Environment Canada

Environmental Conservation Service

Inland Waters Directorate

Water Resources Research in Canada: 1979/80

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PREFACE

This report describes one step in an assessment of water resources research activities and needs. It presents a summary of research activities in the fiscal year 1979/80, and a compilation of research activities that are perceived to have priority in the coming decade. It is based on information received from persons in the federal, provincial, private and university sectors. Some of the information on present activities was obtained from letters responding to a request sent out by the Deputy Minister of Environment Canada early in the summer of 1980. Further information on present activities and future research needs was obtained from interviews with selected groups in November and December 1980.

The report is to serve as background information for proposed workshops on water resources research schedulled for the spring of 1981. Consequently, it is a straightforward presentation of findings without interpretation nor editorial comment. For the most part, sources of information are clearly identified. In some cases, it was necessary to combine suggestions for future research and to show several sources for the ideas. Hopefully, the process of combination has not seriously distorted the meaning of the suggestions made to the author.

Inevitably, this report will be compared with the report of Messrs. Bruce and Maaslund to the Science Council in 1968. Anyone making such a comparison must remember that the 1968 report gave the final syntheses and conclusions for an extensive investigation that included input from several consultants. The report that follows is just the first step in a longer assessment. Information will be found herein, but no synthesis nor recommendations.

Appended to the report is a list of those who made written contributions or who participated in interviews. Their sincere and significant efforts are gratefully acknowledged. Without their help, there would have been no report.

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I INTRODUCTION

This report contains a compilation of water resources research activities in Canada in 1979/80. It also contains a presentation of research needs in the coming 10 years.

An attempt has been made to include, in the report, the activities and perceived needs of federal and provincial government departments and agencies, universities, and the private sector. The information in the report was obtained through correspondence and interviews. It was not possible to write to nor speak to all persons in Canada engaged in water resources research. Consequently, although this provides a national picture of water resources research, it does not claim 100% accuracy. As will be noted later, some estimates and approximations were necessary to allow for work being done by those not interviewed, and to estimate the portion of operational water resources activity that could be described as research.

It is logical to begin a report on water resources research in Canada with answers to two questions "What is water resources research?" and "Why is the subject of interest at this time?"

Water resources research for the purposes of this report is defined in Appendix 1, by category and sub-category. In interpreting that impressive list, a decision to include or exclude a piece of work as research was made by asking the question "Is there a strong element of innovation, or does the work significantly advance the frontiers of knowledge". The nine main categories are:

Category	Title
100	The Nature of Water
200	The Hydrologoc Cycle
300	Water supply augmentation and conservation
400	Water quantity management and control
500	Water quality management and protection
600	Economic, social, and institutional aspects
700	Resources data
800	Engineering work
900	Environmental impacts

The definition is broad because water appears naturally in many forms and settings. Also our high technology has a tremendous appetite for water and a trememdous impact on its quality as well as river flows and lake levels. Our technology is giving us more time to understand and enjoy the rich envvironment of this planet. Our need to maintain that technology in harmony with the environment demands better knowledge of all aspects of water in its natural or altered states. The problems to be solved are diverse, so the definition of research must be broad.

A review of water resources research was reported by Bruce and Massland[1] in 1968 based on activities in 1966. That report was valuable in developing water research policies and setting research priorities for several years. Early in 1980, the Assistant Deputy Minister (ADM) of the Environmental Conservation service (Environment Canada) agreed with his Director General of Inland Waters that it was time to review water resources research again. Since 1968, several new factors have arisen that require another look at research activities and priorities. It is interesting to note that the ADM was co-author of the 1968 report.

After a decade of research - and a decade of population and industrial growth - the problems of water quality management and protection are seen to be much more complex and more difficult to solve. Improved chemical analysis capability has revealed scores of new contaminants, mostly complex organics. Now we must know how they are formed, how they reach the water environment, how they move through biological, chemical and physical pathways to reach man and other biota and how they affect their ultimate hosts. We must know how their production can be controlled or eliminated or how wastes can be treated to eliminate them. And we must know the associated costs or economic trade-offs if policies are enforced to eliminate the release of such substances to the environment.

In the past ten years, a growing public awareness of the need for environmental protection has stimulated interest in the effects of river and Lake regulation on aquatic and riparian habitats (of river and lake regulation). Again, we lack the knowledge to determine fully the short and long term environmental impacts of regulation or to compare the environmental value of alternative regulation policies. Public reaction against pollution, in particular "acid rain" may lead among other things to greater emphasis on hydroelectric developments with a concomitant increase in the degree of regulation in many river systems.

"Water Resources Research in Canada" J.P. Bruce and D.E.I. Maasland, Special Study No. 5, July 1968, Science Secretariat, Privy Council Office, Ottawa.

In some parts of Canada the entire flow of some river systems is now consumed or committed. Large Inter-basin transfers of water are being seriously considered to permit such areas to continue the growth that is seen to be essential to their economic well being. The full implications of water transfers on donor basins is still a matter requiring extensive ad hoc research. Thus far general rules and principles for estimating impacts have eluded researchers.

Skills are gradually evolving for planning the operation of river and lake control works to satisfy a group of conflicting objectives in an optimal or near optimal fashion. However the work is just beginning, both for the numerical rating of individual objectives and for the combining of goals in the mathematical simulation of regulated river systems.

Finally, the availability of improved satellite technology and other remote sensing techniques suggests a wide range of research that can be adapted to hydrologic and meteorologic prediction. The operation of control works and the enforcement of quality control regulations would benefit greatly from the potential improvement in predictions.

A more complete listing of research needs appears later in this report, but the foregoing comments are sufficient to justify this review of water research activities. Also it is interesting to compare todays research activities and needs with the needs outlined in the 1968 report.[1] Some aspects of research lack glamour. Even though they are important they are easily overlooked. By comparing the recommendations and gaps in 1968 with our findings for 1980, some of the important but drab activities can be highlighted.

Throughout this report, complex technical description and discussion has been avoided. The purpose of the report is to present a review of current research activities and the assembled needs for research as seen by a representative cross-section of water people. No attempt has been made to justify current activities nor to recommend certain priorities for future research. This short report cannot do justice to a full discussion of the important topics contained herein, and it would be an insult to the reader's intelligence to imply that a case had been made for giving priority to any special research activity.

As explained in the Preface, this report is one step in the 1980 review of water resources research activities and needs. It deals with statistics not policies, and perceived research needs, not priorities. The information in the report is derived from correspondence and

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interviews as mentioned in the next chapter. That chapter also describes information sources and identifies gaps in the list of those interviewed that should be filled before a final report is produced.

The third chapter is largely statistical. It presents summaries of present activities in tables arranged to show who provides the funds and who does the research. In the summary tables four main headings were used Federal, Provincial, University, and Private Sector. The tables are the end product of detailed working sheets that are not included in this report.

In the fourth chapter, the Water Resources Research needs for the coming 10 years are compiled and presented. These suggestions for future research are a composite prepared from interviews with more than 50 persons. The process of integrating all the suggestions may have altered them somewhat and apologies are extended to those who may feel that too much licence has been taken with their ideas.

In the final chapter, several observations are made that did not fit in the previous chapters. These observations, made by interviewees, are important in shaping future research programs. Time did not permit the author to examine the status quo and suggest whether the observations were accurate and if so, how to achieve the goals inplied in each observation. Therefore, they should not be considered as recommendations guiding future research policies. Rather, they should be accepted as points worth considering before future research policies and programs are forged.

II SOURCES OF INFORMATION

Information for this report was obtained from federal, provincial, university, and private sector sources. Some information was obtained through correspondence and some through interviews. A complete liste of contributors is given in Appendix 3. Their contributions are gratefully acknowledged. Without them the report could not have been produced.

Letters were sent to appropriate provincial deputy ministers and to Universities asking for information on present water resources research activities and perceived needs for research in the coming decade. A sample letters is reproduced in Appendix 2. Responses to the letters were received during the period July through September 1980. In October the responses were reviewed by the Author and a list was prepared of persons and agencies to be interviewed. In preparing the list, the objective was to obtain information supplementary to the responses to the letters and to add representative names from the private sector which was not covered in the initial mailing list. The list of interviewees was not complete but it included persons who represented or could speak for an estimated 80% to 90% of the water resources research activity in Canada.

The author began the interviews in November 1980, and it was quickly apparent that one person could not interview all persons on the list within the time available (this report on current activities and perceived needs was completed as scheduled on January 31, 1981). For a short time Dr. Lowe of the IWD Research Planning and Co-ordination Branch participated in the interviews but his valuable services were lost due to a transfer to a position elsewhere in the Department. Late in November, the regional offices of the Inland Waters Directorate volunteered their assistance and the interviews were completed early in January 1981.

From the letter responses and interviews it was possible to identify the sub-category for each piece of research done in fiscal year 1979/80 (or calendar year 1979). Work sheets were prepared listing individual research projects, their sub-category, and the resources allocated to each. The results were compiled and summarized for this report. Comments on future research needs were noted at the interviews, then assembled later according to subject, without regard to source. Since the list of interviewees included persons who could speak for 80% to 90% of the water resources research activity in Canada, the compiled results should be reasonably accurate. The figures are subject to some interpretation because of assumptions as to overhead, salary conversions, and the inflation factors as explained in the next chapter.

Also in the next chapter, the results are compared with those given in the 1968[1] report. The data in the 1968 report

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were drawn from responses to detailed questionnaires directed toward both organizations and individuals. In addition, studies on selected aspects of water resources research, done by consultants, were incorporated with the responses. Consequently the final results (1968) were built up from a larger body of data that was more detailed than the data gathered for this report (1981). Nevertheless, a comparison may be made since both reports attempt to cover all activities in the four sectors, federal, provincial, university, and private.

One final comment should be made, namely, that the university interviews were incomplete due to time constraints. Some universities publish good listings of their research activities that permit abstraction of data without interviews and that was done. However, there is only one way to obtain a clear picture of perceived research needs in the coming decade, and that is to meet with researchers and discuss problems and solutions. Before the results presented in this report are used to shape programs or policies, it is strongly recommended that more time be spent with the university sector discussing future research needs.

III PRESENT WATER RESOURCES RESEARCH ACTIVITIES

Explanation of Tables

Six tables are presented in this chapter. Some explanation of the tables and of the assumptions made in compiling the tables is presented first.

Table 1 "Water Resources Research funds 1979/80 classified by source", shows the present sources of funds for water resources research activities for each of the four sectors (federal, provincial, university, and private). The expenditures are arranged by category.

Table 2 "Water Resources Research Expenditures according to agency of performance 1979/80" has the same format as Table 1 but the figures indicate who does the research rather than who funds it.

Tables 3 and 4 are based on the 1968 report. They show both funding and doing for 1966 for the four sectors and eight categories (note that the 1981 review added new category 900 for environmental impact). They also shows what the figures would be if converted to 1979 dollars. Table 3 "Research expenditures according to agency of performance: 1966" shows the figures derived from the 1968 report, and the resultant figures after conversion to 1979 dollars. Table 4 is a similar presentation from the 1968 report for "Water Resources Research funds classified by Source".

Table 5 provides a comparison between water research activities in 1966 and 1979 according to agency of performance. Table 6 gives a similar comparison according to source of funds.

Some Assumptions

Several assumptions were made in preparing these tables.

The fiscal year 1979/80 was used in some cases, and the calendar year 1979 in others depending upon the accounting practices of the funding agency.

For some of the federal and provincial agencies, figures provided to the author did not include salaries. In such cases, the person-years allocated to research were multiplied by $25,000 (1979/80) and added to the other expenditures.

For Tables 3 and 4, it was necessary to allow for inflation from 1966 to 1979. To convert a 1966 expenditure to a 1979 equivalents, it was assumed that $1 in 1966 is equivalent to $2.43 1/2 in 1979. This factor is taken from the implicit price index for gross national expenditures as reported in National Income and expense accounts (Catalogue 13201 of Statistics Canada).

TABLE 2 WATER RESOURCES RESEARCH EXPENDITURES ACCORDING TO AGENCY OF PERFORMANCE 1979/80

NAME	CATEGORY									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	210.1	5,262.5	285.4	658.6	11,053.3	676	801.3	393	2,199.7	21,538.9
PROVINCIAL	-	2,511	94	1,601	1,722.9	565	564	195	4,238	11,490.9
PRIVATE	-	1,765	20	20	3,361.7	80	190	3,000	1,400	9,836.7
UNIVERSITY	70.9	2,614.8	263.2	154.5	2,812.9	136	541.6	882.6	459.9	7,936.4
TOTAL	281	12,153.3	662.6	2,434.1	18,950.8	1,457	2,096.9	4,496.6	8,297.6	50,802.9

TABLE 1 WATER RESOURCES RESEARCH FUNDS 1979/80 CLASSIFIED BY SOURCE

SOURCE	CATEGORY									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	311.6	6,840.7	489.4	706.6	14,519.9	911	1,160.3	1,610.6	2,613.4	29,163.5
PROVINCIAL	159	3,182	94	1,505	3,587.3	125	677.6	229.2	4,338.6	13,897.7
PRIVATE	-	1,204.5	20	15	1,741	80	112	1,760	1,125	6,057.5
UNIVERSITY	-	629.9	28.4	-	268.2	57.6	281.9	77	38	1,381.0
TOTAL	470.6	11,857.1	631.8	2,226.6	20,116.4	1,173.6	2,231.8	3,676.8	8,115	50,499.7

TABLE 3 WATER RESOURCES RESEARCH EXPENDITURES ACCORDING TO AGENCY OF PERFORMANCE: 1966: Unadjusted

NAME	CATEGORY									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	22.5	1,850.3	241.3	135.5	1,006.5	49	218.3	200.3		3,723.9
PROVINCIAL (INCLUDING MUNICIPAL)	-	1,148.5	79	133	306.1	48	56	-		1,770.6
PRIVATE (INCLUDING NON-PROF)	17	101.5	89.8	13.3	798.8	70	31.2	145.4		1,267
UNIVERSITY	3	809.6	17.9	18.7	406.8	112.4	121.5	138.3		1,628.2
TOTAL	42.5	3,909.9	428.2	300.5	2,518.2	279.4	427	484		8,389.7

WATER RESOURCES RESEARCH EXPENDITURES ACCORDING TO AGENCY OF PERFORMANCE: 1966 VALUES ADJUSTED TO 1979

FEDERAL	54.8	4,505.5	587.6	329.9	2,450.8	119.3	531.6	487.7	9,067.7
PROVINCIAL (INCLUDING MUNICIPAL)	-	2,796.6	192.4	323.9	745.4	116.9	136.4	-	4,311.4
PRIVATE (INCLUDING NON-PROF)	41.4	247.2	218.7	32.4	1,945.1	170.5	76	354	3,085.1
UNIVERSITY	7.3	1,971.4	43.6	45.5	990.6	273.7	295.9	336.8	3,964.7
TOTAL	103.5	9,520.6	1,042.7	731.7	6,131.8	680.3	1,039.7	1,178.5	20,428.9

TABLE 4 WATER RESOURCES RESEARCH FUNDS CLASSIFIED BY SOURCE, 1966 UNADJUSTED

NAME	CATEGORY									
	100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	24	2,695.5	380	227.3	1,339.4	139.4	304	377.6		5,487.3
PROVINCIAL	-	942.7	41.6	70.3	290.2	35.9	63.6	7.0		1,451.3
UNIVERSITY	1.5	199.5	2.1	0.8	46.2	16.8	1.0	7.3		275.4
PRIVATE	17	25.5	4.5	2.0	700.6	-	10.4	92.1		852.1
FOREIGN	-	23.8	-	-	48.7	17	43			132.5
OTHER	-	22.8	-	-	93	70.3	5	-		191.1
TOTAL	42.5	3,909.9	428.2	300.5	2,518.2	279.4	427	484		8,389.7

WATER RESOURCES RESEARCH FUNDS CLASSIFIED BY SOURCE: 1966 VALUES ADJUSTED TO 1979

FEDERAL (PLUS FOREIGN AND OTHER)	58.4	6,677	925.3	553.5	3,606.5	339.4	740.2	919.5		13,361.6
PROVINCIAL	-	2,295.5	101.3	171.2	706.6	87.4	154.9	17		3,533.9
UNIVERSITY	3.7	485.8	5.1	1.9	112.5	40.9	2.4	17.8		670.6
PRIVATE	41.4	62.1	11	4.9	1,706	-	25.3	224.3		2,074.9
TOTAL	103.5	9,520.6	1,042.7	731.7	6,131.8	680.3	1,039.7	1,178.5		20,428.9

TABLE 5 COMPARISON BETWEEN 1966 AND 1979/80 EXPENDITURES ACCORDING TO AGENCY OF PERFORMANCE

NAME		CATEGORY									
		100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	1966	54.8	4,505.5	587.6	329.9	2,450.8	119.3	531.6	487.7		9,067.7
	1979/80	210.1	5,262.5	285.4	658.6	11,053.3	676	801.3	392	2,199.7	21,538.9
	CHANGE	+155.3	+757	-302.2	+328.7	+8,602.5	+556.7	+269.7	095.7	+2,199.7	+12,471.2
	% CHANGE	283	17	-51	100	351	467	51	-20	LARGE	138
PROVINCIAL	1966	-	2,796.6	192.4	323.9	745.4	116.9	136.4	-		4,311.4
(INCLUDES)	1979/80	-	2,511	94	1,601	1,722.9	565	564	195	4,328	11,490.9
(MUNICIPAL)	CHANGE	-	-285.6	-98.4	+1,277.1	977.5	+448.1	+427.6	+195	+4,238	+7,179.5
	% CHANGE	-	-10	-51	+395	131	383	313	LARGE	LARGE	167
PRIVATE	1966	41.4	247.2	218.7	32.4	1,945.1	170.5	76	354		3,085.1
(INCLUDES)	1979/80	-	1,765	20	20	3,361.7	80	190	3,000	1,400	9,836.7
(NON-PROF)	CHANGE	-41.4	1,517.8	-198.7	-12.4	1,416.6	-90.5	114	2,646	1,400	6,751.6
	% CHANGE	-100	614	-91	-38	73	-53	150	747	LARGE	219
UNIVERSITY	1966	7.3	1,971.4	43.6	45.5	990.6	273.7	295.9	336.8		3,964.7
	1979/80	70.9	2,614.8	263.2	154.5	2,812.9	136	541.6	882.6	459.9	7,936.4
	CHANGE	+63.6	643.4	219.6	109	1,822.3	-137.7	245.7	545.8	459.9	3,971.7
	% CHANGE	871	33	504	240	184	-50	83	162	LARGE	100
TOTAL	1966	103.5	9,520.6	1,042.7	731.7	1,631.8	680.3	1,039.7	1,178.5		20,429.9
	1979/80	281	12,153.3	662.6	2,434.1	18,950.8	1,457	2,096.9	4,469.6	8,297.6	50,802.9
	CHANGE	177.5	2,632.7	-380.1	1,702.4	12,819	776.7	1,057.2	3,291.1	8,297.6	30,374
	% CHANGE	171	28	-36	233	209	114	102	279	LARGE	149

SUB-TOTAL

TABLE 6 COMPARISON BETWEEN 1966 AND 1979/80 EXPENDITURES ACCORDING TO AGENCY OF PERFORMANCE

NAME		CATEGORY									
		100	200	300	400	500	600	700	800	900	TOTAL
FEDERAL	1966	58.4	6,677	925.3	553.5	3,606.5	339.4	740.2	919.5		13,361.6
(INCLUDES FOREIGN)	1979/80	311.6	5,840.7	489.4	706.6	14,519.9	911	1,160.3	1,610.6	2,613.4	29,163.5
(AND OTHER)	CHANGE	+253.2	+163.7	-435.9	153.1	10,913.4	571.6	420.1	691.1	2,613.4	15,801.9
	% CHANGE	434	2	-47	28	303	168	57	75	LARGE	118
PROVINCIAL	1966	-	2,295.5	101.3	171.2	706.6	87.4	154.9	17	-	3,533.9
	1979/80	159	6,840.7	94	1,505	3,587.3	125	677.6	229.2	4,338.6	13,897.7
	CHANGE	+159	4,545.2	-7.3	1,333.8	2,880.7	37.6	522.7	212.2	4,358.6	10,363.8
	% CHANGE	LARGE	198	-7	779	408	43	337	1,248	LARGE	293
PRIVATE	1966	41.4	62.1	11	4.9	1,706	-	25.3	224.3	-	2,074.9
	1979/80	-	1,204.5	20	15	1,741	80	112	1,760	1,125	6,057.5
	CHANGE	-41.4	1,142.4	9	10.1	35	80	86.7	1,525.7	+1,125	3,982.6
	% CHANGE	+LARGE	1,839	82	206	2	LARGE	343	685	LARGE	192
UNIVERSITY	1966	3.7	485.8	5.1	1.9	112.5	40.9	2.4	17.8	-	670.6
	1979/80	-	629.9	28.4	-	268.2	57.6	281.9	77	38	1,381.0
	CHANGE	-3.7	144.1	23.3	-1.9	155.7	16.7	279.5	59.2	38	710.4
	% CHANGE	-100	30	457	-100	138	41	LARGE	333	LARGE	106
TOTAL	1966	103.5	9,520.6	1,042.7	731.7	6,131.8	680.3	1,039.7	1,178.5		20,428.9
	1979/80	470.6	11,857.1	631.8	2,226.6	20,116.4	1,173.6	2,231.8	3,676.8	8,115	50,599.7
	CHANGE	367.1	2,336.5	-410.9	1,494.9	13,984.6	483.3	1,192.1	2,498.3	8,115	30,080.8
	% CHANGE	355	25	-39	204	228	73	115	212	LARGE	147

SUB-TOTAL

Figures provided by federal and provincial sources were not consistant in the treatment of administrative and non-technical support staff (libraries, drafting services, etc.). For some agencies it was possible to separate these costs from "normal" research costs and compute their ratios to the overall budget. This ratio was then used to increase expenditures where the submitted figures did not show support services.

Also, provincial and federal figures on research funding did not show the costs of operating the buildings and non research facilities necessary to house and care for research workers. In the case of the Natural Water Research Institute at Burlington, a surcharge of 25% to 30% on the gross research budget would pay for these operating charges. However the circumstances of other research agencies vary so widely it was decided to accept the submitted costs without an additional allowance for accommodation and similar support. Consequently, the figures used for government expenditures may be slightly lower than they should be.

University figures for water resources research contain no allowance for support services nor for accommodation. The primary function of a university is to teach and train. The facilities and most of the support services must be there for the purpose of teaching whether or not they are used for research. Following that rationale, it is appropriate to accept the figures for research expenditures by the Universities.

The research councils of Alberta and Saskatchewan are gradually increasing the portion of their revenues derived from the private sector, but the largest single source of funds in each case is still the provincial government. Consequently, these two Councils have been included in the provincial government sector. On the other hand the Ontario Research Foundation derives most of its budget (over 75%) from contracts with the private sector and non-provincial government sources. For this reason it has been included with the private sector in the summary tables.

The estimate of expenditures in the private sector was based on interviews with Beak, SNC, André Marsan, Dominion-Sulzer, Dominion Engineering Works, Montreal Engineering, HG Acres, MacLaren, Underwood and MacLellan, Ontario Research Foundation, B.C. Hydro and Power Authority, and Manitoba Hydro. A guess was made that the consultants in the above list performed 50% of the total water research activity by private firms. Their expenditures were doubled to produce an estimate of total national water research activity by private consultants.

The provincial power utilities (B.C., Saskatchewan, Manitoba, Ontario, Quebec, and Newfoundland) with large hydroelectric power installations, do or fund work that has a large water research component. Since all of these utilities were not interviewed, it was necessary to guess at their total research activities. For this report, a total expenditure of $1 million was used mostly in category 900.

The federal expenditures and research activities as shown in the tables are a composite obtained by adding up budgets and activities for several Departments and agencies: Environment, Fisheries and Oceans, Energy Mines and Resources, Transport, National Health and Welfare, Agriculture and the Atomic Energy Control Board. In most cases the budget figures extracted did not include work that was done for the various departments under contract. To overcome that deficiency, the Research and Development bulletin of the Department of Supply and Services was reviewed for each month of 1979/80 to obtain the value and category of research contracts negotiated for all departments. In addition, federal funding of water research through grants and subventions was summarized for the National Science and Engineering Research Council, the Inland Waters (Environment) subventions program and the National Research Council.

The expenditures and activities for Provincial government departments and agencies were obtained by interviews backed-up in some cases by detailed annual reports. At the time of writing of this report, the figures for the Province of British Columbia were still preliminary and subject to review. However, estimates were made for B.C. and the error is small in the overall values presented in Tables 1 through 5.

A careful reader will note that Tables 1 and 2 are not reconciled. That is, the total amount of research being done (Table 2) does not correspond to the total funding (Table 1). Also, the totals are different for each research category on the two tables. Although the lack of correspondence may offend the purist or an accountant, the author considered them satisfactory for this report. If, for the sake of neatness, the figures must be reconciled in the future, a lot of work will be needed. When work is done for a government agency by the private sector, there could be minor differences in project description, that will result in assignment of the project to one research category by the funder and another by the doer. Similarly, the records of fund granting agencies may not lead to the same categorization as the records of the Universities where the work is done. Some organizations budget by calendar year, while governments budget by fiscal year... another factor creating fiscal confusion. And finally, some of the figures used were actual records of expenditure, some were budgets, not yet spent, and some were estimates. Actually, the close agreement of the figures in Tables 1 and 2 is more noteworthy than the differences.

Some Highlights from the Tables

Table 1 shows the total funding of water resources research in 1979/80 to be $50-1/2 million. That can be compared with $20-1/2 million (after adjustment for inflation) in 1966. The increase by a factor of 2-1/2 is encouraging but falls far short of the target recommended in the 1968 report.

It is also interesting to compare the relative importance of each category in 1979 as compared with 1966.

Category	Per Cent of Total Expenditure 1966	1979/80
100 Nature of Water	1/2%	1%
200 Water Cycle	47%	23-1/2%
300 Water Supply Augmentation and Conservation	5%	1%
400 Water Quantity Management and Control	4%	4-1/2%
500 Water Quality Management and Protection	30%	40%
600 Economic, Social, and Institutional Aspects	3%	2-1/2%
700 Resources Data	5%	4-1/2%
800 Engineering Works	5-1/2%	7%
900 Environmental Management and Protection	NIL[1]	16%
	100%	100%

The table illustrates clearly three important shifts in emphasis since 1966.

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[1] Category 900 was not on the list in 1966

The first is a significant increase in the funding for research in water quality management and protection. It advanced from 30% of total funding in 1966 to 40% in 1979/80. That increase, together with the increase in overall funding (factor of 2-1/2) raised the expenditure from $6 million (1966) to $19 million (1979/80). As shown by the details in Table 5, most of the increase in category 500 is due to the large increase in federal programs. The more modest increases in the provincial and private sectors were less, on a percentage basis, than the overall increase in water research expenditures. A large part of the federal increase in expenditure is focused on the problems of the Great Lakes.

The second is a large drop in the relative importance of research on the water cycle. The proportion of the total research effort directed toward the water cycle dropped from 47% to 23-1/2%. However, because of the increase in overall funding there was actually a small increase in absolute terms, from $9-1/2 million in 1966 to $12 million in 1979/80. It would appear that the strong national concern for water quality in the past decase has reduced the emphasis considerably on water cycle research.

The third is the sizeable expenditure in 1979/80 on category 900, Environmental Management and Protection. The total expenditure of over $8 million in 1979/80 can be compared with the 1966 sub-category, 608 (Ecological Impact of Water Development) which showed a nil expenditure in the 1968 report.

Taken together, the increase in expenditure for water quality management and protection ($13 million) plus the new expenditure for environmental management and protection ($8 million) account for 70% of the overall increase in water research funding from 1966 to 1979/80. The increase in research effort in all other categories has been limited to a relatively small amount. The concentration of funds and personnel on problems in categories 500 and 900 no doubt reflect the priorities of governments during the past decade. However, it may be necessary to review priorities very carefully for the coming decade to ensure that important basic research in the other categories does not fall too far behind.

Some Problems with Categories

A further observation should be made regarding the use of the tables to compare the level of activity as between categories, or as betwen 1966 and 1979/80. In preparing these tables, it has been necessary to decide whether or not each project is, indeed, a research activity, or partly research, or not research at all. If it is research, a further decision is required to assign a category. This process cannot be completely objective. Each time it is repeated, the results will differ slightly. Persons using these tables must keep in mind that the figures are only as firm and consistant as the judgement of the persons who assembled them.

The research categories and sub-categories as given in Appendix 1 have been changed slightly from the 1968 list. A new category 900 was added (environmental management and protection). Sub-category 212 was modified slightly, and sub-category 606 was expanded to clarify its scope for the purposes of this report.

Even with these modifications, some of the research projects did not fit neatly. There are many research projects aimed at understanding and describing physical, chemical and biological processes in lakes and rivers under "natural" conditions. Some of this baseline work seems to fit sub-category 208 for lakes and 211 for chemical processes, and those categories were used. However it would be better to create a new sub-category in the 900 series to cover research on the natural ecology of lakes.

Another difficulty was encountered in categorizing research on forecasting techniques for streamflow, and for long and short-term precipitation forecasts. Streamflow forecasting was placed in sub-category 205 with precipitation forecasting in 202. Some research on this subject fell in sub-category 803. For future research reviews it is suggested that a new sub-category be established for forecasting.

IV WATER RESOURCES RESEARCH NEEDS

Those who were interviewed (Appendix 3) were asked to suggest the water research activities that should be given priority in the coming decade. In this chapter a composite list of research needs is presented based on those suggestions. For each sub-category, an indication is given as to the degree of interest, major (many comments), minor (a few comments) or nil (new comments). The principal topics suggested for investigation are listed with some of the more important suggestions given in full.

101 Properties of water: Interest - nil

102 Aqueous solutions and suspensions: Interest - Very minor

No specific research topics were identified.

201 General (Water Cycle): Interest - major

Topics suggested for research:

- Hydrologic models: improve accuracy, document existing models so users know what they are using, interface models so engineer/managers can use them without a programmer, better regional models.

- Forecasts: need 3 to 6 month climate probabilities and 3 to 6 month forecasts to achieve more efficient operation of multi-purpose reservoirs, and narrow the confidence bands on operating plans; are there drought indicators that could be monitored to improve our anticipation of water needs?

- Transfer of hydrologic data from gauged to ungauged areas requires better understanding of hydrologic processes, and identification of data needs.

- Rainfall run-off relationships.

- Hydrology of peatlands.

- Prepare for provision of climatological advice to farmers in Eastern Canada as supplemental irrigation becomes more widespread.

202 Precipitation: Interest - minor

- Application of radar technology to flow forecasting, forest fire prevention and crop insurance.

- Long Range transport of air pollutants and fall out as acid rain.

- Rationalization of precipitation networks.

203 Snow and ice: Interest - major

- Process of ice formation and break-up in rivers and lakes and the interaction between ice and river flows and levels, processes are not well understood and we seldom collect the right field data to answer the problems.
- Most reservoir, lake, and river models for flow or water quality are not appropriate when there is an ice cover.
- What scaling criteria should be used for physical modelling of techniques for ice managament?
- We still need better definition of processes for snowpack accumulation and melt as well as the influence of surface cover on the processes.

204 Evaporation and transpiration - Interest: minor

- Water balance measurements of evaporation from water surfaces are frustrated by lack of understanding of seepage and bank storage losses.

205 Streamflow: Interest - major

- Better methods for flood forecasting and prediction.
- Size and timing of flood events and better techniques for predicting effects of obstructions on flood flows and levels.
- better techniques for evaluating hydro-power potential in ungauged areas (low flows).

It should be noted that there was strong interest in more extensive regional flood frequency analysis, improvement of data networks, and adaptation of routing models, but the author has considered that this type of work requires application of known principles rather than research.

206 Groundwater: Interest - major

- Better understanding of water movement in sub-surface formations, dating and recharge, safe yields.
- Relationship between ground and surface waters to support better allocation procedures, feasibility of using aquifers to store surface waters, impact of surface soil conditions on recharge, consideration of rivers and their alluviance as one system.

- Impact of drainage on groundwater regime.

- How do contaminants move through sub-surface formations including organics as well as other contaminants? What special problems are presented by open pit mines? Can movement be managed to contain contaminants?

- Better understanding of flow through fractured rock formations and contaminant flow through porous media; need predictive capability for flow, velocity and contaminant adsorptiuon (or other loss mechanisms) for long-term (100 years) as well as short-term.

- Better understanding of salt water intrusion and how to manage it.

- What methods and coefficients can be used to plan for use of groundwater for heating or cooling and what criteria must be used for well spacing to avoid interference?

- What is the potential for storage of contaminants in non-crystalline rocks?

207 Water in soils: Interest - minor

- Need better understanding of infiltration processes to support hydrologic modelling.

208 Lakes: Interest - major

- Need continuing research on the physical, chemical and biological processes in lakes, the impact of plumes and density currents on those processes, verification of dispersion models.

- Eutrophication research for lakes that don't perform according to existing eutrophication models, effects of stratification on nutrient cycling.

- Aquatic weeds in lakes, variation in distribution of plants with altitude, biologic zones, nutrients, and physical lake parameters.

- Paleolimnology: improvement of methods to deduce hydrologic, deposition, and biological history from sediment cores.

- Retention times in lakes are needed to predict assimilative capacity.

209 Water and plants: Interest - Nil

210 Erosion and sedimentation: Intrest - minor

- Existing models are cumbersome for predicting scour and deposition in rivers and reservoirs. Improvements needed.
- Better understanding of the processes of sediment transport, degradation, surface erosion, bank stability, fluvial morphology, flood plain modification and hydraulics.
- Prediction of ultimate configuration of the shoreline around new reservoirs.

211 Chemical processes: Interest - minor

- Chemical processes in aquifers.
- Precipitation chemistry.

212 Estuarine and coastal zone problems: Interest - minor

- Deposition and pathways of toxic materials in estuaries.
- Appropriate uses for estuaries where there are severe conflicts.
- Fundamental research and data collection to aid in understanding the overall eco-systems in estuaries.

301 Saline water conversion: Interest - very minor

No specific research suggested.

302 Water yield improvement: Interest - minor

No spefific research suggested.

303 Use of water of impaired quality: Interest - minor

- Use of saline soils and water for agricultural and industrial purposes.

304 Conservation in domestic use: Interest - Minor

- More research is needed on closed system concepts for both domestic and industrial use. Make up water is as little as 1/2 to 1% of gross water requirements. Reduces problems of supply and waste disposal.

305 Conservation in industry: Interest - very minor

No specific research suggested.

306 Conservation in agriculture: Interest - Minor

- Methods for improving irrigation efficiency, structural, managerial, and economic (pricing), better systems for collecting real time data to support improved efficiency.
- Remote sensing for identification of canal seepage and for obtaining real time data for operational management.
- Weed control, salinity control, migration of nutrients, major ions, herbicides, and pesticides.

307 Weather modification: Interest - nil

401 Control of water on the land: Interest - major

- Impact of drainage on floods, includes surface drainage and tile drainage for small watersheds, on a regional basis and for large watersheds; impact of drainage on water quality; impact of drainage on groundwater recharge;
- Criteria needed for designing drain depth and spacing in relation to slope and soil texture; coefficients for movement of water in the soil.
- Impact of agricultural and other land management practices on the quantity and quality of run-off including migration of nitrogen and nutrients.
- Climatic impact of land management practises.

402 Groundwater management: Interest - very minor

No specific research suggested.

403 Effect of man's related activities on water: Interest - minor

- Effect of urbanization on run-off, methods to predict quantity, rate, and quality of municipal and suburban stormwater run-off related to precipitation events and pre run-off conditions, better understanding of peaks of both water quantity and quality.
- Effect of urban drains and floodways on environmental factors.

- effect of logging or agricultural clearing on run-off, monitor existing reservoirs to develop understanding of impact of policies to clear or not to clear reservoir areas before filling.

(NOTE: CATEGORIES 501, 502, AND 503 ARE SIMILAR AND SHOULD BE READ TOGETHER)

501 Identification of pollutants: Interest - major

- Continuing research is required on identification, detection, and monitoring for new and old contaminants, identification of new pollutants in municipal effluents, identification and characterization of storm sewer catchments including precipitation chemistry, and indicators of heavy metals and fecal pollution. Hand in hand with identiake to reach equilibrium after the addition of contaminant(s), need models of the mechanisms that change distribution coefficients such as sediment transport, stripping of the water column, microbial processes, chemical speciation of pollutants, bio-availability.

- The assumption that particulate material falling on a lake is soluble, many be too conservative. Do some particles more quickly into a state of non-availability? What happens to particulate material falling on or flowing through peak swamps?

- Better methods are needed to identify families of organics and to set levels or risk (and detection) for each contaminant.

It might be noted that there are still (January 1981) 80 unidentified peaks on a recent chromatograph for the Niagara River. Complete identification would require huge expenditures. This may be necessary because very little work is done on contaminant sources. If there were more information on the composition and quantities of waste being dumped into the rivers and lakes, the job of contaminant identification would be greatly simplified. Contaminants are much more concentrated in wastewater and easier to detect. Canada does not have a comprehensive program to survey and characterize contaminant sources.

502 Sources and fate of pollution: Interest - major

- Capacity of aquifers to absorb wastes, loading capacities of natural waterways, forms of ions moving through septic fields, movement of contaminants through soils and possible groundwater contamination, mercury dynamics in reservoirs - sources and transformation, pathways for heavy metals and complex organics, change and accumulation of salts in

irrigated and non-irrigated soils, concentration or reduction of radionuclides by flora and fauna in ground and surface waters, movement of herbicides (for aquatic weed control) through lake water, lake sediments, and groundwater, modelling of pathways.

- Composition and contaminant loadings from acid rain, chemical composition and toxicity for complex emissions, effect of road salting on run-off and groundwater, effect of nitrogen based explosives on water quality, monitoring after mining and reclamation to confirm predictions, prediction of quality of run-off given knowledge of land management practices and statistics on herbicide and pesticide use, effect of erosion on loadings, quantification of all non-point sources of pollution.

503 Effects of pollution: Interest - major

- Several persons stressed the importance of research on the impact of pollutant on the eco-system as a whole. This subject was identified as a major gap. Is the total biomass of a system increased or decreased? What is the response of all parts of the biological cycle from fish to bacteria? What are the short term versus long term effects?

- Prediction of the capacity of lakes to accept septic tank discharges.

- More must be known of the epidemiology and toxicology of contaminants and how to identify them by families as well as individually.

- Effect of waste heat and changed circulation patterns due to cooling water discharge including effects on fish spawning and migration.

- What organic and inorganic pollutants are coming from polluted rain.

- Should we disinfect drinking water with chlorine? What are the long and short-term effects? Can we get rid of chlorinated hydrocarbons at reasonable costs?

Note: Some people pointed out that criteria have been developed for many (and objectives and standards for some) substances acting singly. But the effects of contaminants in various background settings and interacting with other contaminants is not officially recognized. Because of the huge number of possible combinations it would be necessary to plan very carefully for a suite of studies that would document priority interactions first. But many questions must be answered: which combinations? What background conditions? What relative concentrations? Only when an overall program has been devised can the work of toxicology proceed efficiently.

504 Waste treatment processes: Interest - major

- Aerated lagoon oxygen transfer and treatment efficiencies under Canadian conditions, relationships between BOD, COD, TOC and non-filterable residue in order to establish new sewage treatment guidelines, hazards and persistance under winter conditions, effects of sewage chlorination (effects on soils and water), hazards and persistance of effects from various methods of virus control.

- More basic research and economic evaluation is needed on small sewage treatment systems. A large system can deliver severe shocks to the environment if not working 5% of the time. Smaller systems might be more acceptable from an environmental point of view.

- Criteria for selecting disposal sites for toxic wastes, and criteria for evaluating effects, design, operation and monitoring. Where, how fast, and with what chemical and biological changes, do solutes move away from disposal areas.

- More research on water re-use is needed for water scarce areas and to reduce high pollution levels. Will require adequate knowledge of toxicology of effluents and monitoring techniques to put in place adequate regulations for control.

- Microbiological processes that will degrade specific contaminants and produce harmless products without detrimental side effects.

- Criteria are needed to support "as low as reasonably achievable" methods for waste treatment. Need quantification of benefits and costs of various actions, processes and regulations. Will help answer the question "how much of a contaminant must be removed from effluents or tailings".

505 Ultimate Disposal of Waste: Interest - major

- What are the long-term consequences of surface disposal of uranium mine tailings?

- Leachate characterization, fate and transformation in soil and groundwater.

- Fate of sludge when dumped in sanitary landfills.

- Capacity of soil and biota to assimilate wastes from municipal and industrial wastewater irrigation.

- Aerosilization and dispersion of enteric micro-organisms in conjunction with spray irrigation of municipal wastewater; die off patterns in dispersed air-borne mixed populations.

- Ammonea removal technology.

- Techniques for measurement and removal of oil and grease.

- Alternate to chromate corrosion inhibitors.

- Treatment processes for leachates from mine tailings and tailings from oil sands and coal sands operatives.

- Effects of field disposal of livestock manure.

506. Water treatment: Interest - major

- If it is not feasible to keep contaminants out of the environment, it may be prefuable in some situations to have better point-of-use treatment, therefore research is required on how to remove many substances, including complex organics, from water supplies at reasonable cost.

- Little is known of the virology of water; the effectieness and side effects of agents to destroy viruses is mostly an open book.

- Research is needed on the concept of closed watersheds to provide run-off for domestic supply. What are the natural contaminants, chemical and biological? What are the economics of establishment and operation.

- Continuing research is needed to devise economical means for maintaining the quality of farm water supplies.

507 Water quality control: Interest: major

- Many closely monitored trials of lake neutralization or rehabilitation are needed, use of nutrients to stimulate growth of organisms that remove target contaminants, addition of lime to raise pH, methods to seal nutrients into the sediments.

- Methods to mitigate adverse effects of agricultural operations on water quality, including research on efficient timing of biocide sprays to reduce overall use.

- Research on methods of weed control that have acceptable side effects and reasonable cost.

- Control of swimmer's itch.

- Resarch on slimes that could play a major role in the take-up of contaminants.

601 Planning: Interest - none.

602 Evaluation Processes: Interest - minor

- Criteria for flood plain management based on economic considerations.
- Consistant definition for design floods, especially along river reaches affected by major tributaries where joint probability of partly related events is involved.

603 Cost allocation, cost sharing, pricing repayment: Interest - minor

- Economic analysis, benefit cost analysis, cost effectiveness, water pricing, sensitivity analysis.
- A better method for classifying irrigable land that makes use of net returns and farm management drills in addition to physical factors.
- If prohibition of input of specific contaminants is considered a viable option for contaminant control, (or reduction of contaminant output to set levels) what would be the social and economic consequences of such a policy?

604 Water demands: Interest - minor

- The economics, cost, and value of water as a production tool.
- Optional manufacturing processes and their water requirements.
- Water demands for flood (once in spring) irrigation related to soil type and other factors.
- Criteria for predicting water requirements and wastewater production as population rises.
- Water needs, availability, re-use, and disposal for oil, oil sands, and coal recovery and processing.

605 Water law: Interest - very minor

- Although none proposed research under this heading, it was suggested that there should be a continuing national review of legislation, policies, programs, procedures, regulations, and methodologies of water management agencies.

606 Institutional aspects: Interest - minor

- Equitable apportionment has been done for river basins where major uses are consumptive. But what principles can be used for apportionment when the corpus of the water is not being shared, but rather, the regime of a river (or lake) and its quality (or assimilative capacity) are to be used or shared to the mutual satisfaction and benefit of the controlling jurisdictions?

- Assessment of public attitudes toward various approaches to flood damage reduction.

607 Sociological and physchological aspects: Interest - minor

- Public attitudes toward various forms of water-based recreation.

608 Ecological impact of water development

See new category 900.

701 Network design: Interest - minor

- Research on improving effectiveness of hydrometeorological networks.

NOTE: Many comments were made on the need for network expansion and rationalization but research needs are small.

702 Data acquisition: Interest - major

- High priority was given to the blending of new forms of data with the old (e.g. satellite observed water temperature and point water surface temperatures). Problems to be solved

  include integration of radar, satellite, remote sensing and ground based measurements for precipitation, snow water equivalent and cover, soil moisture, lake temperatures and others. Research on best ways of archiving, quality control, processing, retrieving. There is a growing institutional problem because of the many people involved. In the satellite transmission of data, there is a need for systems, hardware, and software that will make data available to the users. A concensus is needed first on what to transmit and how to transmit it.

- Methods of sampling and analysis of interstitial water, or methods for inferring what the "in situ" characteristics would be.

- There is a need for a reliable inexpensive gauge to record and accumulate precipitation with emphasis on snow; better instruments and techniques for obtaining chemical quality of precipitation.

- Instruments to detect septic plumes in lakes and rivers, real time sensors for contaminant monitoring that will be free from fouling or easily and automatically replaced, better systems for collection and analysis to lower monitoring costs, develop biological "sensors" once research is done on quantitative bioaccumulation.

- Better methods and standarization is needed for measuring flow in penstocks. (Acoustic methods may be satisfactory but standardized installations needed.)

- A reliable, low cost, accurate method for "hands-off" river discharge measurements.

- Microbiological techniques for monitoring and toxicity screening. Need research on what to monitor and why.

703 Evaluation, processing, and publication: Interest - very minor

- More efficient data handling methods.

801 Specifications and design: Interest - major

- There could be tremendous demand in the near future for standardized, packaged hydro units for low flow or low head applications. The technology must be simple, reliable, and - if possible - low cost. The package should include controls, gates, and even standardized power house or shelter. They should be easy to transport, easy to install and maintain. There should be a minimum of site specific design required. Such a package would have large impact on sale of Canadian products and expertise overseas. There may also be a large potential market in Canada.

- There is no standard (off the shelf) generator (to match with the above packages) available in Canada.

- Research is needed on high capacity water wheels for low head operation. Low head installations are large in diameter and slow in speed. They are sensitive to variations in velocity across the water wheel, and hence in the approach channel, due to large diameter and range of bearing thrusts acceptable. Many installations should have considerable theoretical and model studies of the approach channel, but small installations do not have the budget. Could packaged designs and better equipment avoid some of these problems?

- Better fish ladders are needed.

802 Material: Interest - minor

- Corrosive characteristics of various water qualities vis-à-vis water-wheels. Cavitation is affected by water quality.

- Effect of poor quality water on mechanical seals.

- Brittleness of metals in cold waters.

803 Operations: Interest - minor

- Better methodologies for operating water control works in a complex system or where environmental constraints exist.

- Some work has been done on simulation of large systems (say electrical power systems) where the water resource component is a major input. The models attempt to optimize many factors within an acceptable range of water control options. The integration of economics with such system models needs more development.

901 Lake levels: Interest - major

- There is a growing need for understanding and models of the complete eco-system of lakes and reservoirs, background conditions must be stated before impact analysis can begin. "Natural" background depends in part on what impacts are being studied. A resident of Toronto may consider Orillia as a background situation, the resident of Orillia would refer to Northern Ontario, and so on. Overall models must provide estimates of total biomass and fish production and background physical, chemical, and biological characteristics on a seasonal basis. The models must take into account the hydrology of the system as well as the limnology.

- With the above models it may be possible to do further work to predict long term effects of impoundments, possible climatic effects of major water transfers, effects of level control on aquatic plants, fisheries, and domestic use, effects of reservoir operation on outflowing water quality related to factors such as soils, degree of reservoir mixing, location and elevation of intake works, and the impact of large reservoirs on climate and weather.

- A major emphasis must be placed on monitoring of constructed projects to confirm or modify predictive models.

- The process of model confirmation or adjustment should identify processes that need more research.

- The use of reservoirs for water quality management (dilution) and flood control are not always compatible. It is necessary to evaluate all benefits of regulation so that trade-offs can be presented. Research is needed to fully identify and evaluate all regulation benefits and disbenefits.

902 River regime: Interest - minor

- Potential impact of small and large inter-basin transfers.

- Impact of complete hydrograph reversal (for hydro purposes) on biological conditions in rivers and lakes, ice formation, fish, nutrient balance, temperature...

903 Sociological role of water enhanced environment:
Interest - very minor

No specific research suggested.

904 Impact of environmental constraints on development potential:
Interest: minor

- Impact of environmental constraints on dredging programs.

V OBSERVATIONS

Persons interviewed for this report were invited to comment on actions that might be taken to strengthen the pursuit of water resources research or to create an atmosphere that would make research more effective. Their comments have been compiled, reorganized and presented in this chapter under appropriate headings. Frequently the comments of several persons have been amalgamated and contributors may no longer recognize their ideas. It is hoped that the use of editorial priviledge has not distorted their ideas too severely.

Networks

Many persons commented on the need to improve basic data collection so as to provide a better starting point for all water research. Expansion of hydrometric surveys, surveys of water use, water quality networks and meteorological networks were mentioned specifically.

The strong emphasis on objectives in justifying government budgets has decreased the emphasis on routine data collection because, usually, it is not directly related to urgent or fashionable topics of the day. Yet routine data collection provides absolutely essential data on pre-project conditions, time trends, and areal variability. When the recent acid rain programs started, it was found that some of the pioneering network for precipitation quality, established many years ago, had been dropped due to budgetary pressures, greatly weakening the potential for good results from current activities. Research is urgently needed on spatial and temporal variability of water-related variables. Greater support must be given to routine data collection for the sake of water research and for the development of sound surveillance strategies.

There is extensive interest in, and need for, data from intensive rainfall networks and for frontier areas for hydrologic analyses. To what extent could these needs be considered in setting up the data collection network for the acid rain studies?

There is a need for a national inventory of water wells and water level observations.

Data Storage and Retrieval

It is difficult to use the data from Naquadat for some studies because of the way in which the data are stored. For example in a recent study of the St. Mary River Naquadat print-outs had some inadequacies:

- water samples were located with respect to distance along the river but not distance from shore
- no information on estimated loadings at time of sampling
- day time sampling does not show diurnal variations.

Critical period for DO could be at night. More thought should be given to what the data may be used for and hence what data are needed and how it should be stored.

There should be a system developed for processing and analysis of well log information and groundwater quality and production.

Monitoring

Not enough monitoring is being done of compounds to which man is exposed through drinking water. A major constraint on adequate monitoring is the huge number of compounds in water. It may be necessary to find surrogate parameters before a suitable monitoring program can be devised.

Monitoring waters for general environmental purposes also presents problems. Some contaminants are taken up by clays and sediments very quickly and go from there into the food chain. The monitoring of water would not produce useful results in such cases. Biomagnification suggests an approach to monitoring but it is slow and costly if large organisms (fish) are used. Monitoring of sediments presents a problem in areal variability.

Bio-monitors using small organism are subject to other variables such as nutrients, water levels, turbidity, temperature, etc. and hence cannot be used until entire ecosystems are better understood and reliably modelled.

The recent analysis of herring gull eggs collected years ago (compared with eggs collected recently) is a good approach but only for identification. To get quantitative measures of contamination, much more must be done.

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There should be a system for periodic monitoring of the water quality of major river and lake systems (every 5 years?). The objectives must be clear to ensure efficiency. Present water quality measures are mostly chemical; we must devise, and add, biological measures.

A properly designed program would help us answer the question, 10 years from now "What is the significance of acid rain in Northern Canada" without any crash program.

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To avoid ecological surprises, a group somewhere must be searching continuously for identification of previously un-identified peaks from the gas chromatograph.

Also there needs to be a review of materials used in construction, e.g. coatings on water pipes, paints, corrosion preventatives, etc.

Perhaps a two-tiered early warning system should be devised. At one level a number of common indicators would be monitored according to expected contaminants and available funds. At another level, other contaminants, more costly to detect, would be monitored on a rotation basis. The system might use first identification by families, e.g. organics, and sub-families. If the family or sub-family concentrations were below certain limits there would be no need for detailed analysis. Before setting up such a system one must know

- What contaminants are being released or directed toward the water environment?
- Which contaminants are of concern for various uses.
- Which contaminants are trapped in sediments or degraded, or removed from the environment in an acceptable way.

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There is such a vast number of known and potential contaminants, that a strategy is needed to keep monitoring efficient. First a time interval is selected that will give sufficient information. Then a multi stage screening process can be applied to analysis and perhaps to sampling

Screen 1 - if negative results (a few indicators) stop sampling. If positive do screen 2.
Screen 2 - if negative results (a few more indicators), stop sampling. If positive, do screen 3.
Screen 3 - if negative results (a few indicators) stop sampling. If positive do screen 4.

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Monitoring is just one part of an overall strategy package that must be worked out. We need a structured approach to

- identification of contaminants
- assessment of risk - to individual organisms and entire ecosystems
- determination of pathways and exposure
- when hazard is fully understood make final determination of risk
- chose a level of risk and start an action program to control contaminants within the level of risk selected.

Toxicology

The long term effect of contaminants on people is a large gap. There is not enough data to support regulations or controls on most contaminants.

At the moment many agencies and researchers are involved in toxicity research but the overall situation indicates a somewhat random approach. Some mechanism is needed to help those involved to plan their work to avoid duplication, and gaps in research and enforcement.

It would be helpful if the many centres could agree on objectives and define areas of interest. In the case of government agencies, a further step could be taken to define responsibility and accountability.

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A greater effort is needed to determine the toxicology of contaminants. Perhaps a tiered system would serve here as well. The immediate toxicity of contaminants to simple organisms might be one level, with short term effects on higher level organisms next. Then at both levels of organisms, there is a need to determine long term effects both mutagenic and carcinogenic and to find a means for monitoring that is effective and inexpensive.

A Question of Risk

There is a need for data and methods for making objective assessments of risk of environmental disasters and of risk arising from environmental disasters. We need to know the cost of raising or lowering risk. For example, the long data series available on mine safety yields a relationship between incremental expenditure and lives saved.

Such an approach would give a solid basis for reacting to environmental disasters, better than our present tendency to follow popular reaction as ignited and fanned by newspaper and TV reporting.

Water/Environment Interaction

Site specific investigations are very demanding on research time - in fact they now absorb a major portion of research budgets. Researchers are applying what they already know instead of seeking new knowledge. Somehow, research funds should be sequestered and used for research.

Research progress, therefore will be greatly strengthened by effective control and monitoring programs.

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A portion of the funds earmarked for new developments should be devoted to development of concepts and models for environment/water interactions. The results would be exportable to other countries.

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Developing models of water quality systems has lower priority than understanding the systems themselves. And yet, the attempts to model systems will reveal knowledge gaps. Where knowledge is weak assumptions must be made for modelling, but application of the models will reveal where research efforts should be focused to improve results.

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There is a distinct loss of interest in environmental problems after construction (through some licences now being issued require post construction studies). There is a tendency to say "We have our predictions so the studies may cease". But continual predictions without verification do not lead to improvements in our assessment methods and models.

Post construction monitoring should be given more support. It would show that original predictions were conservative and give owners an opportunity to reduce costs.

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Opportunities should be sought for non-destructive environmental management. For example, could a regulated river be shut down for a few hours at the right time to kill off black fly larvae without serious harm to other biota. In some cases it may be preferable to dump mine tailings into a deep lake rather than placing them in an erodible pile that will cause troubles in surface waters. It may be possible to demonstrate that man can exercise beneficial control from an environmental point of view.

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There are many situations where environmental and economic values must be compared before choosing a course of action. Because of our inability to evaluate environmental attributes, they are often downgraded or overlooked in electing an action plan. Or worse, emotional attachment to an environmental factor may block useful development that would have had only a minor impact on true environmental values.

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There is an urgent need for competent persons to pull together the results of work already done on environmental impact of reservoirs and flow regulation. A manual on this subject would be most useful.

Models

Generally, water quality models for lakes have reached the point where they are understandable and useful. Model improvement will now be

achieved when there is better definition of certain pathways and processes e.g., nutrient and sediment interactions.

An important function of models is to focus research on process and pathways that are poorly understood. The understanding of the problems gained through the use of models stimulates modellers to move back to process research from time to time - a healthy situation.

Background (Baseline) Conditions

There is a lack of natural background data for radioactivity in rocks and perhaps a similar lack for natural waters. How can acceptable background data be obtained at reasonable cost?

In some settlements we may not be able to accept high natural background radiation and removal is the only answer.

Centres of excellence should be established to study thoroughly problems related to leaching of toxic and radioactive substances from tailings into the ground and surface waters. Without such centres, research efforts will be dissipated seeking quick answers to urgent problems.

Problems Definition and Technology Transfer

1. Research people are not always aware of the rapid pace of change in society and their research topics are influenced by their academic specialization and out-of-date perception of problems.

2. Operational people are not always aware of the achievements of the research sector. Much greater use should be made of recent research findings in resource management and development.

3. The attitude described in 1 above is unavoidable if fundamental research is to be pursued without influence from operational people.

4. It is not easy to achieve the objective of keeping management and policy makers fully informed on available technology and knowledge. Perhaps techniques for effective knowledge transfer between researchers and management could themselves be the subject of research.

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In planning environmental and river basin studies, the chances of success are reduced when a researcher defines the problem. They have a tendency "to fight the last war" by imposing ill fitting models on their problem definition. Problem definition is too important to leave to any one group (a comonsub made by management).

A Tropical Institute in Canada

Canada funds a number of agricultural institutes oversees, a potato institute in Peru, a dryland institute in Syria, a rice institute in the Phillipines, wheat breeding in Mexico, etc. Perhaps, it would make sense to establish a central Tropical Research Institute (Agriculture) in Canada for training and central co-ordination. It would enhance Canada's image abroad and lead to greater sales of Canadian expertise and equipment, particularly in irrigation development.

Survey of Industrial Wastes

The U.S. is completing a survey of industrial wastes in the Great Lakes basin. It will be necessary for Canada to mount a similar survey so as not to be disadvantaged during negotiations.

It is relatively straightforward to identify raw material inputs and product outputs. But the by-products of some processes present serious problems, e.g. dioxins are a by product of herbicide manufacturing.

If a survey is done, it should document the manufacture, shipping, and marketing of toxic substances. Much research will be necessary to reach decisions on what to do with the survey results.

Small Hydro Inventory

A national inventory of the potential for small hydro sites would stimulate planning and development interest in Canada. The survey should include the location, size, etc. of existing diesel power stations in remote areas. These sites would be good candidates for study.

Publications

There should be a Canadian Journal of Hydrology or Water Resources Research.

Miscellaneous

More research work should be done by consultants and less "in house" by provincial and federal agencies. The increased research capability in the private sector would increase foreign sales and decrease the need to import expertise. Most of the present research in the consulting sector is a spin-off from planning studies. Total funding for water planning in Canada is decreasing hence research is suffering.

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The development of effluent regulations is not keeping pace with environmental problems. Some of the new problems include new toxic substances, new findings regarding "old" substances, synergistic effects, and new processes.

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In the negotiation of government contracts, there should be a two or three-day "brainstorming" session after the consultant is selected but before the final draft of the contract is prepared. Many ideas could be incorporated at that stage that would improve the results and, possibly, save costs.

If a consultant or contractor should chose to do some further work over and above the contract amount in order to have a large bonus of model confirmation or research knowledge, the additional expenditure by the contractor should be eligible for tax relief.

When a research contract is awarded to a U.S. firm, there should be a supplementary contract awarded to the Canadian runner-up firm. This procedure would stimulate development of Canadian expertise and techniques. It would eventually make unnecessary the use of U.S. techniques and models that may or may not be relevant to the Canadian scene.

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Research in most subject areas is hampered by lack of funds rather than lack of people. However, there is a an urgent need to train more toxicologists.

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Government research establishments have been faced with fixed costs that are inflating more rapidly than overall research funding. The result is a rapid erosion of funds allocate to true research effort. Universities are facing similar problems.

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In the next four years the LRTAP[1] program will generate an enormous pile of data that may give us scientific indigestion. There will be a great need for interpretation, analysis, and synthesis. We should pause at that time and think through the problems rather than moving on to new data collection problems.

We should spend more time studying the results of crash programs and apply our findings to future problems. Stating it another way, we

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[1] Long Range Transport of Air Pollutants

should direct a larger proportion of our effort toward interpreting the data we have.

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Where will we get the land and water to support expansion of irrigation? In seeking answers to that question, a host of research activities will be spawned.

Priorities

Several persons noted that today's priorities for water research are the same as they were a few years ago. Is that because people have not acted on the priorities set previously? Or is learning and change in this business quite slow?

There are several recent documents that suggest priorities for water resources research or provide information on priorities reflected in present programs.

1.	Catalogue of Research Activities on long-range transport of air pollutants	assembled by LRTAP Committee: in press January 1980
2.	Long-Range Plan	Alberta Research Council December 1979
3.	Long-Range Plan	Saskatchewan Research Council in press February 1981
4.	Preliminary Identification of Water Research needs in Saskatchewan	Environment Saskatchewan September 1976
5.	A Report on gaps in knowledge for assessing water demands in Western Canada	Canada West Foundation expected publication April 1981
6.	A perspective on the problem of hazardous substances in the Great Lakes Basin Ecosystem	1980 Annual Report of the Great Lakes Science Advisory Board to the International Joint Commission
7.	Workshop report on research priorities for wetlands ecosystem analysis	National Wetlands Council report to the National Science Foundation, Washington, D.C. December 1978
8.	National Priorities for Water research	Associate Committee on Hydrology June 1979
9.	Canadian Climate program water workshop	Final draft of report in preparation (January 1980) by Atmospheric Environmental Service of Environment Canada.

APPENDIX 1

WATER RESOURCES RESEARCH CATEGORIES

WATER RESOURCES RESEARCH CATEGORIES

100 NATURE OF WATER

Category 100 deals with fundamental research on the water substance.

101 Properties of water -- Study of the physical and chemical properties of water, including its thermodynamic behavior in its various states.

102 Aqueous solutions and suspensions -- Study of the effects of various solutes on the properties of water; surface interactions; colloidal suspensions.

200 WATER CYCLE

Category 200 covers research on the natural processes involving water. It is an essential supporting effort to applied problems in later categories.

201 General. Including: studies involving two or more phases of the water cycle such as hydrologic models; rainfall-runoff relations; surface and ground-water relationships; watershed studies; geomorphology.

202 Precipitation. Including: investigation of spatial and temporal variations of precipitation; physiographic effects; time trends; extremes; probable maximum precipitation; structure of storms; quantitative precipitation forecasting.

203 Snow and ice. Including: studies of the occurrence and thermodynamics of water in the solid state in nature; spatial variations of snow and frost; formation of ice; break-up of river and lake ice; glaciers; ice forces; permafrost and its effects on groundwater and the water cycle.

204 Evaporation and transpiration. Including: investigation of the process of evaporation from lakes, soil, and snow and of the transpiration process in plants; methods of estimating actual evapotranspiration; energy balance.

205 Streamflow. Including: mechanics of flow in streams; flood routing; bank storage; space and time variations (includes high and low-flow frequency); droughts; floods.

206 Groundwater. Including: study of the mechanics of groundwater movements; multiphase systems; sources of natural rechange; mechanics of flow to wells and drains; subsidence; properties of aquifers; saline water intrusion in coastal aquifers.

207 Water in soils. Including: infiltration; movement and storage of water in the zone of aeration, including soil.

208 Lakes. Including: hydrologic, hydrochemical, and thermal regimes of lakes; water level fluctuations; currents and waves.

209 Water and plants. Including: role of plants in hydrologic cycle; water requirements of plants; interception of precipitation.

210 Erosion and sedimentation. Including: studies of the erosion process; prediction of sediment yield; sedimentation in lakes and reservoirs; stream erosion; sediment transport; river-bed evaluation.

211 Chemical processes. Including: chemical interactions between water and its natural environment; chemistry of precipitation.

212 Estuarine and coastal zone problems - including special problems of the estuarine environment, effects of tides on flow and stage, deposition of sediments, sea water intrusion, and land based activities that affect water quality in the coastal zone.

300 WATER SUPPLY AUGMENTATION AND CONSERVATION

As water use increases we must pay increasing attention to methods for augmenting and conserving available supplies. Research in Category 300 is largely applied research devoted to this problem area.

301 Saline water conversion -- Research and development related to methods of desalting sea water and brackish water.

302 Water yield improvement -- Increasing streamflow or improving its distribution through land management; water harvesting from impervious areas; phreatophyte control; reservoir evaporation supression.

303 Use of water of impaired quality -- Research on methods of agricultural use of water of high salinity; use of poor quality water in industry; crop tolerance to salinity.

304 Conservation in domestic use -- Methods for reducing domestic water needs without impairment of service.

305 Conservation in industry -- Reduction in both consumption and diversion requirements for industry.

306 Conservation in agriculture -- More efficient irrigation practices. Chemical control of evaporation and transpiration; lower water use plants; optimum use of soil moisture; etc.

307 Weather modification -- Artificial simulation of precipitation; climate modification by changes in land and water surfaces; etc.

400 WATER QUALITY MANAGEMENT AND CONTROL

Category 400 includes research directed to the management of water, exclusive of conservation, and the effects of related activities on water.

401 Control of water on the land -- Effects of land management on runoff; land drainage; potholes; etc.

402 Groundwater management -- Artificial recharge; conjunctive operation; relates to irrigation.

403 Effects of man's related activities on water -- Impact of urbanization, highways, logging, etc., on water yields and flow rates.

500 WATER QUALITY MANAGEMENT AND PROTECTION

An increasing population increases the wastes and other pollutants entering our water supplies. Category 500 deals with methods of identifying, describing and controlling this pollution.

501 Identification of pollutants -- Techniques of identification of physical, chemical and biologic pollutants; rational measures of character and strength of wastes.

502 Sources and fate of pollution -- Determination of the sources of pollutants in water; the nature of the pollution from various sources; path of pollutant from source to stream or groundwater; prediction of pollution concentrations including prediction by means of mathematical models; effects of ice cover on dissolved oxygen and other pollutants in streams and lakes; etc.

503 Effects of pollution -- Definition of the effect of pollutants, singly and in combination, on man, aquatic life, agriculture and industry under conditions of sustained use; eutrophication; influence of prolonged ice-cover on effects of pollutants; etc.

504 Waste treatment processes -- Research to improve conventional treatment methods to gain efficiency or reduce cost; processes to treat new types of waste; advanced treatment methods for more complete removal of pollutants including purification for direct reuse.

505 Ultimate disposal of wastes - Disposal of residual material removed from water and sewage during the treatment process; disposal of waste brines; underground waste disposal.

506 Water treatment -- Development of more efficient and economical methods of making water suitable for domestic or industrial use.

507 Water quality control -- Research on methods to control stream and reservoir water quality such as flow augmentation; stream and reservoir aeration; control of natural pollution; control of pollution from pesticides and agricultural chemicals; control of acid mine drainage; control of erosion and sedimentation; etc.

600 ECONOMIC, SOCIAL AND INSTITUTIONAL ASPECTS

The problems of achieving an optimal plan of water development are becoming increasingly complex. Category 600 covers research devoted to determining the best way to plan, the appropriate criteria for planning and the nature of the economic legal and institutional aspects of the planning process.

601 Planning -- Application of systems analysis to project planning: treatment of uncertainty; probability studies; non-structural alternatives.

602 Evaluation process -- Development of methods, concepts and criteria for evaluating project benefits; discount rate; project life; methods for economic, social and technological projections; reliability of projections; research on the value of water in various uses; etc.

603 Cost allocation, cost sharing, pricing/repayment -- Research on methods of calculating repayment and establishing prices for vendible products; techniques of cost allocation, cost sharing; pricing and repayment policy.

604 Water Demands -- Research on the water quantity and quality requirements needed to satisfy water demands for various uses.

605 Water law -- Studies of provincial and federal water law looking to changes and additions which will encourage greater efficiency in water use.

606 Institutional aspects -- Investigation of institutional structures and constraints which influence decisions on water at all levels of government, including public participation; investigation of jurisdictional problems including federal-provincial, inter-provincial and Canada-U.S.A.

607 Sociological and psychological aspects -- Attitudes to use of water, perception of responsibilities.

608 Ecologic impact of water development -- Effects of water management operations on overall ecology, including human ecology, of the area. Excludes effect of pollution under 503.

700 RESOURCES DATA

Planning and management of our water resources require information. Category 700 includes research oriented to data needs and the most efficiency methods of meeting these needs. Basic data collection in itself is not here considered research, but studies of ways to improve data collection are included.

701 Network design -- Studies of data requirements and of the most effective methods of collecting the data.

702 Data acquisition -- Research on new and improved instruments and techniques for collection of water resources data, including data on water use and water and erosion damage; telemetering equipment.

703 Evaluation, processing and publication -- Studies of effective methods of processing data; form and nature of published data; maps of data.

800 ENGINEERING WORKS

To implement water development plans requires engineering works. Category 800 describes research on design, materials and construction which is specifically useful to water management. Works relevant to a single specific goal, such as water treatment or desalination, are included elsewhere if an appropriate category exists.

801 Specifications and Design -- Studies of functional requirements of water structures: research leading to improved design of dams, canals, pipelines, locks, fishways and other works required for water resource development.

802 Materials -- Research to improve existing structural materials and to develop new materials for use in water control and conveyance structures.

803 Operations -- Research on efficient operating procedures, and maintenance procedures for water control systems.

900 ENVIRONMENTAL MANAGEMENT AND PROTECTION

Category 900 includes research on the impact of water regulations and use on the aquatic and riparian environment excluding the effects of pollution already covered by 503. This category also includes the impact of environmental management and protection measures on the water resource.

901 Lake levels -- research on impact of change in timing or amplitude of water level fluctuation on the biological and physical processes in lakes.

902 River Regime -- research on impact of long term and short term changes in river flow and level regime on biological and physical processes in the river, on the river bed, and on the river banks. The changes may be caused by flow regulation, obstructions, or both.

903 The sociological role of water enhanced environment -- research on the sociological importance of committing water resources to natural or artificial areas for active or passive recreational use, or to ameliorate otherwise harsh environments.

904 Impact of environmental constraints on development potential -- Research on such impacts and on management concepts, programs, or structures that could minimize conflict between these uses.

APPENDIX 2

LETTERS SENT TO PROVINCIAL OFFICIALS
BY
THE DEPUTY MINISTER, ENVIRONMENT CANADA

Ottawa, Ontario
K1A 0H3

Mr. W. Solodzuk
Deputy Minister
Department of the Environment
Oxbridge Place
9820 - 106 Street
Edmonton, Alberta
T5K 2J6

Dear Mr. Solodzuk:

In 1968, the results of a study concerning activities in water resources research were produced in the Science Secretariat publication "Water Resources Research in Canada"*. In this report an attempt was made not only to assess the current state of the art but also to make recommendations as to the desirable future level of total expenditures on water resources research and the distribution of expenditures in different fields.

Now, twelve years later, we intend to reexamine this report and its impact upon water resources research, to look at the current state of the art and to try to relate these activities to our ability to respond to future needs.

We fully realize the importance of the Provincial Governments in the support of this type of research. In order to help identify those needs of particular concern to your Government I would like to request your assistance in providing information for our study. The results of the study will be made public and it is anticipated that they will be of interest to all managers and policy makers involved with water resources research.

In order to help clarify the research areas of interest I have attached a copy of the water resources research categories extracted from the 1968 report.

* by J.P. Bruce and D.E.L. Maasland
Science Secretariat Special Study No. 5
Privy Council Office, Ottawa

I would very much appreciate it if you would provide us with the name of a suitable contact without your department. This name should be sent, within the next week or so if possible, to Inland Waters Directorate, Environment Canada, Ottawa, Ontario, K1A 0E7.

We shall then get in touch with your nominee with a view to obtaining information concerning the types of research being carried out or supported, the problems this research is intended to help resolve and the resources used. On the basis of this information, we hope to obtain some insight into the future direction of water resources research in Canada.

Thank you for your assistance.

Yours sincerely,

J.B. Seaborn

Ottawa (Ontario)
K1A 0H3

Monsieur Léonce Chénard
Sous-ministre
Ministère des Pêches
King's Place
C.P. 6000
Fredericton (Nouveau-Brunswick)
E3B 5H1

Monsieur Chénard,

En 1968, le Secrétariat des sciences publiait dans sa série intitu;ée "La recherche dans le domaine de l'eau au Canada" les résultats d'une étude sur les acitivités reliées à la recherche sur les ressources en eau.* Le rapport avait pour but non seulement de faire le point en ce qui concerne les connaissances acquises mais aussi de formuler des recommandations au sujet des dépenses totales qui devraient être permises, à l'avenir, pour mener des recherches dans le domaine de l'eau et au sujet de la répartition des ressources entre les divers domaines.

Douze ans plus tard, nous nous proposons de réexaminer le rapport en question, de même que ses répercussions sur la recherche dans le domaine de l'eau, d'étudier la situation actuelle et d'essayer de faire le lien entre ces recherches et notre aptitude à satisfaire les besoins écentuels.

Nous connaissons très bien l'importance des administrations provinciales quant à l'appui de ce genre de recherche. Dans le but de déterminer les besoins particuliers de votre gouvernement, je vous prierais de bien vouloir nous transmettre les renseignements dont nous aurons besoin au cours de notre étude. Les résultats de l'étude seront rendus publics, et nous prévoyons qu'ils intéresseront tous les gestionnaires, en particulier ceux qui sont chargés d'établir les programmes relatifs à la recherche dans le domaine de l'eau.

* menée par J.P. Brue et D.E.L. Maasland
Etude spéciale n° 5 du Secrétariat des sciences
Bureau du Conseil privé, Ottawa

En vue de préciser les divers thèmes de recherche à développer, je joins à la présente une copie des catégories de recherche sur les ressources en eau, tirées du rapport de 1968.

Nous vous saurions gré de bien vouloir nous donner le nom d'un employé de votre Ministère qui ferait fonction d'agent de liaison. Veuillez en informer la Direction générale des eaux intérieures, Environnement Canada, Ottawa, Ontario, K1A 0E7, d'ici une semaine, si possible.

Nous communiquerons ensuite avec la personne désignée pour obtenir des renseignements sur les divers types de recherche effectuée ou subventionnée, les problèmes que l'on espère résoudre à la suite de ces recherches et les ressources utilisées. De cette façon, nous espérons avoir un aperçu de la direction que prendra la recherche dans les sphères d'activités fédérales et provinciales.

En vous remerciant de votre collaboration, je vous prie d'agréer, Monsieur Chénard, l'expression de mes sentiments distingués.

J.B. Seaborn

APPENDIX 3

SOURCES OF INFORMATION

Sources of Information

The attached list shows the sources of information for this report. It should be mentioned that annual reports and other written material on Water Resources Research activities were provided promptly in response to letter requests from th federal Environment department. In particular, the author would like to thank all of those persons who made tenu available for interviews and for compiling follow-up information. Their efforts made this report possible.

Sources of Information

Name	Sector	Annual Reports on other written material	Interviewed
Environment Canada	Federal		
Inland Waters Directorate	Federal	x	x
Canadian Wildlife Service	Federal	x	x
Atmospheric Environment Service	Federal	x	x
Environmental Protection Service	Federal	x	x
Parks Canada	Federal	x	x
Department of Fisheries and Oceans			
Great Lakes Biological Laboratories	Federal	x	
Freshwater Institute	Federal	x	
Ministry of Transport	Federal		x
National Health and Welfare	Federal	x	x
Indian and Northern Affairs	Federal		x
Energy Mines and Resources	Federal		x
National Science and Engineering Research Council	Federal	x	x
National Research Council Associate Committee on Scientific Criteria for Water Quality	Federal	x	x
International Joint Commission	Federal		x
Atomic Energy Control Board	Federal		x

Name	Sector	Annual Reports on other written material	Interviewed
Newfoundland			
Dept. of Consumer Affairs and Environment	Provincial		x
Dept. of Fisheries	Provincial		x
Nova Scotia			
Dept. of Environment	Provincial		x
Dept. of Fisheries			*
Dept. of Mines and Energy			*
N.S. Research Foundation			*
Prince Edward Island			
Dept. of Community Affairs	Provincial		x
Dept. of Fisheries			*
Dept. of Agriculture			*
New Brunswick			
Dept. of Environment	Provincial		x
Dept. of Natural Resources			*
Dept. of Fisheries			*
Quebec			
Environment Quebec	Provincial	x	x
Ministère du Loisir de la Chasse et de la Pêche			x
Ontario			
Ministry of the Environment		x	x
Ministry of Natural Resources			x
Manitoba			
Dept. of Consumer and Corporate Affairs and Environment			x
Dept. of Natural Resources			x

* Responses from these departments collated by Department marked thus x

Name	Sector	Annual Reports on other written material	Interviewed
Saskatchewan			
Dept. of Environment	Provincial		x
Saskatchewan Research Council		x	x
Alberta			
Dept. of Environment	Provincial	x	x
Alberta Research Council	Provincial	x	x
British Columbia			
Ministry of Environment	Provincial		x
Government of Yukon Territory			x
York University	University	x	x
University of British Columbia	University		x
University of Toronto	University	x	
University of Alberta	University		x
University of Calgary	University	x	
University of Manitoba	University	x	x
Univ. of Winnipeg	University		x
Ecole Polytechnique	University	x	
Univ. of Quebec (at Quebec - INRS)	University	x	x
Univ. of Quebec (at Montreal)	University	x	
Univ. of Brandon	University	x	
Memorial University	University	x	
Univ. of Victoria	University	x	
Simon Fraser University	University	x	
Lakehead University	University	x	
University of Montreal	University	x	
McGill University	University	x	
Moncton University	University	x	
St. Francis Xavier University	University	x	
Dalhousie University	University	x	
Trent University	University	x	
Nova Scotia Tech.	University	x	
Prince Edward Island University	University	x	
Waterloo University	University	x	
McMaster University	University	x	
New Brunswick University	University	x	
Ottawa University	University	x	
University of Windsor	University	x	
University of Guelph	University	x	
University of Regina	University	x	
University of Saskatchewan	University	x	
University of Western Ontario	University	x	
Laval University (Centreau)	University	x	
Carleton University	University	x	

Name	Sector	Annual Reports on other written material	Interviewed
B.C. Hydro and Power Authority	Private		x
Manitoba Hydro	Private		x
H.G. ACRES LTD.	Private		x
Ontario Research Foundation	Private		x
MacLaren	Private		x
Beak	Private		x
SNC	Private		x
Montreal Engineering	Private		x
Dominion Bridge - Sulzer	Private		x
Dominion Engineering Works	Private		x
Andre Marsan & Assoc.	Private		x
Underwood MacLellan and Assoc.	Private		x

DATE DUE
DATE DE RETOUR

AUG AOUT 18 1988			

NLR 178