Environment Canada
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Approaches to Water Requirement Forecasting; A Canadian Perspective

T. R. Lee

SOCIAL SCIENCE SERIES NO. 9

CANADA CENTRE FOR INLAND WATERS
BURLINGTON, ONTARIO, 1972

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"You can never plan the future by the past"

——— *Edmund Burke*

Canada is fortunate among the countries of the world in the extent and nature of her freshwater resources. Despite the Arctic location of much of this resource, there can be no doubt that Canada enjoys an abundant supply of water. It is this abundance of the water resource that has historically limited the development of forecasting methodology in Canada and only recently has a growing 'scarcity' of high-quality water led to the generation of a wider interest in the problem of estimating the future use of water. It should be added that scarcity is a relative term and apart from the most arid areas of interior British Columbia and the southern Prairie Provinces only pertains to the quality of water available for certain uses, particularly recreation, in urban areas of Canada. The supply of water cannot be shown to be in any way a restraint on economic and social development in Canada.

SOME COMMENTS ON THE SUPPLY OF WATER

The state of water-requirement forecasting in Canada cannot be fully appreciated outside the context of the supply situation and the nature of the trends in the demands being placed on the water resource. It can be claimed that the generous availability of fresh water has hampered the development of water planning. Despite the intimate relationship between human settlement and the water resource, there has been little conflict among water users and therefore the required management approach has been very simple; largely the provision of a framework within which individual water users could independently develop. Supply remains large compared to the demand placed on it.

Total annual runoff in Canada is in excess of two billion acre-feet, admittedly one third in Arctic Canada, but even the one quarter flowing through populous Ontario and Quebec is more than a sufficient overall[1] supply. In addition to this large streamflow, there are some 291,571 square miles of freshwater lakes in Canada, a larger area of lakes than in any other country. Even then this calculation excludes all minor and seasonal inland ponds and marshes. It is regarded as a deprivation in Canada, outside the maritime regions, to be unable to spend part of the summer on the shore of a lake, large or small.

Groundwater resources are also large, but much is unavailable. In the north, much of the supply is frozen and, in the south, some is saline. In the Prairies, groundwater is an exhaustible resource due to limited recharge capabilities. Finally, Canada has the largest coastline of all nations, almost 18,000 miles on the mainland and 60,000 miles with the inclusion of all islands.

Clearly then, water planning activities and water requirement forecasting in Canada have developed outside a scarcity situation.[2]

Even in the dry Prairies, where drought has been a serious hazard to human activity, there has been only a limited historical development of centralized water management.[3]

Elsewhere in Canada water management has been and largely remains a diffuse function of many elements in society. The rapid decline in water quality observed during

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[1] Accounts of the water supply of Canada are given in, D. Cass-beggs, "Water as a Basic Resource". *In* Resources for Tomorrow, *Conference Background Papers, Volume I* (Ottawa: Queen's Printer, 1961) pp. 173-189.

and

[2] Accounts of Canadian water management are rare. The best recent, although already dated, description is in Atlantic Development Board, Water Resources of the Atlantic Provinces, *Background Paper No. 6* (Ottawa: Information Canada, 1969).

[3] The development of irrigation in what is now southern Alberta in the period 1890-1910 is an interesting example of centralized management. It was, however, an experience of only limited impact although its influence was felt in the later development of federal and provincial cost management policies.

the last two decades and the more recent perception of this deterioration by the Canadian population has given rise to a major shift in water management towards the development of specialized government water agencies.[4] These agencies include in their organization for water planning, a requirement forecasting function although often this remains relatively undeveloped.

APPLICATION OF FORECASTING METHODS IN CANADA

Water requirement forecasting in Canada can be loosely defined as having begun with the earliest attempts to improve navigation facilities in the St. Lawrence River in the mid-eighteenth century.[5] It was not until the late nineteenth century, with the construction of hydro-electric power generating stations and large municipal water supply systems, that recognizable forecasts were made. During the last seventy years, water "demands" or "needs" or "requirements" have been projected very many times for a multitude of different projects. Each forecast has been done with little reference to others, many with no reference to forecasts of related areas of the Canadian economy and few have been made by students of water use and demand behaviour.

The most common form of water requirement forecast technique used in Canada is some form of straight line projection based upon historical needs. There are examples of such projections nationally, provincially and regionally. The sophistication of these techniques varies considerably, from merely estimating current water use on a per capita basis (by dividing supply by population and using one population projection to forecast use at some future date) to detailed investigations of current water requirements and forward projection on a variety of population projections.

The following quotation is a very typical example of the simplest approach to water requirement forecasting.

> It has been estimated that by 1980, the population of the city will be approximately 55,000 persons if growth continues at its present rate. The population of the area served by the Board of Water Commissions will probably approach 60,000 persons by 1980. As a result, the average daily demand is estimated to be 9.0 mgd. (9 million gallons per day).[6]

This particular study, one of a series, has only a minor section devoted to forecasting, but similar calculations of set coefficients of water requirements have underlain many more directly significant forecasts, forecasts used for project evaluation and design.[7] Such techniques have been commonly used because of the lack of readily available information on the use of water and a generally limited appreciation of the significance of such studies.

A more sophisticated variety of these studies can be found in papers presenting forecasts of national or provincial water needs.[8] In most cases, such estimates have involved the manipulation of water-use information and related economic data to provide some projection of future water use.[9] In some cases, reference has been made to the water-use literature to obtain the parameters within which the estimates are made.[10] Empirically, however, the estimates are generally less well developed than the theoretical discussion of the factors impacting upon the water-use sector of the economy.

The difficulty faced by these forecasts is the contrast between the degree of detail known about the demand function, the use pattern and other characteristics of the water sector of the economy compared to other sectors. The paucity of information on and about water use has led to some studies attempting to add to their investigations detailed studies of individual water users, generalizing this information, relating it to other social and economic factors and then projecting it into the future. In most cases this has been done without recourse to complex modelling techniques and only on a limited scale.[11] The most advanced statistical methods used have been correlation analysis and

[4] All ten provinces, the federal government and the territories have water management and planning agencies.

[5] An account of these developments can be found in, H. Neatby, "That Great Street: The St. Lawrence", in C.E. Dolman (ed) *Water Resources of Canada* (Toronto: University of Toronto, 1967) pp. 49-62.

[6] Ontario Water Resources Commission, *Water Resources Survey of the County of Welland*, 1964, mimeographed, p. 86.

[7] Examples include:
Upper Thames Conservation Authority, Brief on Flood Control Measures, March, 1959
and Region Metropolitan Toronto Conservation Authority, Plan for Flood Control and Water Conservation, 1961.

[8] D. Cass-Beggs, *op. cit.*, p. 181.

[9] J.G. Warnock (Our Water Needs—What Will They Be?) Conference on Water Resources Management, The Conservation Council of Ontario, Toronto, 1966.

[10] A. K. Watt, "Adequacy of Ontario's Water Resources", *The Canadian Mining and Metallurgical Bulletin*, Vol. 60, No. 664, August, 1967, pp. 918-921.

[11] The most highly developed of these studies are the investigations undertaken for the Atlantic Development Board of water resource problems in the Atlantic Provinces.

The Shawinigan Engineering Company Limited and James F. MacLaren Limited *Water Resource Study of the Province of Newfoundland and Labrador*, Montreal, 1968.

The Montreal Engineering Company Limited, *Maritime Province Water Resources Study*, Montreal, 1969.

the development of estimating equations from the regression line.[12]

More recently, the operational technology has been pushed forward to the beginning of a program on the introduction of more advanced mathematical modelling techniques. This development is an attempt to bring water use requirement forecasting in step with the technology of supply forecasting which has used operational models for stream flow forecasting for a number of years.

THE FORECASTING FRONTIER IN CANADA

Contemporary events in forecasting are occurring in two areas, the development of an improved data base and the construction and testing of the first elaborate mathematical models of water use in specific river basins. In both cases, this work is being led by the Water Management Service of the Federal Department of the Environment. It has been the formation of a water planning group in the federal water service agency that has led to the development of a more defined and rigorous water requirement forecasting program in Canada.[13] The framework of this national water use inventory and forecast is divided into three steps:

1. Assembly of historical and current use, and consumption data.
2. Analysis and the relating of these data to other significant economic and social data to allow the construction of water use and demand models.
3. Testing, extension and refinement of forecasting models on both micro and macro scales at regional, provincial and national levels.

Data assembly has been a continuous process in many government agencies in both the federal and provincial governments. Unfortunately, until recently it had not been carried out on a systematic basis. There has been, however, a considerable quickening of effort in data collection during the last year and Statistics Canada has agreed to include a sample water-use question on its 1972 Census of Manufacturers Questionnaire. The Department of Industry, Trade and Commerce is undertaking a special survey of the major manufacturing water users. On the basis of the results of these studies, it is intended to organize a detailed industrial water-use inventory in 1973.

Information on other withdrawal uses is more readily available. Agricultural abstractions for irrigation have been licensed in most provinces for twenty years or more. Municipal information is collected by provincially regulated bodies and by private agencies.[14]

The national water forecasting model has been disigned to encompass both withdrawal and *in situ* uses. The model is being constructed to make forecasts for a number of individual sectors of the total water using activity area. These sectors are:

a. municipal, including domestic, commercial, institutional other public uses and losses;
b. manufacturing and mining both municipally and individually supplied;
c. private system and individual supply – domestic use;
d. thermal and hydro-electric power generation;
e. irrigation and other agricultural;
f. in-stream uses such as recreation, navigation and waste disposal.

The preliminary forecasting model, with sub-models developed for each water-use sector, will employ the water-use coefficient approach applied to forecasts of water-related activities.

The result will simply be a projection of historical trends into future years. The horizons to be used are 10 years and 30 years, although it is realized that for longer time periods there are serious drawbacks to the historical projection model. In keeping with demographic forecasting conventions, the model will render a range of future water demands–high, medium and low–based on different social and economic assumptions.[15]

The model is intended to be a macro model with provincial and individual river basin breakdowns of forecasts permissible. The results will be in the form of annual water requirements, both withdrawal and *in situ*. There will also be some analysis of peak-day versus average-day loads and of other sensitive parameters.

It is hoped to refine and extend the model for alternative futures, to permit inclusion of a greater number of local variations and more precise water use or demand coefficients. The more refined national model will depend to a large extent on the improvement and elaboration of

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[12] Similar work has been done for flood damage estimation, H.G. Acres Limited, *Guidelines for Analysis, Streamflows, Flood Damages Secondary Flood Control Benefits,* Report to Canada Ontario Joint Task Force on Water Conservation Projects in Souther Ontario, Niagara Falls, 1968.

[13] See–J.W. MacNeill, Assumptions Made by the Canadian Government in Establishing Strategies for Environmental Quality Improvement, paper prepared for presentation to The Atlantic Council of the United States Conference on "Goals and Strategies for Environmental Quality Improvement in the Seventies"–January 15-17, 1971, pp. 17-20.

[14] The most accessible municipal water withdrawal information is that published annually by the magazine, *Water and Pollution Control*, each September.

[15] The development of this model is being directed by Mr. P.J. Reynolds Head, General Studies and Resource Data Sections, Inland Waters Branch, Department of the Environment.

forecasting models in other sectors of the Canadian economy and for other aspects of Canadian society.

The beginning of this exercise is embodied in the first phase of the National Water Needs Study presently nearing completion and which, hopefully, will be published in the near future.

RIVER BASIN MODELS

Work has also begun on a number of individual river basin forecasting studies.[16] Methodologically, the most advanced forecasting techniques are being investigated in the water quality models for the Saint John River basin in New Brunswick.[17] Unfortunately, this study has not yet been completed so a full account of the forecasting techniques used cannot be given here. It is expected, however, that the report will be issued before the end of 1972.

The Saint John River drains an area of some 26,000 square miles, of which 64 per cent lies in Canada, the major portion within the province of New Brunswick. The river basin supports a variety of economic activities which have an impact on the water resource. The most significant include industrial waste disposal, particularly from pulp and paper, and food processing industries; agriculture; lumbering; municipal waste disposal and hydro-electric power operation. The expansion of many of these activities in both Canada and the United States has led to the development of severe water-use conflicts which become more apparent with the decline in water quality.

The purpose of the model study is to quantitatively evaluate the constraints imposed by water quality requirements on the optimization of social and economic development in the basin.[18] Two basic categories of models are being developed, mathematical programming (linear and non-linear programming) and simulation models. The initial emphasis is being placed by the study on the former since it can be more quickly constructed from the available information. The programming model should aid in the construction and testing of the simulation model.

[16]These programs are being carried out under the terms of the Canada Water Act, 1970, and studies are in progress on the Okanagan Basin, British Columbia, and the Qu'Appelle Basin, Saskatchewan, as well as the Saint John.

[17]The study is being carried out under contract by the H.G. Acres Company Ltd.

[18]This study is only part of a comprehensive planning and management program in the Saint John River basin, a more complete account of the program can be found in Canada, Dept. of Fisheries and Forestry, NATO/CCMS Pilot Project on Inland Water Pollution, report prepared for Program Development Meeting, Brussels, March 1-3, 1971.

The models are being constructed to allow the consideration of the following set of alternative strategies for waste treatment:

- i primary sewage treatment, municipal
- ii secondary sewage treatment, municipal
- iii nutrient and other forms of chemical treatment, municipal
- iv various levels of industrial treatment
- v artificial or "in stream" reservation
- vi control of combined sewer outflows
- vii removal of bottom deposits
- viii low flow augmentation
- ix temporary storage of wastes
- x piping of wastes outside the basin or downstream for disposal in less critical reaches

Not all these alternatives are important nor will they all be considered in the Saint John basin study; nevertheless they are included in the model for the sake of generality and transferability to other river basins. Each of the models is being structured to allow general application. The data requirements for the models are being carefully documented so that relatively inexperienced personnel will be able to collect data and modify the model for application elsewhere.

The methodology being used in the development of the model consists of a number of separate stages. The river basin area has been divided into a number of reaches or sections based on consideration of critical point factors affecting water management. These factors include sources of industrial, municipal and other wastes, regions of urban growth, water supply points and areas of particular economic activity. The reaches will become the basic framework within which the model will operate.

Projections of population and economic activity to 1980, 2000 and 2020 will be disaggregated to the reaches and organic waste loads will be estimated using per employee or per capita coefficients. The resulting waste-loads will be used to evaluate alternative control strategies without violating selected water quality standards.

It can be expected that the major part of Canadian water management and planning will remain preoccupied with problems of water quality. The Saint John River study is typical of future studies for forecasting water uses from the viewpoint of their impact on future water quality. Water quantity forecasting will probably remain of secondary significance except regionally and in the relatively water-short areas of the west.

FORECASTING METHODS AND PROBLEMS

It is perhaps necessary to put the discussion of the state of the art of water requirement forecasting in Canada into a methodological perspective. The forecasting methods have become more sophisticated as the use of forecasting has grown. The technology available for the making of forecasts has improved rapidly over the last decade. The ability to use electronic data processing equipment has enabled the planner to handle far more data and use far more sophisticated and complex models of reality than was possible in his predictions of previous years. It can be shown, however, despite this sophistication, that little improvement has been made in the ultimate forecasting error, the fact that the forecasts often are wrong. This is the major common link between all the different projections of water use, or for that matter, any economic activities.

The point that should concern everyone engaged in making or using water requirement forecasts is the problem of their utility. What is the utility of forecasts that are wrong? What is the logic for forecasting? What form should forecasts take? It is these questions that are most pertinent whether we advise a developed or an undeveloped country or whether our concern is irrigation of five-acre farms or backyard swimming pools. It is to the discussion of these questions that this part of this paper is directed.

Projection in forecasting water requirements over time is a problem of inductive inference.[19] It is subject to the same set of conditions as apply to all attempts to infer one set of conditions from another. A projection is a prediction that a set of events 'A' will develop out of another set of events 'B'. For the prediction to be valid, it requires tested theories in the sense of "lawlike" generalizations. Unfortunately, water requirement forecasting has not developed a set of "lawlike" generalizations.[20] In contrast, the existing situation can be likened to that of the astrologer one sees so often in Canadian shopping centres these days, who makes use of an impressive array of data processing equipment to produce horoscopes. Sophistication of processing technology does not increase the reliability of the relationship between the pattern of the stars and the events of an individual's life nor the reliability of the water use coefficient as a forecasting model.

The situation is not without remedy. The new technology of the planner has in fact given him a tool with which to overcome the problems of the uncertainty that the future holds. It is never going to be possible to accurately foretell the future in quantitative terms. It is possible now, given the data processing ability that the planner has, for a clearer outline of the probability of the outcome of events to be made. All these problems are found in the field of water resource planning. Lacking clairvoyance, the planner can never hope to do more than chart the most probable paths that society will take in the years of the planning period.

Due to historical circumstance in North America, water resource planning has been in the forefront of planning technology for a number of years. Many of the innovations in planning techniques have been first applied in the water sector of the economy. Even in water, unfortunately, many of the more sophisticated techniques available to the planner have not been applied in a rigorous sense. Most plans that are made still remain very heavily based upon the demographic type of projection.

In many cases, the use of such techniques has been raised to a high art, as in the cohort survival-variable immigration methods of population predictions, but they remain mere statistical manipulations which provide no insight into why population levels should change. Similarly, the use of coefficients in water forecasting is limited in utility by the value of the assumptions used in the derivation of the coefficients.

For example, in a recent water requirements study, the prediction of industrial water demand was based upon an observed relationship over three census periods between value added in constant dollars and gross water use. It was noted that water withdrawals are not statistically linked to gross value added but, rather, are a function of the rate of recirculation of water in the manufacturing. This is a relationship dependent upon the availability of water in terms of both quantity and quality, water costs, treatment costs, and effluent requirements. It also was noted that a prediction based upon consideration of these factors would be more accurate than the one that is devoid of them; however their consideration would raise the possibility of of an entirely different and possibly contradictory answer. The pattern of water consumption, or rather water withdrawal, is not just related to the gross value added in the manufacturing process, but is indeed a function of the cost at which water will be supplied.[21] A better understanding of the demands for water, in the economic sense, could lead to a vastly improved comprehension of the likely future pattern of water consumption.

In forecasting, there is far too great a readiness to ignore the fundamental demand-supply relationship. Price is not a significant consideration in most requirement forecasts and

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[19]For an earlier discussion of this point see, S.V. Ciriacy–Wantrup, Projections of Water Requirements in the Economics of Water Policy, in H.L. Amoss (ed) *Water, Measuring and Meeting Future Requirements*, Western Resources Conference, 1960, (Boulders Univ. of Colorado Press, 1961) pp. 211-226.

[20]I.K. Fox and O.C. Herfindahl, "Attainment of Efficiency in Satisfying Demands for Water Resources", *American Economic Review*, May 1964, pp. 203-204.

[21]For a discussion of industrial water demand see B.T. Bower, "The Industrial Water Utilization", in A.V. Kneese and S.C. Smith Water Research (Baltimore: John Hopkins, 1966) pp. 143-174. J.A. Rees, *Industrial Water Demand: A Study of Southeastern England* (Oxford Weidenfald and Nicholson 1969) and D.M. Tate, Water Requirements of the Iron and Steel Industry in the Canadian Great Lakes Basin, Dicussion Paper No. 71-2, Policy Research and Co-ordination Branch, Department of Fisheries and Forestry, Ottawa, 1971, pp. 19-43.

therefore demand in the economic sense is ignored, "There are two ways to ignore demand—to assume that it is inelastic with respect to price—or to claim that it should be".[22]

The demand for water is certainly not inelastic.[23] Even without an explicit market price, the pattern of water demands can be readily shown to be not dissimilar to that of other economic commodities, but too often, predictions of the future are based upon observed statistical relationships between bodies of data without investigation of what these relationships really mean. This is not to suggest that a prediction is not possible without first understanding the nature of every part of the water-resource-dependent sector of the economy. It does suggest, however, that predictions must be based on and related to the general economic and social trends within the economy. A suggested set of characteristics is shown in the water requirement matrix. The reality of the resulting predictions of levels of water demand must be tested rigorously.

Too many studies are based upon assumptions of doubtful validity which, when subjected to a critical review are found to be unacceptable. The assumptions made in the most preliminary study should stand up to testing by the information gathered in the most detail. Unless the basic conceptual framework on which a study has been developed is firmly established, then the study may be not only of limited value but also a dangerous adjunct to policy development. Before a prediction or forecast can be made, the general relationship between overall economic and social development and the use of water must be comprehended.

In a complex and modern industrial society such as that which exists in Canada, the relationship of water to that society is in many ways similar to that of any other industrial sector. The activities of water resource managers can be described in terms of the operation of the water industry, although there are some deficiencies that can be observed in the operation of a "water industry" which mark it off from the traditionally defined industrial sectors. In Canada, public enterprise is very much dominant in the management and exploitation of the water resource, although it remains a debatable point whether this really distinguishes water from other resources. The use of water is and will remain an area of mixed public and private enterprise with future patterns of water use dependent on the individual decisions of large numbers of "water managers". In this situation, increases in water consumption for one use or another do not occur without bearing some relationship to the general economic and social climate and variations in the supply and demand functions of water. It is suggested, therefore, that the aim of any study made to forecast or predict future patterns of water consumption and use should be guided by the goal of understanding the economic relationships between the use of water and other inputs into the economic system under a changing set of social objectives.

There are available a number of tools which allow the planner to make forecasts of this kind. This includes the use of linear programming models with input and output functions established under a given set, or possibly alternative sets of conditions, but these are probably more applicable to a situation where a specific goal must be met. Such models are very useful in water quality studies but seem to be more restricted in application to studies of future patterns of water consumption. In the latter case, the best technique would seem to be the development of input-output type models of the economy to permit one to observe the impact of alternative assumptions about economic growth of individual industries on the pattern of water use and consumption. The information gained from such models of the economy will allow one to observe the impact of alternative assumptions about economic growth of individual industries on the pattern of water use and consumption. The information gained from the input—output model would then have to be translated into spatial and social terms. The growth of one industry, rather than another, may lead to the emergence of a different spatial distribution of industry and population in the region of the study, and may also have different implications for the dominance of one social trend over another. In Ontario for example, predominance of growth in resource industries over secondary manufacturing would have quite a different effect upon the future pattern of population in the province than would be the case if these relative growths were reversed. Any model should be sensitive to changes in a large number of different types of variables. Variables affecting water using decisions may range from changes in fiscal or trade policies to a shift in managerial or user attitudes.

The development of a water requirement forecasting system must achieve and sustain a close reflection of reality. The forecasts must take account of political and social changes since they could affect future patterns of

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[22] N.H. Lithwick, *Urban Canada: Problems and Prospects,* (Central Mortgage and Housing Corporation, Ottawa, 1970), p. 22.

[23] Elasticity of residential demand is discussed in—C.W. Howe and F.P. Linaweaver, Jr., *"The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure"*, Water Resources Research, Vol. III No. 1, 1967, pp. 13-32.

T.R. Lee, *Residential Water Demand and Economic Development,* University of Toronto, Department of Geography, Research Publication No. 2 (Toronto: University of Toronto, 1969) pp. 13-26 and J.W. Milliman, "Price Policy and Urban Water Supplies", *Water and Sewage Works,* Vol. 110, November, 1963, pp. 384-394.

The classic paper on industrial water demand is, G.F. White, "Industrial Water Use: A Review": *Geographical Review,* Vol. 50, No. 3, 1960, pp. 412-430.

DEMAND FACTORS / WATER USE SECTOR	POPULATION	POPULATION DENSITY	AGE STRUCTURE	FAMILY SIZE	INCOME LEVEL	NATURE OF ACTIVITY	LEVEL OF PRODUCTION	SCALE OF PRODUCTION	PRODUCTION PROCESS	SYSTEM LOSS	COST OF WATER PER UNIT ●	NATURE OF WATER / UNIT	ACCESSIBILITY OF SOURCE	CLIMATE	WATER QUALITY	WATER QUALITY REGULATIONS	MAGNITUDE OF SOURCE
DOMESTIC (Residential)	■	■	■	■	■					■	■	■	■	■	■	■	■
COMMERCIAL (Trade & Finance)	■				■	■	■			■	■	■	■	■	■	■	■
PUBLIC (Institutional)	■	■	■		■	■				■	■	■	■	■	■	■	■
MFG.						■	■	■	■	■	■	■	■		■	■	■
MINING						■	■	■	■	■	■	■	■		■	■	■
AGRICULTURE						■	■	■	■	■	■	■	■	■	■	■	■
ELEC. POWER GENERATION							■	■	■	■	■	■	■	■	■	■	■
NAVIGATION							■	■	■			■					■
RECREATION	■	■	■	■	■	■						■	■	■	■		■
AESTHETIC		■			■							■	■	■	■		■

WATER REQUIREMENT FORECAST MATRIX

● COST IS OPPORTUNITY COST WHICH IN SOME CASES MAY BE EXPRESSED AS PRICE water use to the same extent as technological change or economic growth. Unless these, the most significantly dynamic variables, are included in the models used for forecasting then any projection will be incomplete. This is particularly important in the less developed case where the magnitude of future change can be very great. It is a problem faced in water requirement forecasting in Canada as well as in underdeveloped countries. The need is to make the water requirement forecasting exercise a much broader one than it has traditionally been.

WATER FORECASTING AND ECONOMIC AND SOCIAL CHANGE

The role of water in the so-called process of economic development has been consistently overvalued.[24] Although an important natural resource and available in abundance in Canada, water generally requires considerable financial investment before use. This makes the need for forecasting changes in water requirements all the more necessary.

> Many economic policy (water policy) decisions have long-term effects. These decisions inevitably are based on expectations, whether the views of the future are explicitly worked out and recognized or not. There is, therefore, a strong argument for the proposition that the best strategy is to decide questions of economic policy (water policy) in the light of explicit expectations based as carefully as possible on well-marshalled information from the record and on the knowledge and theory of the working of the economy that is available.[25]

The question that remains is "How this forecasting is to be done? " There seems to be little doubt that the forecasts should be technologically simple no matter how complex conceptually. The significant factor is not statistical sophistication but that the assumptions accurately reflect reality. It cannot be expected that growth and changes in water use, or water requirements, in an underdeveloped country will parallel those observed elsewhere. There are general relationships between the level of water requirements and sets of management factors but there are no fundamental coefficients of water use that can be applied to selected indicators of economic activity. Water requirement forecasting, in particular, and water management in general has suffered from ill-grounded 'principles' of development as have other areas of economic management and planning.[26] The forecasting of water requirements can only be done successfully and usefully with a depth of empirically derived experience of the water using system for which the forecast is being made.

It is more significant to completely delineate the assumptions upon which the forecast is based than to strive for the forecasting technological frontier. The requirement for water is a product of the influence of a multitude of individual demands, tastes and preferences. The direction of change in such a variety of factors is difficult to clearly ascertain unless the relationship of water use to the larger economic and social system is understood.

The purpose of forecasting future requirements for water should always be kept in mind. It is an aid to the water resource manager in the task of maximizing the efficiency, in terms of fulfilling desires, of those areas of social and economic activity which involve the use of water. In most cases any particular water is substitutable and is no different from any other goods used in society.

What is lacking, so often, is a clear understanding of the nature of the demand for any specific attribute of the water resource. It is this gap that the practitioner of requirement forecasting must fill if he is to contribute to the improvement of the effectiveness of water management.

APPENDIX OF DEFINITIONS

The widening of the framework within which the water forecast should be made does not remove the necessity to define carefully the economic nature of water. In any forecasting exercise the terms should be carefully explained and some of the basic characteristics of water as a resource clearly understood.

An attempt has been made to offer a definition of some of the important terms in the water resource management vocabulary. These definitions should not be construed to be official Canadian definitions. They are only offered to form a foundation for future discussion.

1. *Water Requirements*. The water requirement is the amount of water necessary to support a particular method and type of activity. It is the specific amount of water used at a particular time by a particular process, for example—a specific set of processes at a steel mill will require a certain amount of water to be supplied to that process.

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[24] The role of water in the economic development process is discussed in,
T.R. Lee, *Residential Water Demand and Economic Development*, pp. 119-126.
and in the classic article,
C.W. Howe, "*Water Resources and Regional Economic Growth in the United States, 1950-1960*", Southern Economic Journal, Vol. 34, No. 2, April, 1968, pp. 477-489.

[25] W.C. Hood and A. Scott, *Output, Labour and Capital in the Canadian Economy*, Royal Commission on Canada's Economic Prospects, 1957, p. 1.

[26] The Growth Centre at Yale University, *Report 1961-1964* (New Haven, Conn., April, 1965,) p. 9.

2. *Water Need.* Although water need is often acquainted with water requirements, it is probably better to make a distinction between the two terms. The term "water need" should be restricted in use to the essential amount of water which must be supplied for the support of any process or means of life. The best example is the human need for 1 litre of water per day for the functioning of the human biological system.

3. *Water Use.* Water use is not a term defining an amount of water, but rather a term defining the purpose to which any given body or amount of water is put, and probably should be used as the most general term. It is, after all, the human use of water with which we are concerned.

4. *Water Demand.* Water demand can only be defined in terms of the specific amount of water demanded by a given consumer at a given price. This price need not be expressed in direct monetary terms, but, in any use of water, there is a certain cost involved in abstracting the water from the source of supply for a specific purpose and this cost influences to a large extent the amount of water that will be demanded.

5. *The Economic Character of Water.* Many authorities have expounded upon the nature of water as an economic commodity or as economic goods. Without venturing fully into this debate, there are some important characteristics of water which must be borne in mind in any attempt to forecast future water demands. By the very nature of the uses to which water is put by man, water cannot be considered as one economic commodity. The economic nature of water varies according to the use to which it is being put. Any attempt to define the economic nature of water can lead into a complex jungle, moral, philosophical, social as well as economic attitudes. A threefold distinction can be made for the purposes of water management and requirement forecasting. These are:

   a. Water as a Social Overhead Capital Commodity. In many uses, water is similar to public education, roads and the like. This is particularly the case in such uses as water supply for domestic consumption, or the use of water for the disposal of waste materials.

   b. Water as an Industrial Raw Material. The major uses that are made of water in the economy are for water as an industrial raw material although it may not, in many cases, be incorporated in the product. Industrial uses include the generation of hydro-electric power, the use of water for cooling in industry and the use of water for irrigation.

   c. Water as an Aesthetic Commodity. Water supply and demand balance has been altered in recent years by the tremendous growth of the use of water for recreation. Water bodies are put to many recreational uses; as a means of navigation, for fishing, for swimming, and lastly, perhaps not of least importance, just for the sheer aesthetic pleasure obtained from viewing an attractive body of water, be it a lake or running stream.

6. *Instream Use.* The use of water in its natural channel or basin. This category includes navigation, recreation, fishing, waste disposal and hydro-electric power generation.

7. *Extractive Use.* The withdrawal of water from its natural channel or basin before use. This category includes water for cooling, irrigation, municipal and industrial water supply. It should be noted that extractive use does not imply consumptive use.

8. *Consumptive Use.* The permanent removal of part of the flow of a water body. Consumption may take the form of evaporation of waters to the atmosphere; the incorporation of water in some product, as in the case of the brewing or soft drink industry, or it may take the form of the diversion of water from one water body to another.

9. *Non-consumptive use.* A type of loan arrangement in which the water is ultimately returned to the water body. Such water may be considerably changed in character as with the addition of wastes in municipal extractions and heat in cooling extractions.

No attempt at comprehensiveness is being claimed for this list of definitions. It is necessary that such definitions be made and a common standard accepted. This should be done not only to permit the adoption of comparable methods in studies at different times and places but more importantly, to emphasize that the use of water is an area of human behaviour that can be understood. Projection and forecast cannot become prediction before it is accepted that the use of water is subject to common variables independent of place or purpose. The multitude of fashions in which man uses water should not be allowed to obscure this fundamental generalization.