dynamic sustainable development lies in gathering a portion of current rents from resource use to allow future generations to develop and prosper. The "bank account" idea has never been properly explored, and may form the basis of a rent calculation that both acts as an incentive today and provides the basis for future development.

6.6 Commonly Held Myths About Economic Instruments

A number of myths and misconceptions currently exist in public decision-making circles about using economic incentives and disincentives in the environmental field. These are of concern, as they may be inhibiting the wider application of economic principles in improving environmental quality. It is important to address these and to try to put them finally to rest.

6.6.1 Raising Taxes

A common response to suggestions concerning the use of economic instruments to achieve environmental ends is that the adoption of such a policy would raise taxes. In an economic situation like the one currently faced by Canada, such a policy suggestion can be anathema, despite the fact that tax regimes are changed all the time. However, public policy makers and, indeed, the public themselves must recognize that a healthy environment is going to cost a considerable amount of money. To solve the toxic chemical pollution problem, for example, is likely to cost many billions of dollars. On the other hand, these costs are quite small relative to the costs of other social objectives, such as income stabilization. Assuming that society, as reflected by our political institutions, decides that this is a legitimate aim, as it appears to have done by passing the Canadian Environmental Protection Act, for example, the economic policy problem is to achieve this objective *at least cost.*

Environmental resources, as shown earlier, are absolutely essential inputs for all industries. In common with other resources, they form part of the production function for all firms. In contrast to most productive inputs, their ownership accrues in Canada to the Crown, usually to the provinces. (This divergence in the pattern of ownership fundamentally has very little to do with the economics of production.) Any input price rise with respect to water and air, regardless of origin, but in this case by a public body, would comprise *a charge for services provided,* as opposed to a "tax." Further, the revenue accruing should be passed back into the maintenance and improvement of the resource. This contrasts strongly with the concept of "taxation" as generally accepted — that is, a set of measures designed to raise money for general government expenditure.

The analogy between the use of environmental charges and other public service charges (e.g., telephone bills, transit fares, cable T.V. payments) is very much stronger than that between such charges and new taxes. *In other words, environmental charges are service charges, not taxes.*

Recognition of this basic concept is crucial, simply because the public may accept charges for essential services more than it would increased levels of taxation untraceable to a specific end. An important part of the research and plan formulation functions for effective water management should be to foster an understanding of this basic distinction and to demonstrate that economic instruments such as input charges are the *cheapest and most effective means of achieving the desired ends.*

6.6.2 "Licences to Pollute"

One of the most common objections to the use of economic instruments for environmental control is that they constitute licences to pollute. The implication is that public agencies should not be party to the sale of such licenses. Thus, many economic instruments are discarded out of hand almost automatically by public agencies.

The actual fact is that any sort of action to prevent any sort of pollution is a licence to pollute. The converse of a regulation is that firms are still permitted to dump *some of the offending material* into the environment, simply because complete elimination through regulatory means, and in the absence of changes in products, processes or technologies, is very expensive. Thus, *any* attempt to control pollution that allows some residual discharge of the harmful material constitutes a licence to pollute. The crucial point about an economic instrument is that it acts as a strong incentive for pollution prevention and technological change, and also raises money (perhaps to remediate past problems). Thus, the "licence to pollute" argument against economic instruments must be dismissed as both facile and fallacious.

6.6.3 International Competitiveness

The argument is frequently put that any attempt to take economic measures against polluting firms will somehow harm Canada's trading position. This argument is counter-productive for at least four reasons.

First, input charges aimed at environmental improvement operate in the direction of making firms more efficient with respect to their resource use. Economic history shows that the more efficient a firm's, and, ultimately, a nation's use of its factors of production, the more productive will be that firm and nation. A clear example, although not from the environmental field *per se*, can be seen in viewing Japan's reaction to the energy price shocks of the 1970s. The fact that Japanese producers, by whatever public policy, were not sheltered from the effects of rising (energy) prices made industry much more efficient. They also paid for the energy by increasing exports. The results are clear today, with the Japanese economy generating a bumper crop of international trade surpluses. It has very significant technological changes in the international auto/truck industry, toward increased fuel efficiency. There is no reason at all why such a dynamic cannot apply equally to the use of environmental resources, given the same type of incentive structure.

Second, the claim that industries will "leave Canada" to search for pollution havens is almost certainly overrated. Industrial location is influenced by a great many factors, chief among them access to markets, access to capital, and access to a trained labour force. Many studies (e.g., Bower, 1966), including this one, have demonstrated that environmentally related costs constitute only a small proportion of production costs, and, as shown above, are unlikely ever to be major locational decision factors. While there may be occasional (and possibly well-publicized) instances of firms moving for environmental cost-related reasons, the authors believe that these are strictly marginal cases. Canada has tremendous advantages for industrial location, which, for example, underpinned the signing of NAFTA. It is unlikely that the adoption of any economic instruments under CEPA will destroy those advantages. Should the issue of "pollution havens" become important, there are multilateral and bilateral forums, such as GATT or NAFTA through which redress can be sought.

Third , Canada is a member of the group of "developed" nations, and the largest trading partner of one of the most developed, the U.S. All of these nations face similar environmental problems, including toxic chemicals, and all must eventually deal with these problems. Again, the economic policy challenge is to do this as cheaply as possible, and as shown earlier, economic instruments such as realistically set water rents are far superior to regulations in this regard.

Finally, there are definite international benefits to being able to show that an effective and efficient environmental program is in place to deal with toxic chemicals. It appears to the authors that there are some international payoffs of a non-monetary nature from such a program.

6.6.4 Market Structures

The principles underlying the call for the use of economic instruments for environmental control derive from a "pure competition" model of the economy. Opponents of such instruments invariably point out that no modern national economy bears much resemblance to a purely competitive market, and therefore that the conclusions which follow from the use of that model are invalid in various degrees. The authors acknowledge that Canada's mixed economic system is quite different from the textbook model of pure competition. The economy, in reality, contains many imperfections, such as monopoly, oligopoly, and other market forms. In addition, the involvement of public agencies themselves in the economy may be a source of such imperfections.

Despite this fact, the question must be asked, "Do these conditions really matter?" in the context of using economic instruments for environmental control. In other words, do market imperfections act in such a manner as to make economically based actions ineffective or even harmful?

The authors believe that the answer here is a resounding "No." The specific instrument put forth earlier, input charges on water to recover economic rents from resource ownership, is relatively free from the influence of market structure. This type of instrument addresses the input side of the production cycle. As such, the issue of market structure is not particularly relevant, except possibly as determining who pays the costs in the first instance.[12] Much more important are issues such as relative production costs, incentives and technologies. Input charges most certainly would have favourable impacts on these factors from the viewpoint of public policy. *In fact, this type of instrument is needed precisely to correct the market imperfections known as externalities.* It is the only way to *use* the market to correct itself.

Thus, objections based on market structure ought to be heavily discounted or even dismissed.

6.7 Summary

This section has outlined an economic interpretation of the patterns of Canadian industrial water use, which emerged from the 1991 industrial water use survey. This interpretation places economic factors at the heart of explaining these patterns. The authors view input charges, based on economic rent principles, as a major way in which public agencies could provide very substantial incentives for improving the management of industrial water use and would lead eventually to significant and environmentally beneficial technological changes. Without these types of economic reforms, improving industrial use of environmental resources will prove very difficult, if not impossible.

7. CONCLUSIONS

- Canadian industry, composed for current purposes of the mineral extraction, manufacturing, and thermal power sectors, use prodigious amounts of water as a basic and essential input to production. For the two largest users, thermal power and manufacturing, water use is very "extensive" in the sense that relatively little recirculation is used. The potential for increased recirculation, to make water use more efficient, is very large. The fact that action here occurs at a "snail-like" pace reflects the cheapness of water to industrial users.

- Recirculation rates in manufacturing continue to decline, as they have done over the entire 1972–1991 period. This trend appears related to two primary factors: the large abundance of water relative to needs and the exceptionally low costs of self-supplied water.

- By far, the greatest proportion of industrial water is derived from self-supplied systems. All major industrial operations have their own intake facilities, and draw only small amounts of water from municipalities, principally for sanitary and other domestic uses. There is, however, a significant variation from this general finding for industry groups characterized by smaller plants, or plants requiring potable water (e.g., the foods and beverages groups). These plants tend to draw more on municipal supplies than plants in the so-called heavy industries. To the extent that the former employ only rudimentary forms of water recirculation, they tend to exacerbate the overcapitalization of municipal water systems.

- Canadian industry still practices only elementary waste water treatment methods. Even the most positive interpretation would find that just over 40% of discharges are treated by means of primary, mechanical methods. Even less is afforded more advanced threatment. The conclusion must be that between 50% and 60% of industrial discharges are untreated at the present time.

- The industrial plants included in the survey, for the most part, discharged their wastes, either untreated or partially treated, directly to surface waters. A relatively minor portion of waste water was discharged to municipal treatment systems. The amounts discharged to municipal systems showed a substantial relationship to plant size, with

[12] Over the long run, of course, all members of society pay for achieving environmental quality. The question "Who pays?" is therefore an equity question, which, although important, does not conflict with the objective of achieving adequate environmental quality *at minimum cost.*

smaller plants tending to use public faciliities to a much greater extent than larger plants, principally because of the costs involved in building, operating, and maintaining on-site treatment facilities.

- Canadian industries paid less than 1% of their gross value of shipments for water and wastewater conveyancing. As noted at several places in the paper, this fact that water is "cheaper than dirt" is thought to explain why Canadian industries are relatively primitive in their water using practices.

- Industrial water use has grown consistently through the entire 1972–1991 period covered by Environment Canada's industrial water use surveys. Growth in the thermal power sector, the largest water-using sector, was the chief contributing factor in this growth, dwarfing all of the other sectors. Manufacturing water use grew during the 1972–1981 period, but has fallen substantially since 1991. Because this decline in manufacturing water use was accompanied by falling recirculation rates, increasing water use efficiency is not the explanation for decreased manufacturing water use. Rather, the authors believe that structural changes in the Canadian manufacturing base are largely responsible for this trend in manufacturing water use, but this will remain hypothetical until the required research to show this structural change effect.

- Total water use was dominated by the thermal power generation industry, which accounts for about two-thirds of total gross water use. Almost exclusively, plants in this industy, which are located adjacent to large water bodies, employ once-through cooling systems and recirculate no water. One exception is a thermal power plant in Alberta. In terms of current economic conditions and relatively narrow private or quasi-private interest, once-through cooling is justified to maximize returns on investment. On the other hand, it is antithetical to sustainability principles, especially should increased water rents be implemented to encourage more efficient water use.

- The explanation for the water use inefficiencies observed in this paper resides to a large degree in the lack of economic incentives to adopt better methods. In spite of a number of unjustified "myths" that have developed concerning the use of économic principles for improved water use, the authors believe that economic reform holds the key to increased efficiency. The principal mechanisms through which this will occur are the adoption of existing improved management practices, such as recirculation technology, and the future occurrence of technological changes to alter production processes and/or products themselves. Such changes are highly unlikely without basic economic reforms, such as realistic pricing, rent capture, and effluent discharge fees.

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Statistics Canada / Statistique Canada

WATER USE IN MANUFACTURING INDUSTRIES 1991

Si vous désirez un questionnaire français, veuillez cocher et retourner à la Division des opérations et de l'intégration, Statistique Canada, Ottawa, K1A 0T6. ☐

In all correspondence concerning the questionnaire please refer to the first seven digits in the top line of the mailing address below:

Mailing Address (Please correct if necessary)

Physical Location of Establishment (Please correct if necessary)

(Form EC-5-3309-2.1)

SECTION 1: GENERAL INFORMATION

1.1 AUTHORITY

This survey is conducted under the authority of the Statistics Act, R.S.C. 1985, Chapter S-19. To reduce response burden and to ensure more uniform statistics, Statistics Canada has entered into an agreement with the Department of the Environment under Section 12 of the Statistics Act for sharing of data herein. This Section 12 agreement shall not apply if an authorized officer or person of your Company **objects in writing to the Chief Statistician and mails that letter to the Operations and Integration Division of Statistics Canada** together with the completed questionnaire.

The Department of the Environment may in turn share data if requested by the provincial agencies (as listed below) with the province in which this establishment is located **if you so consent in writing**. These agencies are: Newfoundland Department of the Environment and Lands, Prince Edward Island Department of the Environment, Nova Scotia Department of the Environment, New Brunswick Department of the Environment, le ministère de l'Environnement Québec, Ontario Ministry of the Environment, Manitoba Department of Natural Resources, Saskatchewan Water Corporation, Alberta Department of the Environment and British Columbia Ministry of Environment, or their successor or equivalent provincial agencies.

I consent to the sharing of the data by the Department of the Environment with the provincial agencies (if requested) within the province in which this establishment is located, for statistical, research and planning purposes.

Signature of authorized official: ____________________

1.2 COMPLETION AND RETURN

The data included in this report must relate to the **calendar year 1991**. Please complete this questionnaire **within 30 days of receipt**, and return it to Statistics Canada utilizing the return envelope provided.

NOTE

(i) Shaded areas are for office use only.
(ii) Water volumes are to be reported in the units in use at the plant. Some of the more common units are:

	Code
☐ thousand imperial gallons	0.1
☐ cubic feet	0.2
☐ cubic metres	0.3

If one of these units has been used, please check the appropriate box.
If another unit has been used, please specify: ____________________ **0.4**

Please confirm that your water is not measured in tens (10's) or hundreds (100's) of units reported.
Please report all monthly or annual water volumes in the units indicated above.
(iii) Please report all cost items in Canadian dollars (to the nearest $000's).
(iv) Where exact values are not available, please estimate.

DETAILS OF OPERATION	Code	Number
1a Indicate the average number of employees:	1.1	
1b Indicate the number of days of operation during the reporting period:	1.2	
1c Indicate the average number of hours worked in an average day:	1.3	

1d Indicate the major products produced by your plant: ____________________

SECTION 2: MONTHLY AND ANNUAL TOTAL WATER INTAKE AND DISCHARGE

INSTRUCTIONS

(i) In this section, under intake, please report by month the quantity of "new water" brought into your operation and under discharge the quantity of water routed to its ultimate point of discharge. For the purpose of this questionnaire "new water" is defined as water introduced for the first time into this establishment regardless of source or quality.

(ii) Report in units specified in section 1.2 (ii).

(iii) Under discharge **do not report** the volume of water released to ponds, lagoons or basins and intended for recirculation or reuse until such water is actually discharged to a location beyond the control of the plant.

(iv) Under discharge **do not include** any water lost in production through evaporation, permanently held in open or closed storage, or otherwise consumed (e.g. included in a final product).

(v) Annual total intake should be greater than or equal to annual total discharge.

(vi) Where you supply water to adjacent industry(ies) or municipality(ies), please report estimated water intake for your plant only.

Month	**Code**	Volume per month		Month	**Code**	Volume per month	
		Intake	Discharge			Intake	Discharge
January	**2.1**			July	**2.7**		
February	**2.2**			August	**2.8**		
March	**2.3**			September	**2.9**		
April	**2.4**			October	**2.10**		
May	**2.5**			November	**2.11**		
June	**2.6**			December	**2.12**		
				ANNUAL TOTAL	**2.13**		

2a	Estimated annual cost of water acquisition	**2.39**	COST	Payment to public utility:	$
		2.40	COST	In-house operating and maintenance costs (excluding water treatment costs):	$
		2.41	COST	Cost of your plant's annual intake licence (if applicable):	$

If the annual total intake amount indicated in box 2.13 above is less than: 1,000,000 gallons, or 160,000 cubic feet, or 4,500 cubic metres, then please ignore the remaining questions, sign the back page, and return the questionnaire as instructed on page 1. Thank you.

SECTION 3: WATER INTAKE BY SOURCE AND KIND

INSTRUCTIONS

(i) Report in units specified in section 1.2(ii), OR as a percentage of the annual total as reported in section 2.13 above. Where percentages are used, please indicate with a percent sign (%).

(ii) "Brackish water" is defined as water containing more than 1,000 parts per million of dissolved solids.

	SOURCE	3.0	%	**Code**	Volume per year	
					Fresh	Brackish
3a	Public water utility system (name)..			**3.1**		**xxxx**
3b	Self-supplied surface water system (lake, river, etc.) (name)..			**3.2**		**xxxx**
3c	Self-supplied groundwater system (well, spring, etc.) (specify)			**3.3**		
3d	Self-supplied tide water (salt water) body (estuary, bay, ocean, etc.) (name)..			**3.4**	**xxxx**	
3d	Other sources (specify...			**3.5**		
3f	Total water intake (sum of 3a to 3e). (Quantity should equal the amount reported in box 2.13 or 100%).......................			**3.6**		

SECTION 4: TREATMENT OF INTAKE WATER

INSTRUCTIONS (i) Indicate the amount of intake water treated within your plant prior to use.

(ii) Report in units specified in section 1.2 (ii).

	CATEGORY OF TREATMENT	Code	Volume per year
4a	Filtration	**4.1**	
4b	Chlorination & disinfection	**4.2**	
4c	Corrosion and slime control	**4.3**	
4d	Screening	**4.4**	
4e	Hardness and alkalinity control	**4.5**	
4f	Other (specify)	**4.6**	

4g	Estimated annual operating and maintenance cost of water treatment	**4.8**	COST	$

SECTION 5: WATER INTAKE BY PURPOSE

INSTRUCTIONS (i) Report the amount of water within your plant by **initial** use. This section should not include recirculated water except as stated in section 5a (For a definition of "recirculated water", see section 6)

(ii) In 5d "Other uses" should not include water pumped by the plant, and intended for initial use outside the plant.

(iii) Report in units specified in section 1.2 (ii) OR as a percentage of annual total as reported in section 2.13. Where percentages are used please indicate with a percent sign (%).

	PURPOSE	5.0	%	Code	Volume per year
5a	Process water - includes all water **which comes in direct contact** with products and/or materials. It is further defined to include water which is consumed in milling and special processes, water which is included in final output or water which has been used for another purpose, and is undergoing its final use as process water.			**5.1**	
5b	Cooling, condensing and steam - defined as water **which does not come in direct contact** with the products, materials or by-products of the processing operation. Includes pass-through water used in the operation of cooling or process equipment (including air conditioning) and water introduced into boilers for the production of steam for either process operations or electric power.			**5.2**	
5c	Sanitary service (including janitorial services) (The average toilet uses 4 gallons, 18 litres, 0.018 cubic metres or 0.64 cubic feet per flush.)			**5.3**	
5d	Other uses (specify)			**5.4**	
5e	Total (5a to 5d should equal sum of figures reported in box 2.13 or 100%)			**5.5**	

SECTION 6: WATER RECIRCULATED OR REUSED BY PURPOSE

INSTRUCTIONS (i) For water recirculated or reused within your plant, please indicate the additional quantity of water that would have been required by purpose had no water been recirculated or reused. For the purpose of this questionnaire, "**water recirculated or reused**" is defined as water which is discharged from the plant or from a particular process within the plant, and which is subsequently recycled into the same process or into a different process within the plant.

(ii) Report in units specified in section 1.2 (ii).

	PURPOSE	Code	Volume per year
6a	Process	**6.1**	
6b	Cooling, condensing, and steam	**6.2**	
6c	Other uses (specify)	**6.3**	
6d	Total (items 6a to 6c)	**6.4**	

6g	Estimated annual operating and maintenance cost of water recirculation	**6.5**	COST	$

SECTION 7: TREATMENT OF WATER PRIOR TO DISCHARGE

INSTRUCTIONS
(i) In items 7a to 7c, specify treatment process used in each of the treatment methods.
(ii) Include only on-site treatment.
(iii) Report in units specified in section 1.2 (ii).

	TREATMENT METHOD	Code	Volume per year
7a	Primary or mechanical (specify process) (i)	**7.2**	
	(ii)	**7.3**	
7b	Secondary or biological (specify process) (i)	**7.4**	
	(ii)	**7.5**	
7c	Tertiary or advanced treatment (specify process) (i) (include toxics removal)	**7.6**	
	(ii)	**7.7**	

7d	Estimated annual operating and maintenance cost of treatment prior to discharge	**7.9**	COST	$

7e	Please indicate if your final plant effluent is monitored (by any agency) for (check the appropriate items ☒): ☐ B.O.D. ☐ S.S. ☐ Phenols ☐ Toxics ☐ pH ☐ Grease ☐ Temperature ☐ Colour ☐ Other	**7.10**	

SECTION 8: WATER DISCHARGE

INSTRUCTIONS
(i) In this section, please report the volume of all water routed to its ultimate point of discharge.
(ii) Report in units specified in section 1.2 (ii), OR as a percentage of the annual total discharge reported in section 2.13. Where percentages are used, please indicate with a percent sign (%).
(iii) **Do not report** the volume of water released to ponds, lagoons or basins and **intended for recirculation or reuse** until such water is actually discharged to a location beyond the control of the plant.
(iv) **Do not include** the volume of water lost in production through evaporation, permanently held in open or closed storage or otherwise consumed and not brought to the ultimate point of discharge.
(v) In item 8e, please identify the use intended.
(vi) If discharge is not metered, please provide your best estimate.

	DISCHARGE POINT	8.0	%	Code	Volume per year
8a	Public utility sewer (municipality, etc.) (name)			**8.1**	
8b	Fresh water body (lake, river, etc.) (name)			**8.2**	
8c	Tide water (salt water) body (estuary, bay, ocean, etc.) (name)			**8.3**	
8d	Ground (including well disposal) (specify)			**8.4**	
8e	Transferred to other uses outside your plant (specify)			**8.7**	
8f	Total water discharge (Quantity should equal discharge values as reported in box 2.13 or 100%)			**8.8**	

8g	Gross value of shipments for your plant in 1991 (or fiscal year 1995-96)	**8.14**	VALUE	$
8h	Total capital expenditures made at this plant on water related facilities in 1991 (or fiscal year 1990-91)	**8.15**	EXPENDITURES	$

CERTIFICATION *I certify that the information herein is complete and correct to the best of my knowledge and belief and covers the calendar year 1991.*

Signature of authorized person		Title	Date
Name of contact regarding this report	Area code	Telephone number	Ext.
Comments			
			Thank you

Statistics Canada / Statistique Canada

WATER USE IN MINERAL EXTRACTION INDUSTRY 1991

Si vous désirez un questionnaire français, veuillez cocher et retourner à la Division des opérations et de l'intégration, Statistique Canada, Ottawa, K1A 0T6. ☐

In all correspondence concerning the questionnaire please refer to the first seven digits in the top line of the mailing address below:

Mailing Address (Please correct if necessary)

Physical Location of Establishment (Please correct if necessary)

(Form EC-5-3309-1.1)

SECTION 1: GENERAL INFORMATION

1.1 AUTHORITY

This survey is conducted under the authority of the Statistics Act, R.S.C. 1985, Chapter S-19. To reduce response burden and to ensure more uniform statistics, Statistics Canada has entered into an agreement with the Department of the Environment under Section 12 of the Statistics Act for sharing of data herein. This Section 12 agreement shall not apply if an authorized officer or person of your Company **objects in writing to the Chief Statistician and mails that letter to the Operations and Integration Division of Statistics Canada** together with the completed questionnaire.

The Department of the Environment may in turn share data if requested by the provincial agencies (as listed below) with the province in which this establishment is located **if you so consent in writing**. These agencies are: Newfoundland Department of the Environment and Lands, Prince Edward Island Department of the Environment, Nova Scotia Department of the Environment, New Brunswick Department of the Environment, le ministère de l'Environnement Québec, Ontario Ministry of the Environment, Manitoba Department of Natural Resources, Saskatchewan Water Corporation, Alberta Department of the Environment and British Columbia Ministry of Environment, or their successor or equivalent provincial agencies.

I consent to the sharing of the data by the Department of the Environment with the provincial agencies (if requested) within the province in which this establishment is located, for statistical, research and planning purposes.

Signature of authorized official: ______________________________

1.2 COMPLETION AND RETURN

The data included in this report must relate to the **calendar year 1991**. Please complete this questionnaire **within 30 days of eceipt**, and return it to Statistics Canada utilizing the return envelope provided.

NOTE

(i) Shaded areas are for office use only.
(ii) Water volumes are to be reported in the units in use at the plant. Some of the more common units are:

	Code
☐ thousand imperial gallons	0.1
☐ cubic feet	0.2
☐ cubic metres	0.3

If one of these units has been used, please check the appropriate box.
If another unit has been used, please specify: ______________________ **0.4**

Please confirm that your water is not measured in tens (10's) or hundreds (100's) of units reported.
Please report all monthly or annual water volumes in the units indicated above.
(iii) Please report all cost items in Canadian dollars (to the nearest $000's).
(Iv) Where exact values are not available, please estimate.

	DETAILS OF OPERATION	Code	Number
1a	Indicate the average number of employees (including administrative staff):	1.1	
1b	Indicate the number of days of operation during the reporting period:	1.2	
1c	Indicate the average number of hours worked in an average day:	1.3	
1d	Indicate the principal output and the type of operation carried on by this unit (i.e. underground mine, stripmine, gas plant, oil extraction plant, etc.)	1.12	
1e	Has there been an addition to or a change of technology in the mine or plant since the 1991 survey or in the last five (5) years? If yes, please explain	1.11	1 ☐ **yes** 2 ☐ **no**

SECTION 2: MONTHLY AND ANNUAL TOTAL WATER INTAKE AND DISCHARGE

INSTRUCTIONS

(i) In this section, under intake, please report by month the quantity of "new water" brought into your operation and under discharge the quantity of water routed to its ultimate point of discharge. For the purpose of this questionnaire "new water" is defined as water introduced for the first time into this establishment regardless of source or quality.

(ii) Report in units specified in section 1.2 (ii).

(iii) In mining operations please include waste water pumped from the mine, and not used for any other purpose **as discharge water only**.

(iv) In oil and gas operations please include produced water not reused for any other purpose (or for reinjection) **as discharge water only**. "Produced water" is defined as water which is removed from the original oil-water mixture.

(v) Under discharge **do not include** any water lost in production through evaporation, permanently held in open or closed storage or otherwise consumed (e.g. included in a final product or slurry), include such water only as intake.

(vi) Under discharge **do not report the volume of water** released to ponds, lagoons, or basins **and intended for recirculation or reuse**, until such water is actually discharged to a location beyond the control of the mine or plant.

(vii) Annual total discharge may be greater than annual total intake as explained above in items 2(iii) and 2(iv).

(viii) Where you supply water to adjacent industry(ies) or municipality(ies), please report estimated water intake for your operation only.

Month	Code	Volume per month		Month	Code	Volume per month	
		Intake	Discharge			Intake	Discharge
January	**2.1**			July	**2.7**		
February	**2.2**			August	**2.8**		
March	**2.3**			September	**2.9**		
April	**2.4**			October	**2.10**		
May	**2.5**			November	**2.11**		
June	**2.6**			December	**2.12**		
				ANNUAL TOTAL	**2.13**		

		Code			
2a	Of the reported annual volumes of discharge water (2.13) what volume of water originated as mine water or waste water pumped from the mine?	**2.26**		OR	%

		Code			
2b	Estimated annual cost of water acquisition	**2.39**	COST	Payment to public utility:	$
		2.40	COST	Operating and maintenance costs (excluding water treatment costs):	$
		2.41	COST	Cost of your mine's or plant's annual intake licence (if applicable):	$

If the annual total intake amount indicated in box 2.13 above is less than: 1,000,000 gallons, or 160,000 cubic feet, or 4,500 cubic metres, then please ignore the remaining questions, sign the back page, and return the questionnaire as instructed on page 1. Thank you.

SECTION 3: WATER INTAKE BY SOURCE AND KIND

INSTRUCTIONS

(i) Report in units specified in section 1.2 (ii), OR as a percentage of the annual total as reported in section 2.13 above. Where percentages are used, please indicate with a percent sign (%).

(ii) "Brackish water" is defined as water containing more than 1,000 parts per million of dissolved solids.

	SOURCE	3.0	%	Code	Volume per year	
					Fresh	Brackish
3a	Public water utility system (name)..			**3.1**		**xxxx**
3b	Self-supplied surface water system (lake, river, etc.) (name)..			**3.2**		**xxxx**
3c	Self-supplied groundwater system (well, spring, etc.) (specify)..			**3.3**		
3d	Self-supplied tide water (salt water) body (estuary, bay, ocean, etc.) (name)..			**3.4**	**xxxx**	
3e	Other sources (specify)..			**3.5**		
3f	Total water intake (sum of 3a to 3e). (Quantity should equal the amount reported in box 2.13 or 100%).......................			**3.6**		

SECTION 4: TREATMENT OF INTAKE WATER

INSTRUCTIONS (i) indicate the amount of intake water treated within your operation prior to use.
(ii) Report in units specific in section 1.2 (ii).

	CATEGORY OF TREATMENT	Code	Volume per year
4a	Filtration	**4.1**	
4b	Chlorination & disinfection	**4.2**	
4c	Corrosion and slime control	**4.3**	
4d	Screening	**4.4**	
4e	Hardness and alkalinity control	**4.5**	
4f	Other (specify)	**4.6**	

4g	Estimated annual operating and maintenance cost of water treatment	**4.8**	COST	$

SECTION 5: WATER INTAKE BY PURPOSE

INSTRUCTIONS (i) Report the amount of water within your establishment by **initial** use. This section should not include recirculated water except as stated in section 5a. (For a definition of "recirculated water", see section 6)
(ii) In 5d "Other uses" should not include water pumped by mine or plant facility, and intended for initial use outside the operation.
(iii) Report in units specified in section 1.2(ii) OR as a percentage of annual total as reported in section 2.13. Where percentages are used please indicate with a percent sign (%).

	PURPOSE	5.0	%	Code	Volume per year
5a	Process water - includes all water **which comes in direct contact** with products and/or materials. It is further defined to include water which is consumed in milling and special processes, water which is included in final output or water which has been used for another purpose, and is undergoing its final use as process water.			**5.1**	
5b	Cooling, condensing and steam - defined as water **which does not come in direct contact** with the products, materials or by-products of the processing operation. Includes pass-through water used in the operation of cooling or process equipment (including air conditioning) and water introduced into boilers for the production of steam for either process operations or electric power.			**5.2**	
5c	Sanitary service (including janitorial services) (The average toilet uses 4 gallons, 18 litres, 0.018 cubic metres or 0.64 cubic feet per flush.)			**5.3**	
5d	Other uses (specify)			**5.4**	
5e	Total (5a to 5d should equal sum of figures reported in box 2.13 or 100%)			**5.5**	

5f	What volume of intake water was used as injected water or steam in the secondary recovery of oil or natural gas?	**5.22**	
5g	Of the annual volume of intake water for process reported in 5a, what volume of water was consumed or lost?	**5.23**	
5h	Of the volume of intake water for cooling, condensing, or steam production reported in 5b, what volume of water was consumed or lost?	**5.24**	

SECTION 6: WATER RECIRCULATED OR REUSED BY PURPOSE

INSTRUCTIONS (i) For water recirculated or reused within your plant, please indicate the additional quantity of water that would have been required by purpose had no water been recirculated or reused. For the purpose of this questionnaire, "**water recirculated or reused**" is defined as water which is discharged from the plant or from a particular process within the plant, and which is subsequently recycled into the same process or into a different process within the plant.
(ii) Report in units specified in section 1.2 (ii).

	PURPOSE	Code	Volume per year
6a	Process	**6.1**	
6b	Cooling, condensing, and steam	**6.2**	
6c	Other uses (specify)	**6.3**	
6d	Total (items 6a to 6c)	**6.4**	

6e	Does this operation have a tailings pond?	**6.6**	1 ☐ Yes 2 ☐ No
	If yes, indicate the volume of water recirculated or reused from the tailings pond	**6.7**	
6f	Does this operation inject water into an oil bearing formation?	**6.11**	1 ☐ Yes 2 ☐ No
	If yes, indicate the volume of water injected	**6.12**	

6g	Estimated annual operating and maintenance cost of water recirculation	**6.5**	COST	$

SECTION 7: TREATMENT OF WATER PRIOR TO DISCHARGE

INSTRUCTIONS
(i) In items 7a to 7c, specify treatment process used in each of the treatment methods.
(ii) Include only on-site treatment.
(iii) Report in units specified in section 1.2 (ii).

	TREATMENT METHOD	Code	Volume per year
7a	Primary or mechanical (specify process) (i)	**7.2**	
	(ii)	**7.3**	
7b	Secondary or biological (specify process) (i)	**7.4**	
	(ii)	**7.5**	
7c	Tertiary or advanced treatment (specify process) (i) (include toxics removal)	**7.6**	
	(ii)	**7.7**	

7d	Estimated annual operating and maintenance cost of treatment prior to discharge	**7.9**	COST	$

7e	Please indicate if your final plant effluent is monitored (by any agency) for (check the appropriate items ☒): ☐ B.O.D. ☐ S.S. ☐ Phenols ☐ Toxics ☐ pH ☐ Grease ☐ Temperature ☐ Colour ☐ Other	**7.10**	

SECTION 8: WATER DISCHARGE

INSTRUCTIONS
(i) In this section, please report the volume of all water routed to its ultimate point of discharge.
(ii) Report in units specified in section 1.2 (ii), OR as a percentage of the annual total discharge reported in section 2.13. Where percentages are used, please indicate with a percentage (%).
(iii) **Do not report** the volume of water released to ponds, lagoons or basins and **intended for recirculation or reuse** until such water is actually discharged to a location beyond the control of the mine or plant.
(Iv) **Do not include** the volume of water lost in production through evaporation, permanently held in open or closed storage or otherwise consumed and not brought to the ultimate point of discharge.
(v) In items 8e and 8f, please identify the use intended.
(vi) If discharge is not metered, please provide your best estimate.

	DISCHARGE POINT	8.0	%	Code	Volume per year
8a	Public utility sewer (municipality, etc.) (name)			**8.1**	
8b	Fresh water body (lake, river, etc.) (name)			**8.2**	
8c	Tide water (salt water) body (estuary, bay, ocean, etc.) (name)			**8.3**	
8d	Ground (including well disposal) (specify)			**8.4**	
8e	Discharged from tailings pond or injected to producing formation (specify)			**8.5**	
8f	Transferred to other uses outside your operation (specify)			**8.7**	
8g	Total water discharge (Quantity should equal discharge values as reported in box 2.13 or 100%)			**8.8**	

8h	Gross value of shipments for your plant in 1991 (or fiscal year 1990-91)	**8.14**	VALUE	$
8i	Total capital expenditures made at this plant on water related facilities in 1991(or fiscal year 1990-91)	**8.15**	EXPENDITURES	$

CERTIFICATION *I certify that the information herein is complete and correct to the best of my knowledge and belief and covers the calendar year 1991.*

Signature of authorized person		Title	Date
Name of contact regarding this report	Area code	Telephone number	Ext
Comments			
			Thank you

Statistics Canada | Statistique Canada

WATER USE BY THERMAL POWER PLANTS 1991

In all correspondence concerning the questionnaire please refer to the first seven digits in the top line of the mailing address below:

Si vous désirez un questionnaire français, veuillez cocher et retourner à la Division des opérations et de l'intégration, Statistique Canada, Ottawa, K1A 0T6. ☐

Mailing Address (Please correct if necessary)

Physical Location of Establishment (Please correct if necessary)

(Form EC-5-3309-3.1)

SECTION 1: GENERAL INFORMATION

1.1 AUTHORITY

This survey is conducted under the authority of the Statistics Act, R.S.C. 1985, Chapter S-19. To reduce response burden and to ensure more uniform statistics, Statistics Canada has entered into an agreement with the Department of the Environment under Section 12 of the Statistics Act for sharing of data herein. This Section 12 agreement shall not apply if an authorized officer or person of your Company **objects in writing to the Chief Statistician and mails that letter to the Operations and Integration Division of Statistics Canada** together with the completed questionnaire.

The Department of the Environment may in turn share data if requested by the provincial agencies (as listed below) with the province in which this establishment is located **if you so consent in writing**. These agencies are: Newfoundland Department of the Environment and Lands, Prince Edward Island Department of the Environment, Nova Scotia Department of the Environment, New Brunswick Department of the Environment, le ministère de l'Environnement Québec, Ontario Ministry of the Environment, Manitoba Department of Natural Resources, Saskatchewan Water Corporation, Alberta Department of the Environment and British Columbia Ministry of Environment, or their successor or equivalent provincial agencies.

I consent to the sharing of the data by the Department of the Environment with the provincial agencies (if requested) within the province in which this establishment is located, for statistical, research and planning purposes.

Signature of authorized official: ______________________________

1.2 COMPLETION AND RETURN

The data included in this report must relate to the **calendar year 1991**. Please complete this questionnaire **within 30 days of eceipt**, and return it to Statistics Canada utilizing the return envelope provided.

NOTE

(i) Shaded areas are for office use only.

(ii) Water volumes are to be reported in the units in use at the plant. Some of the more common units are:

	Code
☐ thousand imperial gallons	0.1
☐ cubic feet	0.2
☐ cubic metres	0.3

If one of these units has been used, please check the appropriate box.
If another unit has been used, please specify: ______________________________ | 0.4

Please confirm that your water is not measured in tens (10's) or hundreds (100's) of units reported.
Please report all monthly or annual water volumes in the units indicated above.

(iii) Please report all cost items in Canadian dollars (to the nearest $000's).

(iv) Where exact values are not available, please estimate.

	DETAILS OF OPERATION		Code	Number
1a	Indicate the average number of employees required to operate the power plant in 1991:		1.1	employees
1b	Indicate the number of days of operation during 1991:		1.2	days
1c	Indicate the average number of hours worked in an average day:		1.3	hours
1d	Indicate the amount of power produced at this plant in 1991:	(i) net generation	1.4	Mwh
		(ii) station service	1.5	Mwh
1e	Indicate the average heat rate of the plant:		1.6	BTU / kwhr
1f	Indicate the capacity of water intake pumps (specify units):		1.7	
1g	Indicate the generation capacity of this plant in 1991:		1.8	MW
1h	Does your facility provide water for uses other than in the power plant: (specify use) ------------------------------		1.9	1 ☐ **yes** 2 ☐ **no**

SECTION 2: MONTHLY AND ANNUAL TOTAL WATER INTAKE AND DISCHARGE

INSTRUCTIONS

(i) In this section, under intake, please report by month the quantity of "new water" brought into your operation for power plant use and under discharge the quantity of water routed to its ultimate point of discharge. For the purpose of this questionnaire "new water" is defined as water introduced for the first time into this establishment regardless of source or quality. " New water" also includes water diverted from a natural resource into storage ponds or outside holding facilities for later use.

(ii) Report in units specified in section 1.2 (ii).

(iii) Under discharge **do not include** the volume of water released to ponds, lagoons or basins and **intended for recirculation or reuse**, until such water is actually discharged to a location beyond the control of the plant.

(iv) Under discharge **do not include** any water lost in production through evaporation, permanently held in open or closed storage, or otherwise consumed.

(v) Annual intake should be greater than or equal to annual total discharge.

(vi) Where you supply water to adjacent industry(ies) or municipality(ies), please report estimated water intake for your plant only.

Month	Code	Volume per month		Month	Code	Volume per month	
		Intake	Discharge			Intake	Discharge
January	**2.1**			July	**2.7**		
February	**2.2**			August	**2.8**		
March	**2.3**			September	**2.9**		
April	**2.4**			October	**2.10**		
May	**2.5**			November	**2.11**		
June	**2.6**			December	**2.12**		
				ANNUAL TOTAL	**2.13**		

2a	Estimated annual cost of water acquisition	**2.39**	COST	Payment to public utility:	$
		2.40	COST	Operating and maintenance costs (excluding water treatment costs):	$
		2.41	COST	Cost of your plant's annual intake licence (if applicable):	$

SECTION 3: WATER INTAKE BY SOURCE AND KIND

INSTRUCTIONS

(i) Report in units specified in section 1.2 (ii), OR as a percentage of the annual total as reported in section 2.13 above. Where percentages are used, please indicate with a percent sign (%).

(ii) "Brackish water" is defined as water containing more than 1,000 parts per million of dissolved solids.

SOURCE	3.0	%	Code	Volume per year	
				Fresh	Brackish
3a Public water utility system (name)..			**3.1**		**xxxx**
3b Self-supplied surface water system (lake, river, etc.) (name)..			**3.2**		**xxxx**
3c Self-supplied groundwater system (well, spring, etc.) (specify)			**3.3**		
3d Self-supplied tide water (salt water) body (estuary, bay, ocean, etc., etc.) (name)..			**3.4**	**xxxx**	
3e Other sources (specify)			**3.5**		
3f Total water intake (sum of 3a to 3e) (Quantity should equal the amount reported in box 2.13 or 100%)			**3.6**		

SECTION 4: TREATMENT OF INTAKE WATER

INSTRUCTIONS (i) indicate the amount of intake water treated within your plant prior to use.
(ii) Report in units specific in section 1.2 (ii).

	CATEGORY OF TREATMENT	Code	Volume per year
4a	Filtration..	**4.1**	
4b	Chlorination & disinfection..	**4.2**	
4c	Corrosion and slime control..	**4.3**	
4d	Screening..	**4.4**	
4e	Hardness and alkalinity control..	**4.5**	
4f	Other (specify)	**4.6**	

4g	Estimated annual operating and maintenance cost of water treatment	**4.8**	COST	$

SECTION 5: WATER USAGE

INSTRUCTIONS (i) Report the amount of water used within the thermal plant by **initial** use. This section should not include recirculated water
(ii) Report in units specified in section 1.2 (ii) OR as a percentage of annual total as reported in section 2.13. Where percentages are used please indicate with a percent sign (%).

			Code		
5a	Is there a water-cooled condenser in your plant?		**5.6**	1 ☐ Yes	2 ☐ No
	If yes, what is the design temperature rise of the cooling water in your condenser cooling cycle?		**5.7**	___________	°C (ex. 25°C)
5b	What kind of cooling system is employed in your plant?	(i) once-through	**5.25**	1 ☐ Yes	2 ☐ No
		(ii) cooling pond	**5.26**	1 ☐ Yes	2 ☐ No
		(a) on stream	**5.27**	1 ☐ Yes	2 ☐ No
		(b) off stream	**5.28**	1 ☐ Yes	2 ☐ No
		(iii) other methods (e.g. tower) (explain)...............................	**5.29**	1 ☐ Yes	2 ☐ No
5c	Did this plant produce steam for purposes other than power generation (i.e. process, for sale)?		**5.8**	1 ☐ Yes	2 ☐ No

		5.0	%	Code	Volume per year
5d	What was the amount of boiler make-up water required for power generation purpose (excluding production for steam sales or transfer)?			**5.9**	
5e	Of the total water intake reported in box 2.13 what was the amount required for:	(i) condenser cooling for power generation purpose only?		**5.10**	
		(ii) sanitary, fire protection or other (i.e. service water)?		**5.11**	
5f	What were the estimated water losses (including evaporation and seepage):	(i) in cooling cycle?		**5.19**	
		(ii) in ash control system (include evaporation losses from ponds)?		**5.21**	

SECTION 6: WATER RECIRCULATED OR REUSED

INSTRUCTIONS (i) In this section "**water recirculated or reused**" is defined as water which is discharged from the plant or from a particular process within the plant, and which is subsequently recycled into the same process or into a different process within the plant.
(ii) Report in units specified in section 1.2 (ii).

			Code	Volume per year
6a	If this plant recirculated water in the cooling and condensing system (open or closed) estimate the amount of additional intake water that would have been required WITHOUT such recirculation having taken place (i.e. the amount of water recirculated).	(i) fresh	**6.9**	
		(ii) brackish	**6.10**	

SECTION 7: WATER DISCHARGE

INSTRUCTIONS

(i) In this section please report the volume of all water routed to its ultimate point of discharge from the plant (and/or the cooling pond if applicable).

(ii) Report in units specified in section 1.2 (ii) OR as a percentage of the annual total discharge reported in section 2.13. Where percentages are used, please indicate with a percent sign (%).

(iii) **Do not report** the volume of water released to ponds, lagoons or basins and **intended for recirculation or reuse** until such water is actually discharged.

(iv) **Do not include** the volume of water lost in production through evaporation, permanently held in open or closed storage, or otherwise consumed and not brought to the ultimate point of discharge.

(v) In item 7f please identify the use intended.

(vi) If discharge is not metered, please provide your best estimate.

DISCHARGE POINT	8.0	%	**Code**	Volume per year
7a Public utility sewer (municipality, etc.) (name)			**8.1**	
7b Fresh water body (lake, river, reservoir, etc. (name)..			**8.2**	
7c Tide water (salt water) body (estuary, bay, ocean, etc.) (name)..			**8.3**	
7d Ground (including well disposal) (specify)			**8.4**	
7e Final discharge from plant to artificial surface body (specify)..			**8.5**	
7f Transferred to other uses outside your plant (specify)..			**8.7**	
7g Total water discharge (sum of 7a to 7f)			**8.8**	
7h Was the discharge water reported in 7g treated so as not to exceed a certain given temperature? If yes, please specify the methods of heat dissipation employed			**8.9**	1 ☐ Yes 2 ☐ No

7i Indicate the highest and lowest temperatures of water permanently discharged from the plant during 1991 along with the corresponding months of occurrence (ex. 45°C).

	Code	Temperature	**Code**	Month
High	**8.10**	°C	**8.11**	
Low	**8.12**	°C	**8.13**	

7j Total capital expenditures made at this plant on water related facilities in 1991 (or fiscal year 1990-91)

8.15	EXPENDITURES	$

SECTION 8: MONTHLY AND ANNUAL POWER GENERATION

INSTRUCTIONS

(i) In this section, please break down, as accurately as possible, for the calendar year 1991 the electrical net power generation as specified in 1d (i). Please report below in net Mwh (megawatt hours) per month.

Month	**Code**	Mwh per month	Month	**Code**	Mwh per month
January	**9.14**		July	**9.20**	
February	**9.15**		August	**9.21**	
March	**9.16**		September	**9.22**	
April	**9.17**		October	**9.23**	
May	**9.18**		November	**9.24**	
June	**9.19**		December	**9.25**	
			ANNUAL TOTAL	**9.26**	

CERTIFICATION *I certify that the information herein is complete and correct to the best of my knowledge and belief and covers the calendar year 1991.*

Signature of authorized person		Title	Date
Name of contact regarding this report	Area code	Telephone number	Ext
Comments			
			Thank you

Statistics Canada Statistique Canada

HYDRO GENERATION WATER USE 1991

In all correspondence concerning the questionnaire please refer to the first seven digits in the top line of the mailing address below:

Si vous désirez un questionnaire français, veuillez cocher et retourner à la Division des opérations et de l'intégration, Statistique Canada, Ottawa, K1A 0T6. ☐

Mailing Address (Please correct if necessary)

Physical Location of Establishment (Please correct if necessary)

(Form EC-5-3309-4.1)

SECTION 1: GENERAL INFORMATION

1.1 AUTHORITY

This survey is conducted under the authority of the Statistics Act, R.S.C. 1985, Chapter S-19. To reduce response burden and to ensure more uniform statistics, Statistics Canada has entered into an agreement with the Department of the Environment under Section 12 of the Statistics Act for sharing of data herein. This Section 12 agreement shall not apply if an authorized officer or person of your Company **objects in writing to the Chief Statistician and mails that letter to the Operations and Integration Division of Statistics Canada** together with the completed questionnaire.

The Department of the Environment may in turn share data if requested by the provincial agencies (as listed below) with the province in which this establishment is located **if you so consent in writing**. These agencies are: Newfoundland Department of the Environment and Lands, Prince Edward Island Department of the Environment, Nova Scotia Department of the Environment, New Brunswick Department of the Environment, le ministère de l'Environnement Québec, Ontario Ministry of the Environment, Manitoba Department of Natural Resources, Saskatchewan Water Corporation, Alberta Department of the Environment and British Columbia Ministry of Environment, or their successor or equivalent provincial agencies.

I consent to the sharing of the data by the Department of the Environment with the provincial agencies (if requested) within the province in which this establishment is located, for statistical, research and planning purposes.

Signature of authorized official: ____________________

1.2 COMPLETION AND RETURN

The data included in this report must relate to the **calendar year 1991**. Please complete this questionnaire **within 30 days of receipt**, and return it to Statistics Canada utilizing the return envelope provided.

NOTE

(i) Shaded areas are for office use only.

1.3 LOCATION

(ii) In the space below, please indicate:

		Code
1a. Plant Name:	____________________	**0.5**
1b. River:	____________________	**0.6**

SECTION 2: MONTHLY FLOWS

INSTRUCTIONS (i) For the calendar year 1991, please provide the monthly average flow through turbines in cubic metres/second (m^3/s).

Month	Code	Flow in m^3/s	Month	Code	Flow in m^3/s
January	**2.14**		July	**2.20**	
February	**2.15**		August	**2.21**	
March	**2.16**		September	**2.22**	
April	**2.17**		October	**2.23**	
May	**2.18**		November	**2.24**	
June	**2.19**		December	**2.25**	

SECTION 3: MONTHLY SPILL

INSTRUCTIONS (i) For the calendar year 1991, please provide the monthly average spill in cubic metres/second (m^3/s) at this plant.

Month	**Code**	Spill in m^3/s	Month	**Code**	Spill in m^3/s
January	**2.27**		July	**2.33**	
February	**2.28**		August	**2.34**	
March	**2.29**		September	**2.35**	
April	**2.30**		October	**2.36**	
May	**2.31**		November	**2.37**	
June	**2.32**		December	**2.38**	

SECTION 4: WATER USE DETAILS

INSTRUCTIONS (i) Please answer the following questions in the units specified.

4a In relation to long run averages at this plant, was calendar year 1991 (please check ☒):

(1) a high water year ? ☐ (2) an average level year? ☐ (3) a low water year? ☐ | **5.14** | |

4b What was the maximum (1 hour) output of this plant in calendar year 1991? | **5.15** | MW |

4c What flow (in m^3/s) was associated with the maximum output given in question 4b above? | **5.16** | m^3/s |

4d In 1991, the capacity of this plant was used for: (check either or both items as appropriate).

(1) Peaking ☐ (2) Baseload ☐ | **5.17** | |

4e In 1991, what was the capacity factor of the plant? | **5.18** | % |

4f In 1991, the total usable storage (including pondage) available to this plant in thousands of cubic metres (000 m^3) was: | **5.18** | 000 m^3 |

SECTION 5: MONTHLY AND ANNUAL POWER GENERATION

INSTRUCTIONS (i) In this section please break down, as accurately as possible, for the calendar year 1991, the total gross electrical power generation. Please report below in Mwh (megawatt hours) per month.

Month	**Code**	Mwh per month	Month	**Code**	Mwh per month
January	**9.1**		July	**9.7**	
February	**9.2**		August	**9.8**	
March	**9.3**		September	**9.9**	
April	**9.4**		October	**9.10**	
May	**9.5**		November	**9.11**	
June	**9.6**		December	**9.12**	
			ANNUAL TOTAL	**9.13**	

CERTIFICATION *I certify that the information herein is complete and correct to the best of my knowledge and belief and covers the calendar year 1991.*

Signature of authorized person		Title	Date
Name of contact regarding this report	Area code	Telephone number	Ext.
Comments			
			Thank you