Inquiry on Federal Water Policy

Enquête sur la politique fédérale relative aux eaux

Research Papers #17

Documents de recherche

ALTERNATIVE FUTURES OF CANADIAN WATER USE 1981-2011

by

Donald M. Tate

Canada

Inquiry on Federal Water Policy
Research Paper # 17

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THE INQUIRY ON FEDERAL WATER POLICY

The Inquiry on Federal Water Policy was appointed by the federal Minister of the Environment in January of 1984 under the authority of the Canada Water Act. The members were Peter H. Pearse, chairman; Françoise Bertrand, member; and James W. MacLaren, member. The Inquiry was required by its terms of reference to review matters of water policy and management within federal jurisdiction and to make recommendations.

This document is one of a series of research papers commissioned by the Inquiry to advance its investigation. The views and conclusions expressed in the research papers are those of the authors. Copies of research papers and information on the series may be obtained by writing to the Enquiry Centre, Environment Canada, Ottawa, Ontario K1A 0H3.

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Abstract

Projections of withdrawal water use in Canada, its five major regions and 47 major river basins are contained in this research report. The time period covered by the forecasts carried out here is 1981-2011. The methodology used is based upon structural modelling, employing a thirty-sector regional input-output model, augmented for use in a water demand projection mode. Major variables used in the forecasting were economic activity levels, production technology and water use practices, as defined in the first chapter. The effects of a concerted effort at promoting water conservation were also modelled.

An alternative approach to the forecasting problem is outlined in chapter five, using the Red Deer River basin as a hypothetical case study. The advantages of this simulation modelling approach relate to the integration into the water use forecasting process of water supply considerations, and the ability to conduct studies on a river basin and subbasin level, as opposed to an economic region level.

Six recommendations for further work are made in the final chapter.

Résumé

Ce rapport de recherche contient des projections sur l'utilisation de l'eau hors de son cours normal pour le Canada, pour chacune de ses cinq régions majeures et pour chacun de ses 47 bassins principaux. Ces prévisions couvrent la période 1981-2011. La méthodologie utilisée repose sur l''emploi d'une modélisation structurée elle-même basée sur un modèle régional d'entrée-sortie à 30 secteurs; ce modèle a été modifié afin d'être utilisable dans le domaine de la projection de la demande en eau. Les principales variables utilisées pour ces prévisions sont les niveaux d'activité économique, la technologie de production et les pratiques habituelles d'utilisation tel que décrites au chapitre 1. Les effets d'un effort concerté afin de promouvoir la conservation de l'eau ont aussi été modelisées.

Une approche différente du problème de la prévision est décrite au chapitre 5. Le bassin de la rivière Red Deer y est utilisé comme étude de cas hypothétique. Les avantages de cette approche simulative sont liés à l'intégration dans le processus de prévision de considérations sur les approvisionnements en eau de même qu'à la possibilité de faire des études au niveau du bassin et des sous-bassins d'une rivière par opposition à la simulation à l'échelle d'une région économique. Le dernier chapitre contient six recommandations quant aux travaux futurs dans ce domaine.

Summary

Projections of withdrawal water use in Canada, its five major regions and 47 major river basins are contained in this research report, commissioned by the Inquiry on Federal Water Policy. The time period covered by the forecasts carried out here is 1981-2011. The methodology used is based upon structural modelling, employing a thirty-sector regional input-output model, augmented for use in a water demand projection mode. Major variables used in the forecasting were economic activity levels, production technology and water use practices, as defined in the first chapter. The effects of a concerted effort at promoting water conservation were also modelled. The range of expected withdrawal and consumptive water uses for Canada and the regions to 2011 are shown in tabular form as follows.

EXPECTED RANGES OF WATER USE, CANADA AND REGIONS
1981-2011 (MCM)

Region		Intake		Consumption	
		Low*	High**	Low*	High**
B.C.	1981	3789	3789	487	487
	1991	3950	5043	512	645
	2001	3989	6623	508	850
	2011	3726	8057	464	1046
Prairie	1981	5363	5363	2256	2256
	1991	6167	7569	2494	3172
	2001	6580	10158	2485	4227
	2011	6687	12895	2262	5318
Ontario	1981	21230	21230	589	589
	1991	23987	28355	711	776
	2001	26925	38146	649	1031
	2011	29235	48258	625	1291
Québec	1981	4252	4252	435	435
	1991	4523	5514	428	525
	2001	4567	7184	417	661
	2011	4327	8901	380	804
Atlantic	1981	2884	2884	139	139
	1991	3222	3795	150	179
	2001	3529	4902	153	223
	2011	3764	5929	151	263
Canada	1981	37518	37518	3906	3906
	1991	41848	50275	4292	5298
	2001	45589	67011	4212	6990
	2011	47738	84039	3882	9025

* Scenario 2, as defined in Chapter three

** Scenario 5, as defined in Chapter three.

An alternative approach to the forecasting problem is outlined in Chapter five, using the Red Deer River basin as a hypothetical case study. The advantages of this simulation modelling approach relate to the integration into the water use forecasting process of water supply considerations, and the ability to conduct studies on a river basin and subbasin level, as opposed to an economic region level.

Six recommendations for further work are made in the final chapter. In summary form, these are:

1. The major focus of future water demand studies at the federal level should be at the major river basin level, and should be oriented toward comparing available supplies with current and projected uses, using a simulation modelling approach such as that suggested in Chapter five.
2. The structural model of Chapter two should be developed further in order to obtain regional overviews of emerging water demands.
3. The range of alternatives for water conservation and their impacts on water demand should be studied and assessed with regard to their impacts in reducing water demand.
4. The impacts on water demand of emerging production technology may be substantial, and should be examined beyond the analysis contained in this report.
5. Water use data for industries and municipalites should continue to be collected on a regular basis to provide basic information for future water demand forecasting exercises.
6. Research should be carried out to integrate nonwithdrawal water uses into the forecasting framework established in this report.

ACKNOWLEDGEMENTS

This project was made possible only with the assistance of several persons. Ms. P. Dossett served as research assistant throughout the project, and performed most of the mathematical computations and graphical presentations contained in the report. Dr. A. Kassem co-ordinated most of the work carried out in Chapter 5. These persons also provided useful day-to-day discussions and advice. D. Scharf, D. Lacelle and P. Hess provided much of the data on current water use on which the study is based. Ms. C. Lefebvre provided clerical assistance throughout the project. Finally, the Advisory Committee established for the project provide many useful ideas and suggestions. Members of this committee were Dr. Duane Baumann, Dr. Peter Harrison, Mr. Clive Simmonds, Mr. Carl Sonnen, Mr. Bruce Stokes, Mr. Douglas Vallery and Dr. Terry Veeman. Any errors or ommissions in the report, of course, are my responsibility.

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CHAPTER 1

INTRODUCTION

1.1 Need for the Project

The use of water is one of the most fundamental transactions between man and nature. It is an integral part of most of man's activities, and, in turn, water is affected greatly by man's use of the resource. When considering the economic and social development of a nation, one important but often underplayed issue relates to water use. Will there be enough water to support development? Will it be of adequate quality, in the right location, and available at the right time to be of use? Can society achieve the desired degree of development while preserving and conserving available water resources? Are water transfers required to achieve development? In answering these and other equally important questions, one fundamental piece of required information is a set of water use projections over a fairly long term period (e.g. thirty years).

1.2 Purpose of the Project

This project is one of a series of research investigations commissioned by the Inquiry on Federal Water Policy (the "Inquiry"). The overall purpose is to forecast water uses in Canada, its five regions and its major river basins to the year 2011. The forecasts will be broken down to the latter level to facilitate comparison of future water uses with supply conditions. The latter task is assumed here to be one of the analyses to be carried out by the Inquiry staff.

The remainder of this chapter deals with the scope of the project. Chapter two contains a detailed discussion of the methodological framework used in this research. It may be skipped if the reader is interested only in the substantive findings. Chapter three documents the selection of alternative futures which underlie the water use forecasts. The results of the principal research investigations of this project are outlined and discussed in Chapter four. Based upon limitations identified in this chapter and on research currently underway but not yet completed, Chapter five outlines an alternative forecasting approach. Finally, Chapter six draws the major conclusions and implications from the study. The water use forecasts themselves plus the background of historical water use constitute the principal conclusions of the report. It is beyond the scope of this project to draw conclusions about water supply:use imbalances across the country.

1.3 Scope of the Project

1.3.1. Forecasting Time Horizon

As noted above, the water use forecasts prepared during this project cover the 30-year period 1981-2011. This time period posed many problems of uncertainty, which will be discussed below. In spite of these problems, a thirty year period is required in view of at least three factors. First, water projects require lengthy planning and implementation periods. These long planning and construction times required in the water resource field stand in marked contrast to most business decisions, which require shorter implementation times, and therefore shorter forecasting horizons. Second, water related structures are permanent and expensive capital assets and, accordingly, should be planned with some idea in mind of future water use conditions over the long term. Third, water projects tend to affect many persons and activities for long periods of time. Thus, again, good planning requires a long range view of the future.

The chief implication of a 30-year forecasting period is a large degree of uncertainty. While water use forecasts can be prepared simplistically by extrapolating past trends, such procedures are of limited usefulness. Trend is definitely not destiny, and much of the work in any water use forecasting exercise must be devoted to attempting to cope with economic, social, technological and policy uncertainties in the future.

1.3.2. Basic Approaches to Forecasting

Study of the future and the preparation of forecasts has grown over the past two decades into a virtual industry, with its set of academic journals, university courses and frequent conferences. Although the array of forecasting techniques is formidable, it can be divided into those techniques which are analytic in nature, and those which can be termed futuristic.

The analytical techniques involve detailed computer models, large amounts of quantitative data and a general reliance on the traditional logical positivist approach to the subject. Forecasts tend to rely on those variables which can be quantified, and the effects of factors such as lifestyle variations, social trends and other unquantifiable variables are downplayed. The advantages of analytic procedures for forecasting lie in the quantitative answers which are produced, the availability of computer techniques and the built-in logical relationships between variables. Disadvantages are several and substantial. The forecasts are at best partial in nature, for only those variables modelled can be displayed. Significant changes in the society in lifestyles or social attitudes may be equally significant to the quantified factors in changing water use and yet remain unconsidered.

Futuristics, on the other hand, tends to be a broader and more wholistic approach than analytic modelling. The approach considers not only trends which are quantifiable, but also broader issues, such as the social context of the future, lifestyles, ethics and philosophies. Being wholistic in nature, futuristic approaches are more difficult to model mathematically. Rather, techniques such as Delphi panels, content analysis, and "brainstorming" are used.

The distinction between these two classes of techniques is of interest here because this project is based very much on the analytical approach. Variables which are quantifiable and which are thought to be important in determining the level of water use in various activities have been combined in a mathematical model to produce quantitative forecasts. Unquantifiable factors have been omitted. Also, the forecasts contained here are "positive" in nature, in that they show what would happen to water use if specified conditions emerge. This stands in contrast to so-called "normative" forecasts which focus upon specifying what should occur to achieve specified goals (e.g. maximum economic growth).

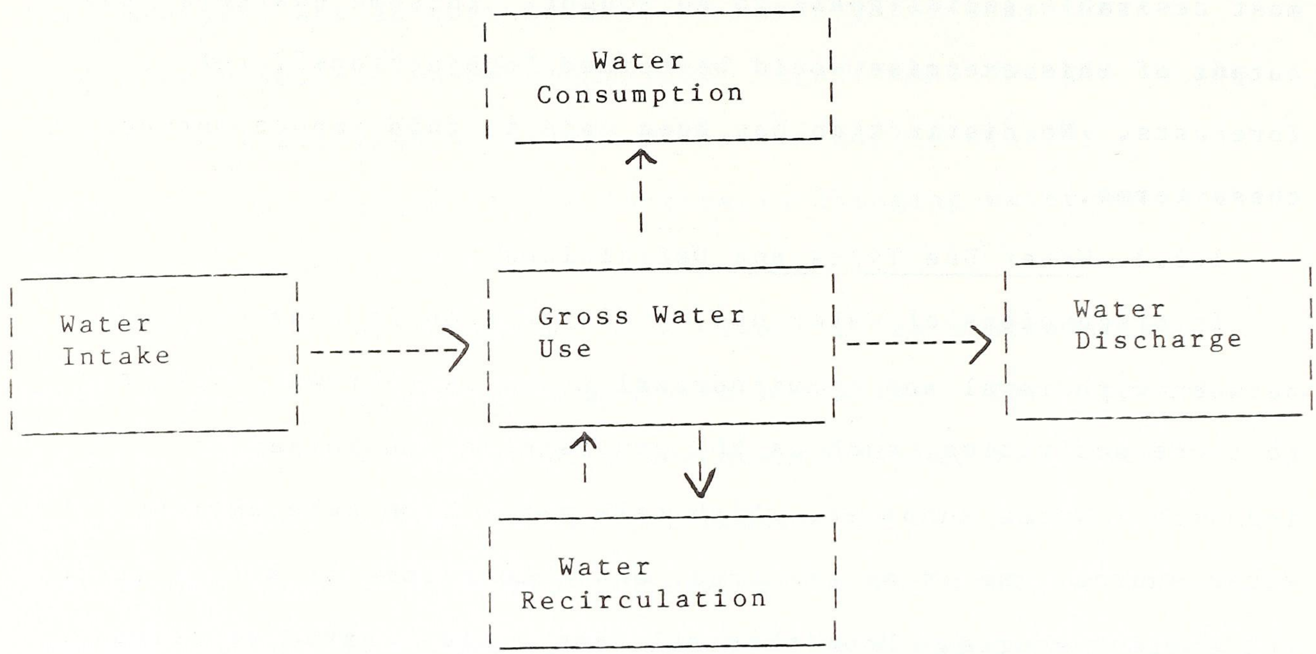
Normative forecasting has not been attempted here because it has not been posible to prescribe the ideal future or to define even the most desirable social goals to be sought. In some quarters, the output of this exercise would be termed "projections", not forecasts. No distinction has been made in this report between these terms.

1.3.3. Water Use Types and Definitions

In discussions of water use, a distinction is commonly drawn between withdrawal and nonwithdrawal uses. Withdrawal uses refer to those activities, such as the provision of municipal or industrial water supplies, which take water from some ambient water source, use it as required, and return some or all of it to the ambient source. Nonwithdrawal uses employ characteristics of the water resource as it occurs in its natural state. Common examples of the latter type of usage are hydroelectric power generation and water-based recreation. The distinction between these two types of usage is important here, because this research pertains mainly to the former type of use. Many of the concepts employed here would be inappropriate for a study of nonwithdrawal water use.

In collecting data and conducting research on industrial water use, the following concepts have been used (Figure 1.1). Water is taken into a plant by way of some type of intake system composed of pipes, pumps and intake treatment. The amount of water taken in for first time use is termed "water intake" or simply "intake". To produce a product or service, some total amount of water is used; this amount is referred to as "gross

FIGURE 1.1 A GENERALIZED DIAGRAM OF AN INDUSTRIAL PLANT WATER SYSTEM



water use". The arithmetic difference between water intake and gross water use is made up of "water recirculation". In their use of water, all users are considered as having water intake and gross water use; not all recirculate water. Many relatively small users and some users adjacent to large water bodies may employ "once through" water systems, in which water is taken into the plant, used and discharged, with no recirculation at all.

The ratio of gross water use to water intake is called the "use rate", and is an index of water recirculation in a plant of activity. The minimum value of the use rate is 1.0 (for once through systems); the ratio increases as more and more water is recirculated, and may reach values of 15 or higher. To quantify the amount of water recirculated, on the survey which constitutes the major source of water data for this project (Canada, 1985), industrial firms were asked to estimate the amount of water which would have been required had there been no recirculating system; this amount is the gross water use at the plant. From this amount was deducted the amount of water intake, the residual being taken as the amount of recirculation.

On the discharge side of a typical plant water circulation system three components are apparent. "Water discharge" is the amount of water put back into receiving waters after use, and, in many cases, subsequent to some form of waste treatment. The arithmetic difference between water intake and water discharge is termed "water consumption". The third discharge component of the system is composed of water recirculation, discussed in the previous paragraph. The ratio of water consumed: water intake is called the "consumption rate" and varies in value between 0 and 1.

In making comparisons of water use with available water supplies, both intake (Canada, 1972) and consumption (Wolman and Bonem, 1971) have been used. Neither measure is completely satisfactory. Water intake denotes the total instantaneous withdrawal from an ambient water source by a given set of industries. Most or, in some cases, all of this water is returned to the watercourse from which it was withdrawn, and therefore does not constitute a "loss" to water quantity. Alterations which may occur as the result of industrial use, such as water quality degradations, are acknowledged but not addressed in this report.

Water consumption, in contrast, is a measure of water apparently lost during a plant's operation, consisting of components such as evaporative losses, water incorporated into products, water removed from the plant site to landfill sites, and other such losses. The concept of water consumption thus measures the water loss at a particular location. But this concept does not necessarily indicate losses to the water resource system as a whole, even in a local area. Evaporative losses may fall subsequently as precipitation; products which incorporate part of plant water intake may be used in the local area, with the water re-entering the watercourse near the plant; water in wastes deposited in local landfill sites will eventually re-enter the local water system. Thus, water consumption may not be a true indicator of water loss to the local or regional water supplies. As used here, the concept of water consumption is <u>relative to the industrial operation itself</u> and not to the concept of the hydrologic cycle.

1.3.4. Spatial Focus

The research consisted of two separate spatial contexts. Most of the work was performed at the national and regional levels. The regional level refers to the five major Canadian political-economic regions: the Atlantic (Newfoundland, Prince Edward Island, Nova Scotia and New Brunswick), Quebec, Ontario, the Prairies (Manitoba, Saskatchewan and Alberta) and British Columbia. The two Northern Territories were not included because they contained a negligible amount of withdrawal water use, and because water use:supply balances are generally not a problem in these areas. The national:regional work was carried out to provide a uniform set of forecasts for the major regions of the country. The regional forecasts were broken down on the basis of current proportions into estimates of future water use for each major river basin. The basin estimates were considered to reflect the water use of the entire basin area, and may be used in making preliminary supply:use comparisons.

1.3.5. Economic Sectors

The national:regional model was built to be comprehensive in its coverage of economic sectors. Work was performed at the two-digit level of Statistics Canada's Standard Industrial Classification(SIC) system. The model consisted of 30 sectors (Table 1.1), 5 primary sectors, 19 secondary sectors and 6 tertiary sectors, which included 2 sectors covering municipal water use. Three of the tertiary sectors (construction; transportation, storage and communication; and "other") contained no water use, and were included merely to preserve the comprehensiveness of the model.

The rural domestic water use sector, although accounted for in the 1981 water use totals, were not forecasted. Rural domestic usage, the use of water in rural residences, accounted for less than 1% of total Canadian water withdrawals (see Chapter 4). It did not correspond, for forecasting purposes to any of the input-output sectors. An attempt was made to forecast it as part of the agriculture sector, but this was not successful since

WATER USE SECTORS

TABLE 1.1

Industry Number	Description
1	Agriculture
2	Forestry, Fishing, Hunting and Trapping
3	Metallic Minerals
4	Mineral Fuels
5	Non-metallic Minerals
6	Food and Beverages
7	Tobacco Products
8	Rubber and Plastics
9	Leather Products
10	Textiles, Knitting Mills and Clothing
11	Wood Products
12	Furniture and Fixtures
13	Paper and Allied Products
14	Printing and Publishing
15	Primary Metals, except Iron and Steel
16	Iron and Steel
17	Metal Fabricating
18	Machinery
19	Transportation Equipment
20	Electrical Products
21	Non-metallic Mineral Products
22	Petroleum and Coal Products
23	Chemicals and Chemical Products
24	Miscellaneous Manufacturing
25	Construction
26	Transportation, Communication and Storage
27	Electric Power
28	Gas and Other Utilities
29	Wholesale and Retail Trade
30	Other (i.e. Finance, Insurance, Real Estate, etc.)

agricultural water use is tending to increase, while farm population is falling. Neither did the sector fit logically into the population-related "industries" of the inpt-output table. Thus, the rural domestic sector was not included in the forecasts contained in this report.

In the main report, water use forecasts will be reported for five aggregated sectors: agriculture, mineral extraction, manufacturing, power generation and municipal uses. Detailed data on each of the 30 sectors are available upon request.

1.3.6. Primary Research Emphasis

The primary variables considered in this research were economic activity levels, the state of production technology and various types of water use practices. This selection was made because the author recently found, in another piece of research (Tate, 1984) that these three factors working together could account for all of the change in water use through time. The economic factor was responsible for large increases in inter-period water use. The increases were offset by trends in production technology, which tended to lower water use. The water use coefficient factor had a small and variable (in sign terms) effect on total water use. Choice of approaches to the research was based upon an extensive methodological review carried out previously by the author (Tate, 1984a, Chapter 3).

The approach used for the national:regional analysis was based on a structural model of the five regional economies, augmented to include the analysis of water uses. This 30-sector model produced consistent estimates of water use for each region under a variety of assumed future scenarios. Economic activity levels were reflected in these regional models as final demands for goods and services. Production technology was assumed to be captured by the input-output inverse matrices used. Water use practices were modelled by means of water use coefficients. The complete structural model is described in Chapter 2.

1.3.7. Coping with Future Uncertainty

The hallmark of futures studies is a large degree of uncertainty, and that is certainly the case in this piece of research. Uncertainty arises in virually every facet of this work. Economic forecasting, beyond a one or two year period enters the realm of speculation. Forecasting technological and structural change is even more speculative. Water use practices by industrial plants is the product of many unpredictable decisions. These somewhat gloomy and negative statements are made, not to express the imprecise nature of the forecasting task, but to place into perspective the methodology and outcome of this study.

It follows from the assumption of uncertainty that unitary forecasts of future water use are not very useful. The chance of being accurate on a forecast of water use 30 years hence are virtually zero. In any event, one predicted value for the future is much less useful for planning and management purposes than a knowledge of a range of possibilities and a prediction of how water use will react to changes in the underlying variables. The latter two tasks are the real challenge of the research.

The "alternative futures" approach has been used here to offset partially the uncertainty factor. The approach, which was formalized by the U.S. National Water Commission (1973), concentrates upon developing a range of values for each major variable underlying water use, and grouping these values into logical and consistent views of the future. Examination is then made of the impact of each future view or "scenario" on water use in each sector. The alternative futures approach as used in this research is documented in detail in Chapter 3.

1.3.8. Issues of Water Demand Management and Water Pricing

In Canada, as in much of the rest of the world, water has traditionally been considered a "free" good. Approaches for water use forecasting have tended to view the future as a series of "requirements", which had to be met. However, many studies (e.g. Grima, 1972; Howe, 1968; de Rooy, 1972, Kindler and Russell, 1984) have demonstrated that water use, in most activities and beyond certain minimal amounts, displays a "negative price elasticity", such that an increase in water price leads to a decrease in demand. This type of behavioral finding suggests that the level of water use can be manipulated, not only through pricing, but also through a variety of "demand management" measures. There are few Canadian studies in this area, despite the fact that demand management may offer many cost savings for water resource development in the future. Thus, while definitive answers are not possible as to the impact of, say, price on water use, some attempt will be made here to provide some indications of these impacts.

1.3.9 The Forecasts in Perspective

A note of interpretive caution is added at the end of this chapter. It is often true that an audience unfamiliar with the problems of forecasting will take the output of a study such as this as the true shape of the future. This note is intended to dispel such a notion. The forecasts contained here are hampered in at least two major ways. First, the problems of uncertainty have been described. Second, the methodology used, while soundly based and the best one possible given the circumstances, it is quite far removed from that of an ideal study. Thus, the interpretation given to these results is related more to the reaction of water use to a given series of conditions than as a series of "requirements" to be met. In chapter 5, some discussion is given of an alternative approach to water use studies which would be possible given a longer study period. This approach would supplement and improve the results obtained in the main part of the paper.

CHAPTER 2

METHODOLOGICAL OVERVIEW

This chapter provides an overview of the methodology used in compiling the water use forecasts produced during this project. The principal model employed is outlined at the level of detail considered necessary in this report, although many technical points have been omitted; these may be found in the references contained here. The methodology for the simulation modelling exercise is outlined separately in Chater five.

2.1 An Overview and Comparison of Methodologies

This section comprises an overview of six distinct types of methodologies which have been used in the past for water use and demand forecasting. These methodologies are dealt with summarily here; more detail may be found in Whittington (1978), Kindler and Russell (1984) and Tate (1984a)

2.1.1 The Coefficients Approach

Many water use studies (e.g. Cass-Beggs, 1961; Canada, 1972) have been based upon the coefficients approach, which is the simplest approach to water use forecasting. A relationship is assumed between water use and one (independent) variable, such as time, employment, or level of output. A coefficient of water use per unit of the independent variable is calculated or assumed from other sources. This coefficient is taken as constant over the forecasting time horizon, and is multiplied by forecasts of the independent variable to produce water use forecasts. This "methodology" is cheap to implement in time and cost terms, but is normally unreliable in the absence of any theoretical basis for linking water use to one independent variable and for projecting this relationsip into the future.

2.1.2 The Regression Approach

This type of methodology is based on multiple regression analysis. Relationships are hypothesized between water use and a number of independent variables, such as output levels and types, recirculation rates, water price, etc. Statistical data are then collected on the hypothesized relationships, and used to calibrate the regression equation. Future values of the exogenously projected independent variables are then used in conjuction with the regression equation to project water use. This type of methodology is a substantial improvement over the coefficient approach, being based upon testable hypotheses and a firm statistical foundation. Its wide application in studies such as the present one is limited, however, because it must be tailored to fairly homogeneous groupings of industrial or municipal water use (see Rees, 1969; Grima, 1972). While this presents no limitation if the requisite studies exist, it is a severe limitation in resource terms if they do not, as is the case in Canada. For these and other reasons summarized in Table 2.1, the regression approach was rejected as the basis of this project.

2.1.3 The Demand Management Approach

As used in this paper, the demand management approach to water use forecasting refers to studies in which a price:quantity relationship is used to define an equilibrium between water use and water supply. Water supply shortages under this approach are

TABLE 2.1

COMPARISON OF WATER USE FORECASTING METHODOLOGIES

	Criteria for Comparison						
Methodology	Data Avail- ability	Alterna- tive Futures	Techno- logical Change	Economic Interrel- ationships	Spatial Resolution	Overall Cost	Theoretical Basis
Coefficients	High	Medium	Low	Low	High	Low	Low
Regression	Low	Medium	Low	Low	Low	High	Medium
Demand Management	Low	Medium	Low	Low	Low	High	High
Process Modelling	Low	High	High	Low	Low	Very High	High
Structural Modelling	High	High	High	High	Low	Low	Medium
Simulation Modelling	Medium	High	High	High	High	High	Medium

Critera Descriptors

Data Availability - Ease with which data can be collected. High is best.
Alternative Futures - Ability to consider a wide variety of alternative futures. High is best.
Techological Change - Ability to incorporate technological change. High is best.
Economic Interrelationships - Incorporation in the model of relationships between economic sectors. High is best.
Spatial Resolution - Ability to consider river basin and subbasin detail. High is best.
Overall Cost - The total required expenditure in terms of money and person-years. Low is best.
Theoretical Basis - The degree to which the methodology is based in theoretical principles. High is best.

met through a combination of water price rises (to decrease demand) and supply augmentation where this is shown to be the most economically efficient approach. In Canada, few studies have been made which could be classified under the demand management approach (e.g. Grima, 1972; Canada, 1975; Sewell and Roueche, 1974), and thus the required statistical basis for using it generally is not available. The resources were unavailable to carry out a full demand management approach during the present project, although the topic of demand management was explored in one of the scenarios developed as the basis of the water use forecasts (see Chapter three).

2.1.4. The Process Modelling Approach

In contrast to the methodologies outlined to this point, which treat the actual operation of the water using process as a "black box", the process modelling approach attempts to model water use as an integral part of the production process under study. Examples of this approach may be found in Russell, 1973), Russell and Vaughn (1976) and Kindler and Russell (1984). The forecasts produced are of high quality, since water use and the productive process are closely linked, and subjects such as technological change can be addressed specifically. The limitation of the approach in a broad regional study is that each operation (e.g. one industrial plant) must be dealt with individually, imposing very high time, labour and budgetary costs. The approach was not used here.

2.1.5 The Structural Modelling Approach

Structural modelling of water uses is founded upon the use of input-output models (see Richardson, 1972; Myernick, 1965) to forecast water use. The approach incorporates a comprehensive view of the economic structure under consideration, and is relatively straight-forward to implement. It is the basis of much of the research in this project and will be described more fully in the following section.

2.1.6 The Simulation Modelling Approach

This approach relies upon relating the variables underlying water use in a logical and consistent fashion into a computerized model. This model, once calibrated, can then be used to produce water use forecasts for a variety of future conditions. Simulation modelling is outlined in more detail in Chapter 5.

2.2 Structural Modelling of National and Regional Water Use

The model used in examining future water use in Canada and its regions is based upon input-output analysis, as indicated in section 2.1.5. Input-output analysis is an econometric technique which examines the flows of goods and services in an economy, both between the industrial production sectors themselves and from those sectors to the points of final consumption, or final demand. The analysis is based upon an input-output transactions table, such as the one shown in Figure 2.1. The X factors refer to interindustry flows. For example, x_{ij} refers to the flow of product from industry i to industry j. C, I, G and E refer to the final demand sectors, namely consumption by households, private investment, government purchases and exports,

Figure 2.1 A Simplified Input-Output Transactions Table

	To	Purchasing Sectors	Final Demand Sectors				
From		1.......i.......n	Households	Private Investment	Government	Exports	Total Gross Outlays
Producing Sectors	1	X_{11}.....X_{1i}.....X_{1n}	C_1	I_1	G_1	E_1	X_1
	.	. . .	.	.	.	.	.
	.	. . .	.	.	.	.	.
	.	. . .	.	.	.	.	.
	i	X_{i1}.....X_{ij}.....X_{in}	C_i	I_i	G_i	E_i	X_i
	.	. . .	.	.	.	.	.
	.	. . .	.	.	.	.	.
	.	. . .	.	.	.	.	.
	n	X_{n1}.....X_{nj}.....X_{nn}	C_n	I_n	G_n	E_n	X_n
Labour		L_1......L_j......L_n	L_C	L_I	L_G	L_E	L
Other Value Added		V_1......V_j......V_n	V_C	V_I	V_G	V_E	V
Total Gross Outlay		X_1......X_j......X_n	C	I	G	E	X

Source: Richardson (1972, p. 19).

respectively. These are the final points of consumption for the goods and services produced. L and V refer to input from primary sources external to the production system, in this case labour and other value added repectively. Reading across the rows of the table, one can determine the distribution of the product of each industry, to itself, to other producers and to the various final demand sectors. Conversely, reading down the table, one sees from where each industry draws its inputs. As portrayed in the bottom row and right-most column, total inputs to each industry balance total outlays.

Input-output tables can be used to formulate accounts comparable to the system of Keynesian national accounts used traditionally in government descriptions of production in the economy (e.g. gross national product). However, the normal use of an input-output table is as the basis for a model linking changes in industrial production to changes in final demand, and for examining the processes of structural and technological change. Although many forms of input-output models exist, the one described below is probably the most basic, having a "square", or industry-by-industry format and pertaining to a single region or a nation as a whole.

For industry-by-industry models, the set of producing sectors is identical to the set of purchasing sectors. The relationships between total output, intermediate output and final demand for any industry can be stated as:

$$x_i = \sum_{j=1}^{n} x_{ij} + y_i \qquad \text{(Eq. 2.1)}$$

where: x_{ij} = the sum of sales from industry i to industry j;

x_i = the total value of sales of industry i;

y_i = the sum of the final demands for the products of industry i.

Assuming that industry j's purchases from industry i are stable in terms of industry i's output, equation 2.1 may be re-written as;

$$x_i - a_{i1} x_1 - a_{i2} x_2 - \ldots - a_{ij} x_j = y_i \qquad \text{(Eq. 2.2)}$$

where: a_{ij} = the direct input requirements for industry i's product per unit of output in industry j.

In equation 2.2, the a_{ij}'s are termed "direct input coefficients" since they denote how much of industry i's output must be purchased by each industry per unit of output.

The objective of input-output analysis is to estimate total output in each industry, given the level of final demand for each industry's product. This task involves tracing not only the direct first round output required to meet these final demands, but also the secondary production resulting as the initial demands filter through the productive system. The methodology for accomplishing this is outlined by Miernyck (1965) and is summarized mathematically here. In terms of matrix algebra:

$$x - Ax = y \qquad \text{(Eq. 2.3)}$$

where: x = a column vector of gross output;

y = a column vector of final demands;

A = an (n x n) matrix of direct input coefficients.

Using an identity matrix, equation can be rewritten:

$$(I - A).x = y \qquad \text{(Eq. 2.4)}$$

where: I = an (n x n) identity matrix.

Since the level of gross output in each industry is the variable being solved for, the system can be rewritten as:

$$x = (I - A)^{-1}.y \qquad \text{(Eq. 2.5)}$$

where: $(I - A)^{-1}$ = the inverse of $(I - A)^{-1}$, derived through the process of matrix inversion.

The elements of the inverse matrix quantify the direct plus indirect requirement of industry i per unit of final demand for the outputs of industry j. Equation 2.5 defines a linear transformation of final demands in an economy into industrial outputs.

The assumptions behind this model have been discussed by Richardson (1972), Davis (1968) and Victor (1972), and reference should be made to these sources for more detail. Very quickly, two major assumptions allow the model to operate. First, outputs by industries are considered to be homogeneous, such that one industry produces a uniform product or an "average bundle" of products. This assumption has received strong criticism (see Victor, 1972), and has led several countries, including Canada, to adopt a "commodity-by-industry" approach to input-output modelling. The more conventional "industry-by-industry" approach was used here because of the infeasibility of dividing water use data into commodity groupings. Second, the technological coefficients (a_{ij}) are assumed constant in many input-output analysis exercises; this assumption has proven false in many cases because of structural and technological change. It has been overcome in one of the scenarios examined here by alterations to the inverse matrices in accordance with past trends.

In a study of the California water industry, Lofting and McGauhey (1963) augmented the basic input-output model to include water use considerations. Their augmentation consisted of inserting a matrix of water use coefficients into equation 2.5, as follows:

$$w = (I - A)^{-1} . W. y \qquad \text{(Eq. 2.6)}$$

where: w = a vector of total water uses for each industry in the system

W = an (n x n) matrix of water use coefficients in which the coefficients (in terms of water use per million dollars of output) form the elements of the matrix's principal diagonal, and all off-diagonal elements are zeroes.

This model formed the basis of the national and regional water use forecasts developed in the present research.

The model specified in equation 2.6 contains the three factors suggested in Chapter 1 to underlie water use in the various economic sectors. Economic activity and its growth are captured by the final demand factor (y). The elements of the inverse matrix $(I - A)^{-1}$ denote the state of production technology. Water use practices (e.g. trends in recirculation) are captured by the elements of the water use coefficients matrix (W).

2.3 Making The Structural Model Operational

This section contains an outline of the procedures and data used to make the structural model operational. Each of the model's variables are dealt with separately here; the ways in which they were combined to produce the forecasts are dealt with in Chapter 3.

2.3.1 Economic Activity

Economic activity levels were dealt with in the model through the final demand variable. The regional models used were based on 1974, the latest year for which complete input-output data are available. The 1974 final demand data were projected to the 1981 base year of this study by using growth rates experienced between the two years. With the 1981 final demand calculated, the original 1974 tables were used in conjunction with the model described in equation 2.5 to calculate the gross outputs in each of the 30 industries. For industry 28, Gas and Other Utilities, and industry 29, Wholesale and Retail Trade, which are substantially related to population, population growth rates were used to calculate the 1981 final demand and output levels. (It is acknowledged here that interregional structural models could isolate and thereby model the effects of interprovincial trade. The interregional modelling approach was not used here, however, due to time constraints, and thus regional exports and imports are considered here to be part of the regional final demand vectors.)

Forecasting future growth rates in industry and the population is a complex undertaking done normally by specialist forecasting agencies using sophisticated econometric models. In addition, forecasts are rarely performed over a 30-year horizon. For this project, extensive work was done to obtain a consistent set of growth rates for the 30 industry sectors, some of it working from historical statistics published by Statistics Canada, some of it searching through past work by the author and some of it examining forecasts produced by private forecasting agencies. In the end, it was decided to use one of the latter sources, namely the forecasts recently produced by Informetrica (Informetrica, 1984), and available to Environment Canada by subscription.

From the Informetrica forecasts, projected real domestic product (RDP) and labour force series were compiled for 1983, 1991, 2000 and 2005, and for each industrial group except the two groups related more closely to population. For 1981, 2001 and 2011, years required by this study but not available from the Informetrica data, extrapolation and interpolation procedures were used. Growth rates for the 1981-1991, 1991-2001, and 2001-2011 periods were then calculated for both RDP and labour force series. In general the growth rates for the former were greater than those for the latter, due to capital substitution effects. Accordingly, a low set of growth rates was based upon the labour force series and a high set upon the RDP series. A medium set of rates was constructed from an average of the high and low rates.

2.3.2. Production Technology

The modelling of trends in technological change is an exceedingly difficult undertaking, largely because there is much controversy about the variables which lead industries to make modifications to their production processes. Trends are the product of thousands of individual decisions, and few summary statistics are available about the outcome of these decisions.

In this research, it was assumed that the coefficients of an inverse matrix resulting from input-output models reflect the state of production technology for the time period covered by the input-output table. Thus, a time trend on each coefficients constitutes a production technology time trend. A set of trends consisting of trends for each coefficient can be calculated by linear regression techniques, making appropriate adjustments for autocorrelation. The statistically significant trends can then be projected, while those which are not significant can remain constant. This procedure was used for forecasting production technology.

All of the regression work was performed at the national level, for which a 20-year time series of annual input-output tables was available. While it would have been more desirable to work with a time series of regional tables, these were unavailable. As a "second-best" alternative, the national trends were superimposed on the regional industrial sectors. To begin this part of the analysis, regression lines were computed for each of the 900 coefficients of the 20 inverse matrices. For example, each industry is tied by the coefficients of the inverse to itself and to each of the other 29 industries. Thus, each industry forms one column of the inverse matrix, consisting of 30 coefficients. Each of the 30 coefficients in turn has been analyzed through time by means of the regression procedure outlined above. In those cases where the regression equation accounted for 50% or more of the total variance (i.e. $R^2 = 0.5$), the trend was considered significant. Where the industry being analyzed was significant in a region, the national trends were used to project the respective regional coefficients. Where the national equation was found insignificant, the regional coefficients were assumed to be constant. Using this procedure, adjusted inverse matrices were calculated for the years 1981, 1991, 2001 and 2011 for each of the five regions. These matrices were assumed to simulate the magnitude and direction of technological change over the forecasting time horizon.

2.3.3. Water Use Practices

As used in this paper, water use practices refer to the amount of intake, recirculation, gross water use, consumption and discharge which occurred in the industrial sectors covered by this study. Trends in water use practices, likewise, refer to trends observed or anticipated in these five parameters. Water use practices were quantified for use in the model by calculation coefficients of water use (i.e. by parameter) per million dollars of total industrial output for the year 1981. This set of water use coefficients formed the major means of quantifying water use practices throughout the period of study. The recent federal and Alberta surveys of industrial water use (Canada, 1985) were used as the quantitative basis for the coefficients.

The set of 1981 coefficients were modified demonstrate (1) the potential impact of raising the price of water in the various sectors, and (2) the effects of other conservation measures. The point must be made here that the results of this water conservation analysis are considered theoretical and indicative in nature rather than certain projections of what would happen under a water management philosophy which tries to control water use with pricing and other conservation techniques.

Several articles referred to in Chapter 1 have shown that water demand, like demand for the vast majority of goods and services, behaves in a "conventional" economic fashion, such that when its price rises, the quantity demanded falls. In Canada, water pricing data are not available on a consistent basis across the country in such a manner that regional water demand curves can be constructed. The best data available are those collected during the 1981 federal and Alberta surveys of industrial water use referred to earlier. On these surveys, the cost of water at a plant was taken as the sum of intake cost, intake treatment cost, recirculation cost and effluent treatment cost. By adding these cost components together and dividing by the amount of intake, the average cost of water for each industry can be calculated. This amount, which has been used in the past as a proxy for water price (e.g. see de Rooy, 1972, 1974), can be taken as the price of water to industries, which is felt in the absence of a commodity price for water. In other words, it is assumed here that the industries face a zero or minimal commodity price for their water. This method of estimating water cost is biased somewhat downward since there is no allowance made for the capital cost of water conveyancing facilities in plants.

Another important piece of information required for the pricing analysis is a set of price elasticities of demand for water in the various industries. Price elasticity of demand indicates the percentage change in the quantity of water demanded for a given percentage change in water price. On a normal downward sloping demand curve, price elasticity changes along the curve. In this paper, the elasticity figures assumed are taken to be average elasticities, and are thus constant through the range of price. Estimates of price elasticities of water demand, which were unavailable in many cases for Canada, were taken from various secondary sources (Hanke, 1978; Grima, 1972; Leone, 1975; Boland et al., 1984). Where no data were available, judgemental estimates were made for related industrial groups for which data were available. By assuming average demand elasticities for each industrial group, an analysis was performed of the impact of water price rises on the quantity of water demanded. The price increase assumed was 10% by 1991, 25% by 2001 and 35% by 2011.

The water intake coefficients calculated from survey data show how much water is used by industry in the absence of a commodity price for water. It is suggested that the pricing analysis outlined above indicates how the coefficients will alter as increasing prices are charged. In other words, with the elasticity data available or assumed, it was possible to estimate the response of water intake in the various groups to given percentage increases in the average cost (i.e. price) of water. Gross water use and consumptive use coefficients were calculated for each industrial group using the use rates and consumption rates respectively. This type of analysis was the basis for one of the scenario analyses outlined in Chapter three.

In addition to price change impacts, there are many additional water conservation measures possible. To allow for these additional impacts the effects of the hypothesized water pricing arrangements were accentuated by an arbitrary 50%. As noted earlier, this analysis is quite hypothetical, but is felt, nevertheless, to be feasible should serious attempts be made to apply water conservation incentives in managing Canada's water resources.

CHAPTER 3

FORECASTING AND THE ROLE OF ALTERNATIVE FUTURES

The process of forecasting water uses is highly dependent upon the underlying view taken of the future. It is this view which governs the mix of industries used for forecasting, their technological conditions, the level of population, energy and water use practices, and many other factors. As noted in Chapter one, each of these factors by itself is subject to considerable uncertainty, and when the factors are combined the resulting uncertainty may be compounded.

As noted in Chapter one, the "alternative futures" approach has been used in preparing the forecasts for this paper. This type of approach has been used in many forecasting exercises, and was specified in detail by the U.S. National Water Commission (1976). Obviously, not all of the permutations and combinations of variables can be examined. However, it is possible to try to select a number of typical combinations of future situations. (Throughout the remainder of this paper, these combinations will be referred to as "scenarios".) In this way, an attempt can be made to place "a fence around the ballpark of future water use."

In this chapter, the first section discusses some of the general considerations made in designing the scenarios. The second section defines in operational terms the five scenarios finally selected for analysis.

3.1 General Considerations

In this project, as noted in Chapter one, an analytical approach to the future has been taken. Several types of factors can be approached analytically, and are built into the five scenarios. Population was allowed to assume three alternative projections, based upon the latest Statistics Canada work (Canada, 1982). Various future mixes of primary, secondary and tertiary industrial activities resulted from using high, medium and low alternative growth rates. Energy use assumptions are implicit in these projections. Technological change was allowed in one of the scenarios according to the methodology of Chapter two. Finally environmental policy as it affects water use was varied in one scenario to simulate the effects of a conservationist policy stance.

The principal task in scenario design is to translate these various assumptions about the future into terms which can be dealt with by the structural and simulation models used as the basis for the analysis. This translation task is described in section 3.2. Before turning to that description, it is necessary to define some of the factors which have been assumed constant.

In any forecasting exercise, certain factors must be held constant in order that a common background for the scenarios may be established. In general, the more time available for the analysis, the fewer the number of constancies required. In this exercise, time limitations were quite severe, with the result that even some of the analytically tractible variables were assumed to be common to all scenarios. The forecasts assume an absence of global armed conflict. This was necessary because one has no means of foretelling what kind of devastation or socio-economic conditions would arise from such conflict.

Lifestyles are assumed not to alter radically with regard to their water needs. This allows for lifestyle changes as they may occur, but assumes that water demands caused by new lifstyles will not be radically different. Current institutional and administrative arrangements have been assumed to continue throughout the forecasting time horizon. The one exception here will be an assumed rise in water price, and the aggregate results of a concerted water conservation effort in scenario three. Urbanization trends, implicit in the population projection, have not been considered explicitly in the forecasts. Finally, it was assumed that no new industrial classifications would originate during the forecasting period.

3.2. Five Views of the Future

As specified in the structural model, three sets of growth rates (low, medium and high), two types of technological conditions (stable and changing) and two sets of water use coefficients (stable and price-altered) were used in preparing the forecasts for this project. Thus twelve possible scenarios could have been prepared by altering just the major variables. However, within each major variable, assumptions could have varied by industrial sector, thereby increasing enormously the number of alternative future outlooks.

The author has been forced to compromise between designing scenarios which could be described in detail, and presented as feasible views of the future, and those which would describe the sensitivity of the model to broad changes in assumptions about each major variable. It was decided to emphasize the latter task.

Thus, the scenarios reported below have been designed to indicate the sensitivity of the structural model to changes in each of its major variables. The reader may then combine the variables as he himself sees fit and thus examine other futures. It should be noted that none of these scenarios has been designated "most likely".

3.2.1 Scenario 1 - A Reference Case

The reference scenario was constructed by holding all factors constant except the economic growth rate, and is, therefore, essentially an extrapolation of past trends. No changes in production technology was incorporated and the water use coefficients were held at their 1981 levels. A medium level of population growth was also used. The scenario assumes no severe energy shocks such as those experienced during the 1970's. It has been kept as simple as possible to serve as a reference point for the other scenarios. For this reason technological change has not been incorporated, even though it is on-going.

This scenario is a "business as usual" view of the future, with no significant shocks to the socio-economic system. Water is managed as it is currently, with major capital works occuring as required, under Canada's current supply management orientation to water development (Tate, 1984b). No requirements are foreseen here for major regional water transfers.

3.2.2 Scenario 2 - A Conservationist Scenario

In the water management field, increasing attention is being paid to policies for water conservation, and the potentialities of water demand management in Canada (Mitchell, 1984). One major instrument offered for demand management is an increase in water price, accompanied by a major incentive system to implement other non-price related possibilities for decreasing water use. The scenario assumed a medium rate of economic growth, a constant production technology and the set of price-altered water use coefficients specified in Chapter 2.

3.2.3 Scenario 3 - The Effects of Technological Change

This scenario was designed to isolate the effects of production technology changes on water use in the five regions. It is difficult to describe the exact characteristics of this scenario, for changes on growth and water use practices would likely accompany it. Emphasis would be placed on technological change, so as to achieve at least the rates of change experienced in the past. Operationally in the model, the medium set of growth rates, the contstant 1981 water use coefficients and the technology-altered set of inverse matrices were used in preparing this scenario.

3.2.4 Scenario 4 - A Recession Scenario

Scenario 4 was based upon a prolonged period of slow economic growth throughout the country. Under such an assumption, recessionary conditions would ensue, as reflected in the scenario by the use of low growth rates. No money would be available to alter either the state of production technology or the water use practices. Thus the latter two variables were held at their 1981 levels.

Under this scenario, unemployment might reach the 16% - 20% levels. No attention at all could be afforded to environmental programs, and few water conservation efforts would be made. Increasing forced leisure time would generate the need for more recreational resources.

3.2.5 Scenario 5 - High Economic Growth

In scenario five, emphasis was placed upon maximizing economic efficiency and achieving a high rate of economic growth. Partially this will be achieved through exploiting to the full the raw material wealth of the country and developing its primary industry base. Rapid development was also foreseen in the manufacturing sectors, based upon acclerating the role of these industries (i.e. industries 1 to 5 in the model). Thus the primary and the secondary sectors assumed high rates of growth. To support this growth, high growth rates were also assumed in the tertiary sectors. Techological change and water use practices were held constant in order to isolate the effects of the high growth rate.

Under this scenario, economic growth was the primary public objective. Little or no attention was assumed in environmental programs and water conservation. Water use practices were held at the 1981 levels. Unemployment would probably be below the rates experienced under the medium scenario.

The operational components of the six scenarios are summarized in Table 3.1.

Table 3.1 A Summary of the Scenarios Used in Forecasting

Scenario Number and Name	Principal Components of the Structural Model		
	Economic Growth	Production Technology	Water Use Practices
1. Reference	Medium	Constant	Constant
2. Conservation	Medium	Constant	Altered
3. Technological Change	Medium	Altered	Constant
4. Recession	Low	Constant	Constant
5. High Growth	High	Constant	Constant

CHAPTER 4

CURRENT AND PROJECTED CANADIAN WITHDRAWAL WATER USES

This chapter is devoted to a discussion of the study results. The first section outlines the major observations deriving from the forecasting exercise. More detailed data have been placed in the Appendix. The second section deals with limitations which must be placed upon these results.

4.1 Results of the Study

4.1.1. Water Use in 1981

In 1981, just over 37 500 million cubic metres (MCM) of water were withdrawn from Canadian water sources (Table 4.1). About

TABLE 4.1 TOTAL WATER USE BY WATER USE PARAMETER CANADA AND REGIONS, 1981 (MCM)

Region	Water Intake	Recirculation *	Gross Water Use	Consumption	Discharge**
Atlantic	2884	965	3849	139	2745
Quebec	4252	3094	7346	435	3817
Ontario	21230	4122	25352	589	20641
Prairie	5363	4675	10038	2256	3107
B.C.	3789	3062	6851	487	3302
Canada	37518	15918	53436	3906	33612

* Imputed figure. Recirculation = gross water use - water intake.
** Imputed figure. Discharge = water intake - consumption.
Source: Appendix tables

56% of this amount was withdrawn by users in Ontario, mostly from the Great Lakes. Of the 21 230 MCM withdrawn in Ontario, about 70% was accounted for by use in thermal cooling at power plants. The Prairie region was the next highest with respect to water withdrawal, with a large amount of this water being used in irrigation. The other three regions followed as indicated in Table 4.1.

Gross water use followed essentially the same pattern, totalling 53 436 MCM. In other words, recirculation practices allowed the available water supplies to be "stretched" some 1.4 times. The aggregate use rate (i.e. gross water use divided by water intake) was about 1.4, being lowest in Ontario (1.2) and highest in the Prairies (1.9). In all, almost 16 000 MCM of water were recirculated throughout Canada in 1981.

Water consumption totalled 3 906 MCM in 1981, just over 10% on total intake. The lion's share of this amount was accounted for by agricultural (mainly irrigation) use in the Prairie region, with 1 892 MCM (see Appendix tables). The consumption rate (i.e. water consumed divided by water intake) in this region was 0.4, very high in comparison with the other four regions. The lowest consumption rate (0.03) was experienced on Ontario, where none of the intake water at thermal power plants was recirculated. With a consumptive use of 3 906 MCM, discharge totalled 33 612 MCM in 1981.

Table 4.2 views the same data from the viewpoint of the major economic sectors included in the study. The largest proportion of water intake, over 51% of the total was attributable to thermal cooling at electric power plant, centred in Ontario, but also important in the Prairie and Atlantic regions. Recirculation was practiced principally in the mineral extraction and manufacturing

TABLE 4.2 TOTAL WATER USE BY WATER USE PARAMETER AND INDUSTRY, CANADA, 1981

(MCM)

Region	Water Intake	Recirculation *	Gross Water Use	Consumption	Discharge**
Agriculture	3125	0	3125	2412	713
Mineral Ext.	648	2792	3440	179	469
Manufacturing	10201	11258	21459	507	9694
Power Generation	19281	1868	21149	168	19113
Municipal	4263	0	4263	640	3623
Canada	37518	15918	53436	3906	33612

* Imputed figure. Recirculation = gross water use - water intake.
** Imputed figure. Discharge = water intake - consumption.
Source: Appendix tables

industries, with use rates of 5.3 and 2.1 respectively. A small amount of water recycling also occurred in the power sector, at two plants in Alberta. Recirculation occured in neither the agriculture nor the municipal sectors.

Consumptive use was concentrated in the agriculture sector, focussing upon irrigation in the Prairie region. Due to this activity the consumption rate for agriculture was 0.77, greatly above the average for all sectors of 0.12. This rate was also relatively high for mineral extraction, where significant quantities of water were used for deep-well injection for enhanced petroleum recovery.The consumption rate was lowest in the thermal power sector, at 0.008, and, as noted in Chapter 2, the same rate for the municipal sector was 0.15.

Water intake in the rural domestic sector, which has been included in neither Table 4.2 nor the subsequent forecasts, totalled 348 MCM for Canada in 1981. Recirculation and consumption were 0 for this activity. The water withdrawal in this sector was distributed as follows:

Region	% of Total Intake
Atlantic	17
Quebec	24
Ontario	28
Prairies	20
B.C.	11

4.1.2 Projected Water Use, 1981-2011

This section presents the results of the forecasting exercise undertaken for this project, concentrating on the reference case scenario. The other four scenarios are presented as comparisons to the reference case. It is stressed again that the reference case is not portrayed here as a "most likely" projection, but rather as a relatively simple extrapolation of past trends performed as a baseline for the comparison of alternatives. None of the scenarios, in fact, are designated "most likely", although the author considers that future water use will probably fall within the bands defined by combining the scenarios.

Table 4.3 shows how total national and regional water use grow under the assumptions of the reference case scenario. The average annual growth rate for total Canadian water intake under this scenario will be about 2.3% per annum, for consumptive use about 2.1%. The difference between the two rates occurs because some of the smaller industrial groups have a water intake but no consumptive use. The Ontario and Prairie regions will, under the reference case scenario, experience growth rates slightly above average at about 2.4%, while Quebec, with a 2.0% rate, will be somewhat below average. The Prairie rate is a

TABLE 4.3 PROJECTED TOTAL WATER INTAKE AND TOTAL CONSUMPTION BY REGION AND YEAR, 1981-2011 - REFERENCE CASE (MCM)

a. Total Water Intake

Region	1981	1991	2001	2011
Atlantic	2884	3575	4449	5584
Quebec	4252	5192	6276	7629
Ontario	21230	26484	33640	42861
Prairie	5363	7019	8832	11172
B.C.	3789	4608	5700	7085
Canada	37518	46878	58897	74331

b. Total Consumptive Use

Region	1981	1991	2001	2011
Atlantic	139	169	209	244
Quebec	435	494	582	690
Ontario	589	726	888	1093
Prairie	2256	2924	3600	4443
B.C.	487	598	729	893
Canada	3906	4911	6008	7363

response to continued agricultural growth slightly higher than the national average, as the region continues to dominate the country's agricultural sector. Ontario's relatively high rate is explained by expanded thermal power production at above the national rate. Neither of these two major sectors are important in Quebec, which will continue its reliance on hydro electric power (not included in the forecasts) and its traditional and relatively old economic base of manufacturing. The growth rate of water use in B.C. will be slightly below the national average, while that in the Atlantic region will be closest to the average.

TABLE 4.4 WATER INTAKE PROJECTIONS BY SCENARIO, CANADA, 1981-2011

(MCM)

Year	Scenario Number 1	2	3	4	5
1981	37518	37518	37518	37518	37518
1991	46878	41848	50511	43641	50275
2001	58897	45589	67222	51599	67011
2011	74331	47738	90879	58719	84039

Source: Appendix tables.

The forecasts for total Canadian water intake are shown in Table 4.4. Scenario 3, the technological change scenario, shows the highest rate of growth over the 30-year forecast period, with an average annual rate of 3.0%, while the lowst rate of growth occurs in conjunction with scenario 2 (0.8%). Scenario 3, the technological change future, was somewhat surprising in its outcome. Previous work had shown that production technology trends, taken by themselves, during the 1966-1976 period tended to lower industrial water use during the decade (Tate, 1984a). Thus, with the growth rate held constant, one would have expected the technological change scenario to track below the reference case. It is unfortunate that more time was not available to confirm the results obtained from scenario 3. The methodology selected for projecting the coefficients of the inverse matrices should be examined in more detail With regard to scenario 2, the impact of the hypothetical emphasis on conservation mechanisms to lower water use is clear. Water intake under such a regime would be 65% of that experienced using the reference case assumptions.

Table 4.5 summarizes the forecasting results in the context of the reference case scenario. This table confirms that the lowest and highest water intakes are associated with scenarios 2 and 3 respectively.

TABLE 4.5 - IMPACTS OF ALTERNATIVE ASSUMPTIONS ON THE REFERENCE CASE SCENARIO FOR WATER INTAKE, CANADA, 1981-2011 (%)

Year	Scenario Number			
	2	3	4	5
1991	-11	8	-7	7
2001	-23	14	-12	14
2011	-36	22	-21	13

National trends in consumptive water use for the five scenarios are given in Table 4.6. The patterns shown in this table are essential the same as those estalished for water intake, with the growth rates being slightly less than the corresponding ones for intake. The consumptive use growth rates,

TABLE 4.6 WATER CONSUMPTION PROJECTIONS BY SCENARIO, CANADA, 1981-2011 (MCM)

Year	Scenario				
	1	2	3	4	5
1981	3906	3906	3906	3906	3906
1991	4411	4292	4977	4441	5298
2001	6008	4212	6319	5141	6990
2011	7363	3882	8074	5721	9025

are slightly less than those for water intake, because some of the smaller water using industrial sectors experience no water consumption. Impacts of alternative projection assumptions on the reference case are shown in Table 4.7. The figures are essentially the same as those shown in table 4.5.

TABLE 4.7 IMPACTS OF ALTERATIVE ASSUMPTIONS ON THE REFERENCE CASE SCENARIO FOR WATER CONSUMPTION, 1981-2011 (%)

	Scenario Number 2	3	4	5
1991	-13	2	-8	8
2001	-29	5	-14	16
2011	-47	10	-22	18

Table 4.8 shows the same set of data taken across industry groups. The thermal power sector continues to dominate the water intake projections, while agriculture continues its dominance of consumptive use. The average annual growth rates cluster between 2% and 2.5%, with the lowest rate being 1.6% for municipal intake, and the highest being 3.3 for the mineral extraction sector. Under the reference scenario, total water intake grows to 74 331 MCM in 2011, an average annual increase of 2.3%; consumptive use to 7 363 MCM (2.1%)

The growth patterns of water intake and consumptive use for Canada as a whole are shown in Figure 4.1. Both the reference case and the other four scenarios are compared in the top half of this figure. By 2011, the end of the forecasting period, water intake will range between 47 738 MCM and 90 879 MCM. These represent increases of 0.8% and 3.0% per annum respectively. The industrial composition, or structure, of the reference case for each forecast year for the reference case scenario is shown in the bottom half of Figure 4.1. This figure demonstrates graphically the dominance of thermal power with respect to water intake and of agriculture with respect to water consumption.

TABLE 4.8 PROJECTED TOTAL WATER INTAKE AND TOTAL CONSUMPTIVE USE, BY INDUSTRY AND YEAR, 1981-2011 - REFERENCE CASE

a. Total Water Intake

Industry	1981	1991	2001	2011
Agriculture	3125	3991	4851	5897
Mineral Ext.	648	912	1255	1733
Manufacturing	10201	12602	15954	20274
Power Generation	19281	24216	30906	39558
Municipal	4263	5157	5931	6869
Total	37518	46878	58897	74331

b. Total Consumptive Use

Industry	1981	1991	2001	2011
Agriculture	2412	3089	3756	4567
Mineral Ext.	179	237	320	433
Manufacturing	507	639	812	1038
Power Generation	168	209	269	349
Municipal	640	737	851	976
Total	3906	4911	6008	7363

The forecasting results for each of the five regions are shown in Figure 4.2 through 4.6, supported by the tables in the Appendix. The regional forecasts are broken down into their component river basins also in the Appendix. Figures 4.7 to 4.13 highlight withdrawal and consumptive use amongst the basins of each region. Since the model used for forecasting was

FIGURE 4.1 - WATER USE PROJECTIONS, CANADA, 1981 - 2011

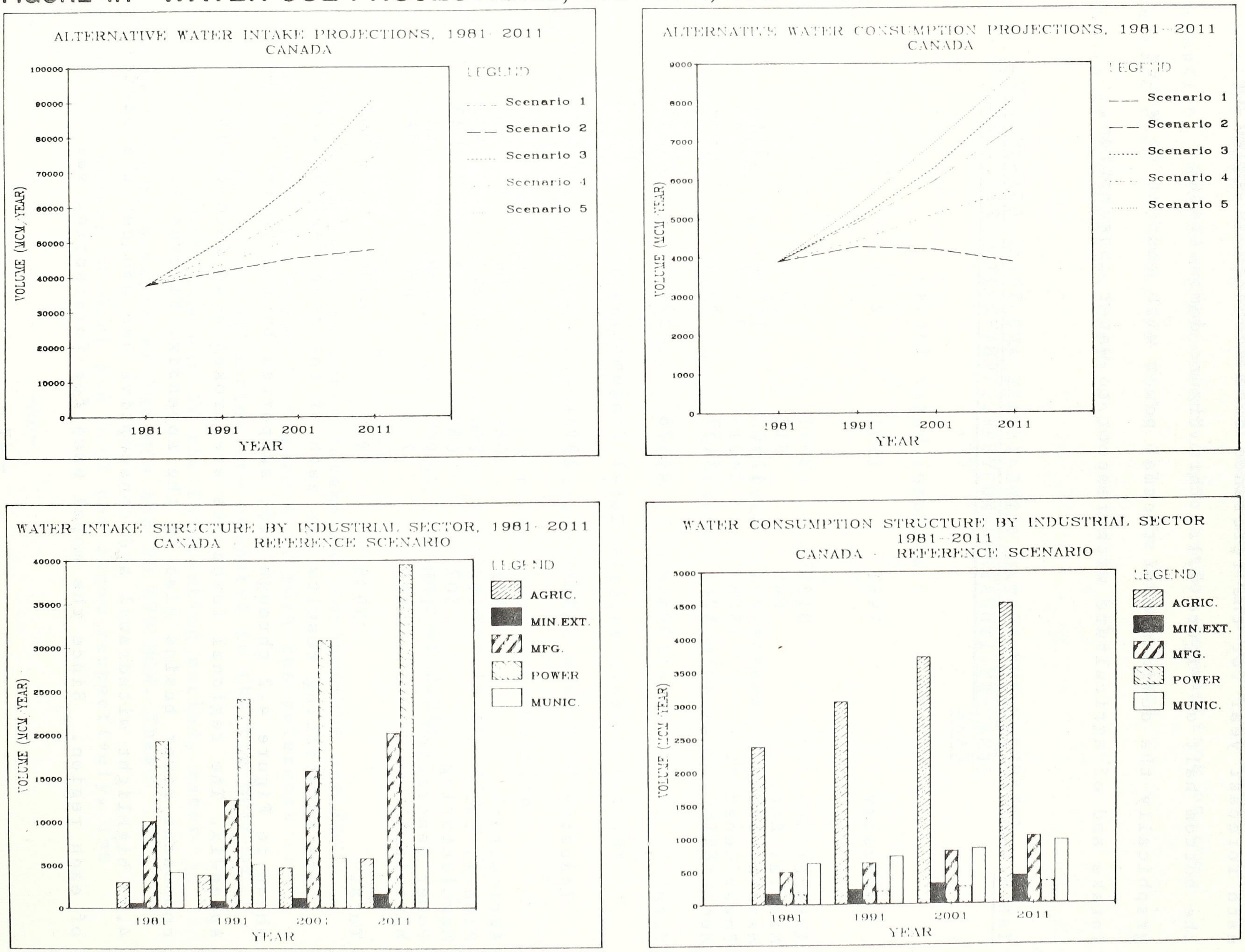


FIGURE 4.2 - WATER USE PROJECTIONS, ATLANTIC REGION, 1981 - 2011

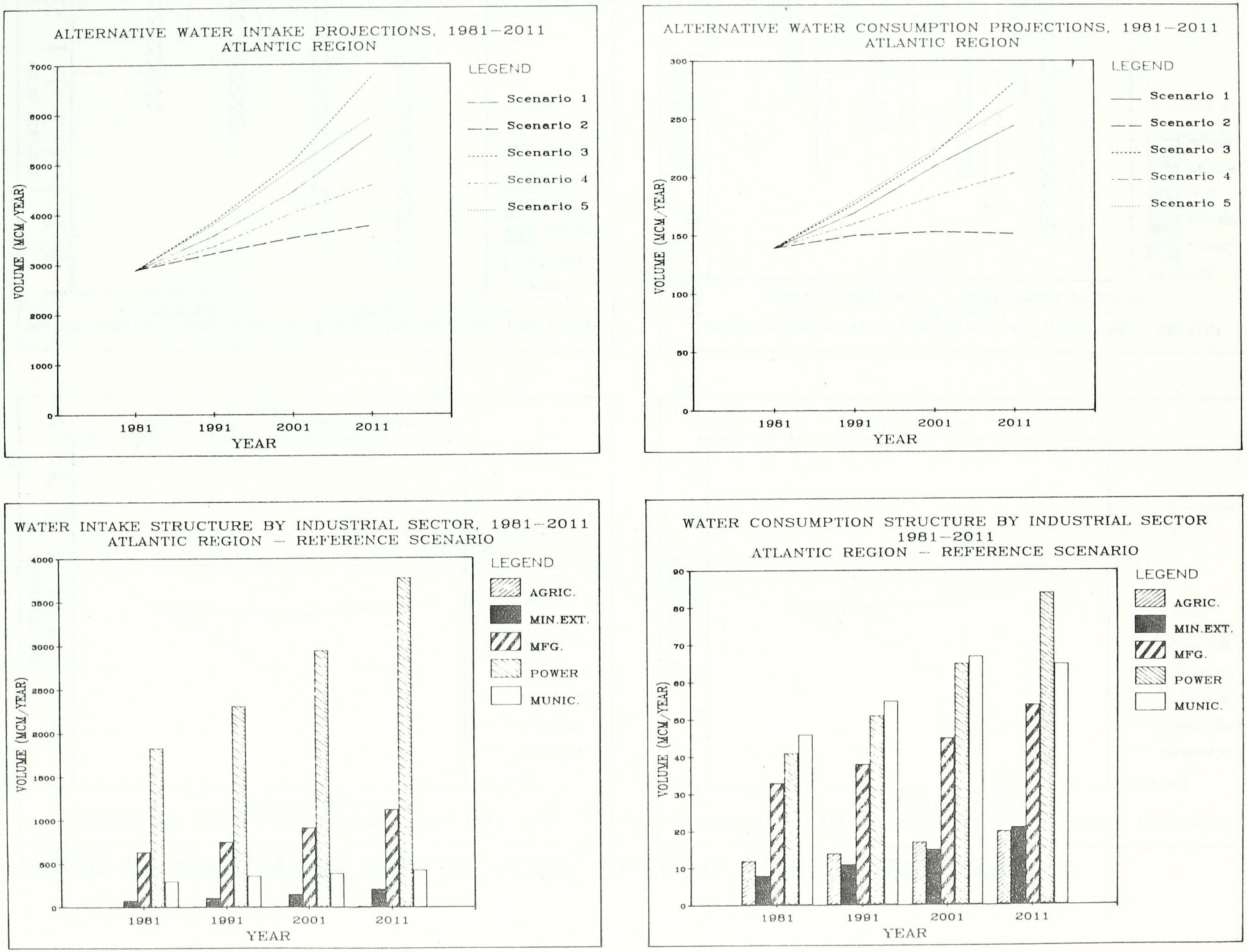


FIGURE 4.3 - WATER USE PROJECTIONS, QUEBEC REGION, 1981 - 2011

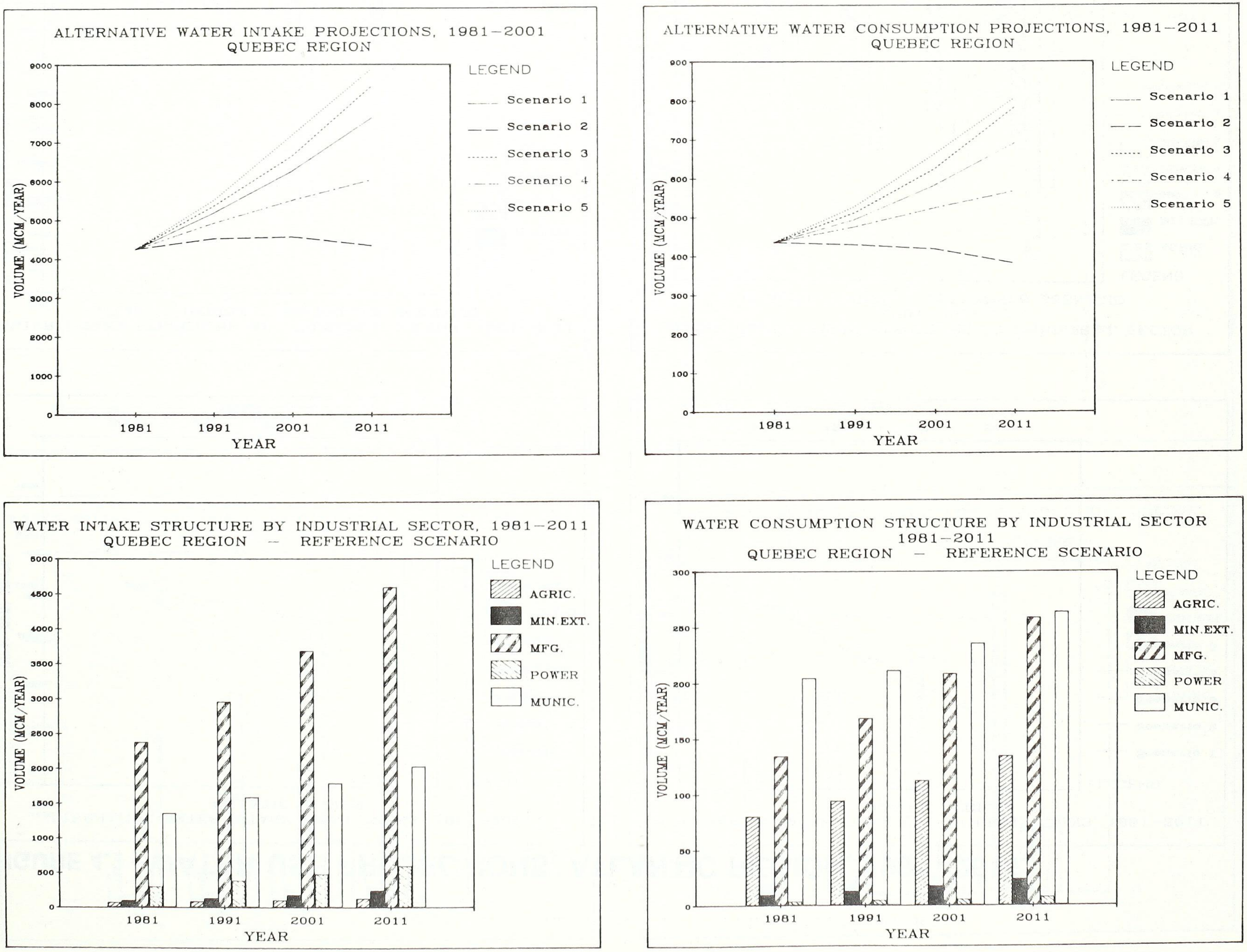


FIGURE 4.4 - WATER USE PROJECTIONS, ONTARIO REGION, 1981 - 2011

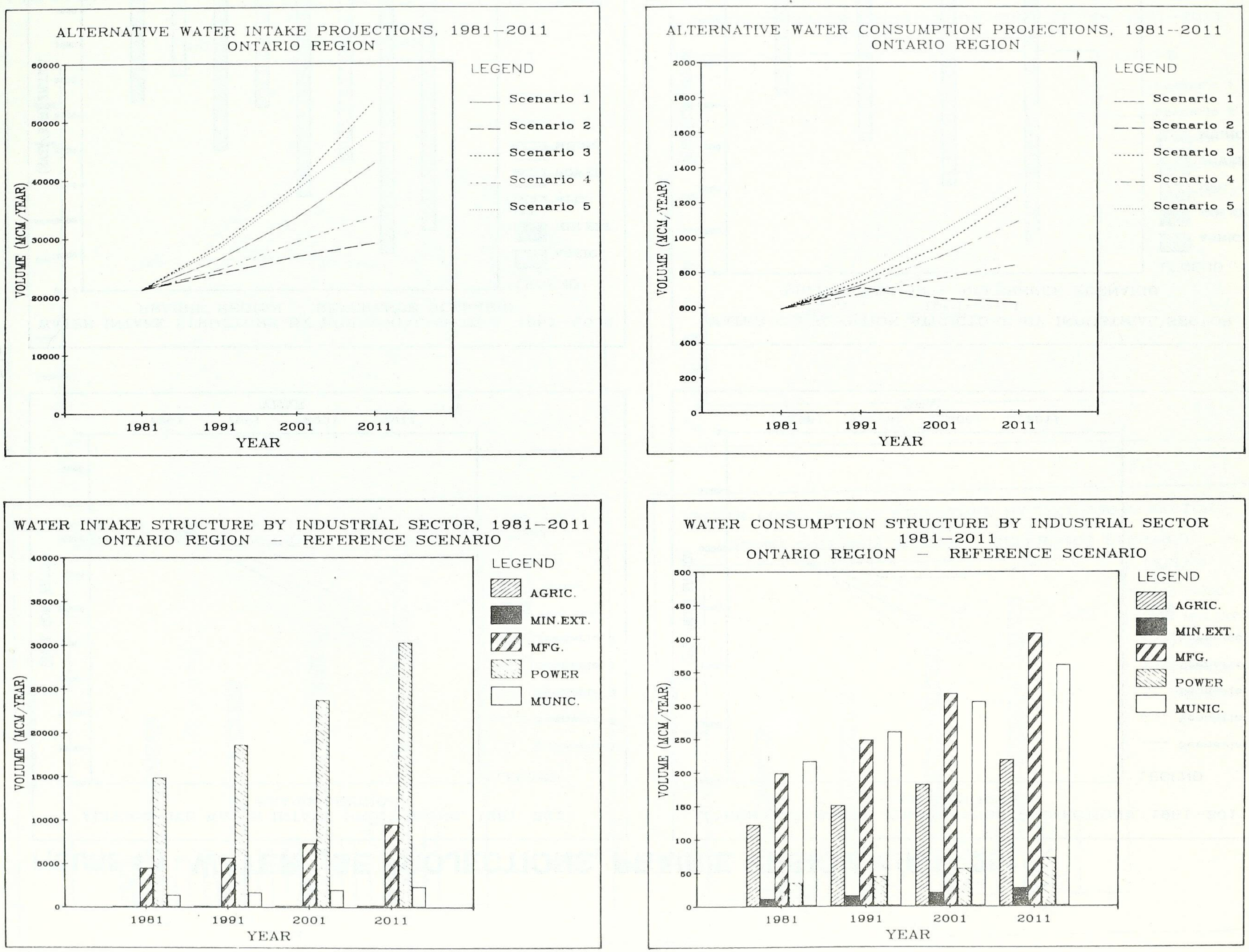


FIGURE 4.5 - WATER USE PROJECTIONS, PRAIRIE REGION, 1981 - 2011

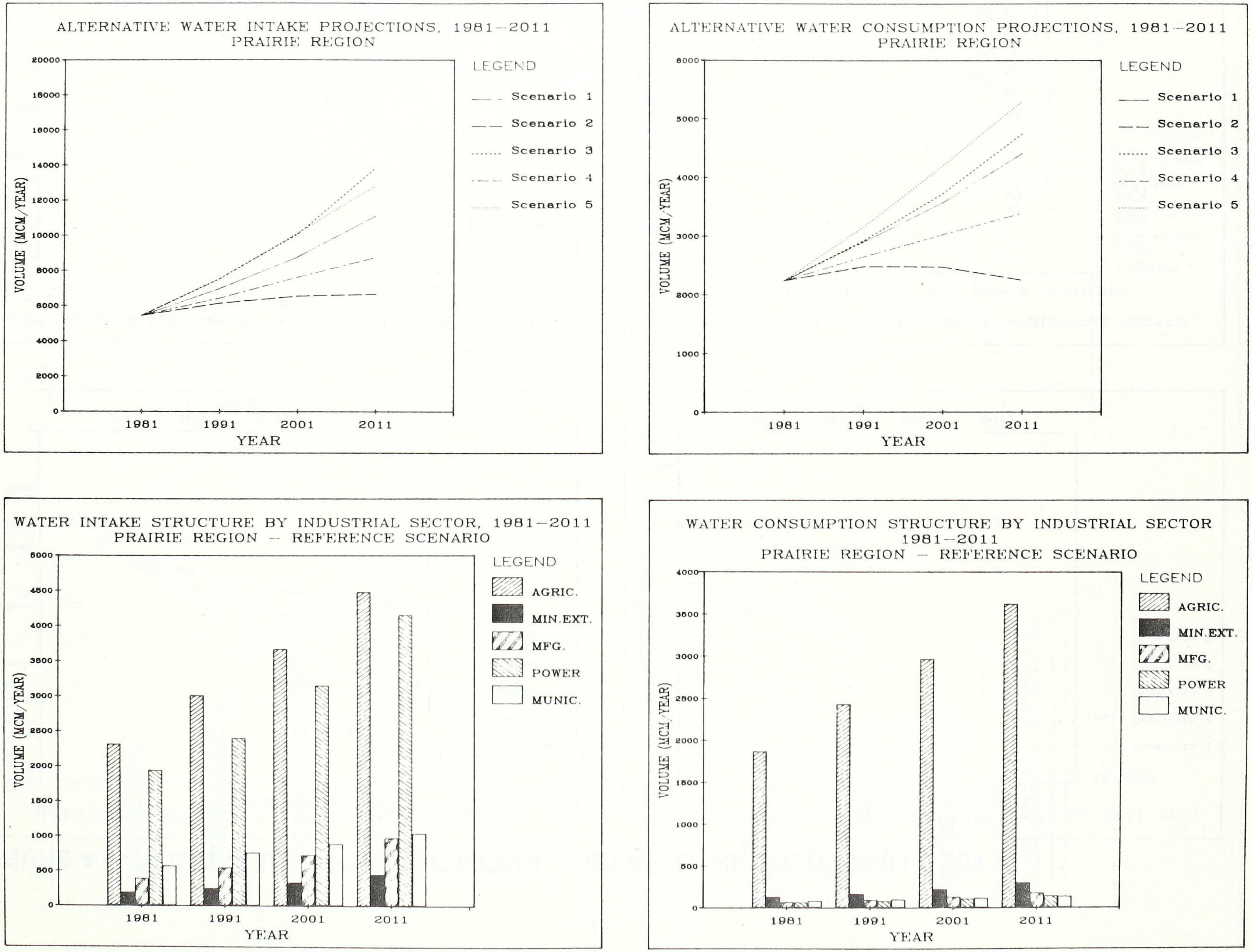
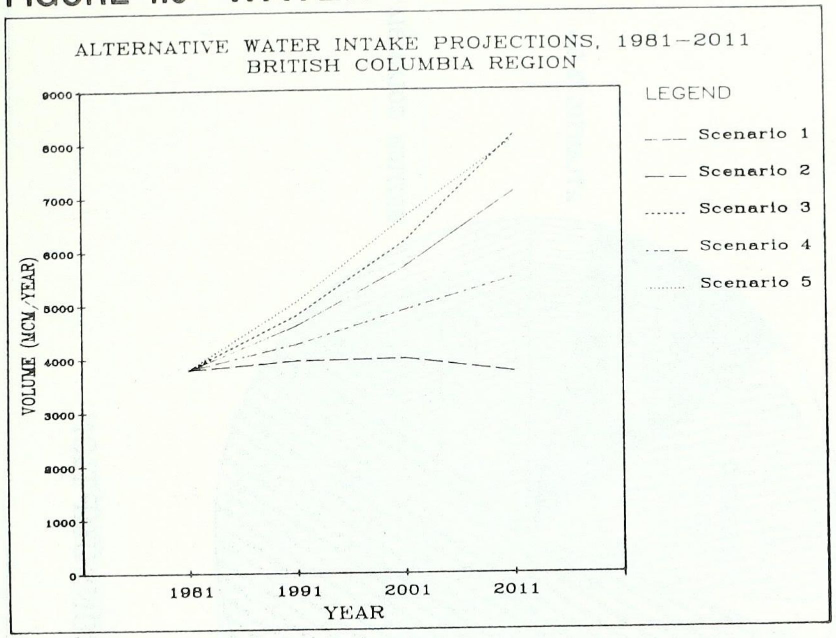
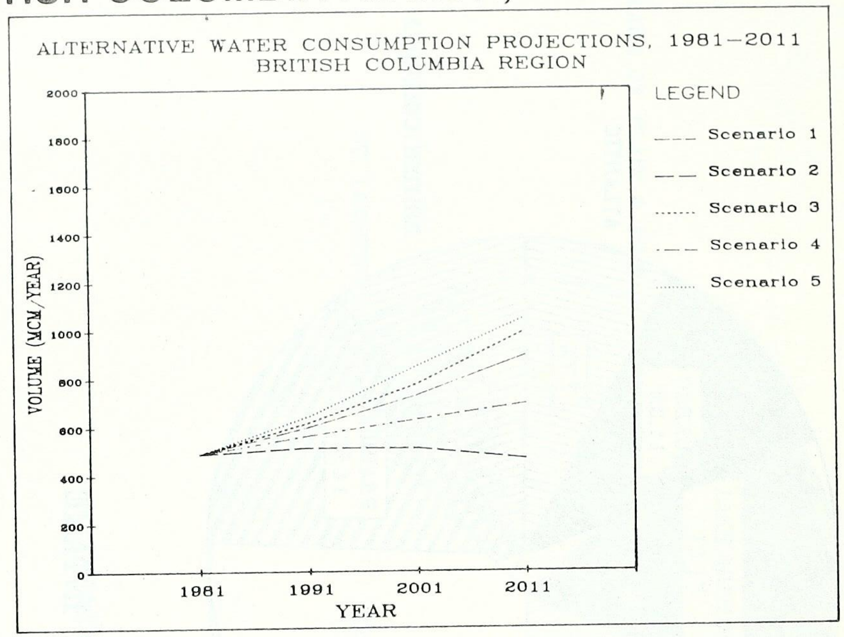
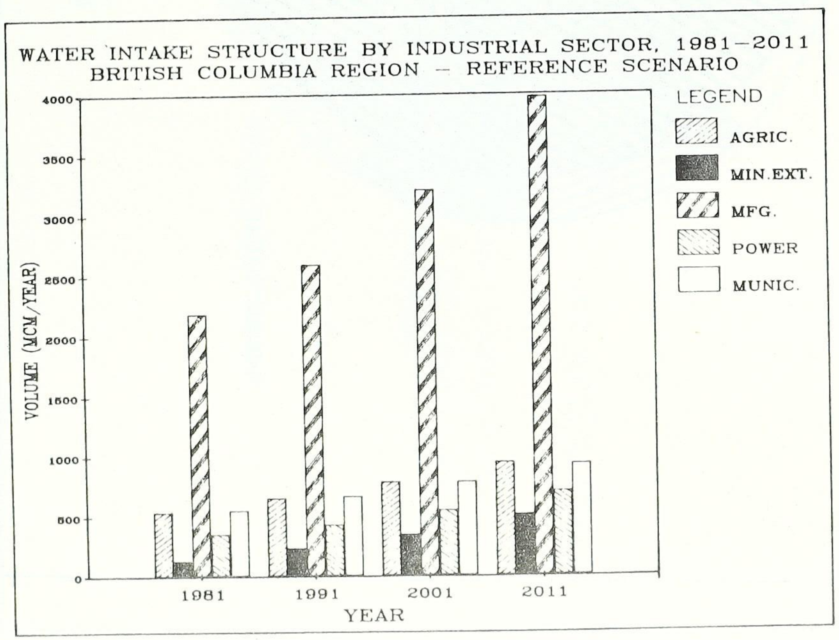


FIGURE 4.6 - WATER USE PROJECTIONS, BRITISH COLUMBIA REGION, 1981 - 2011







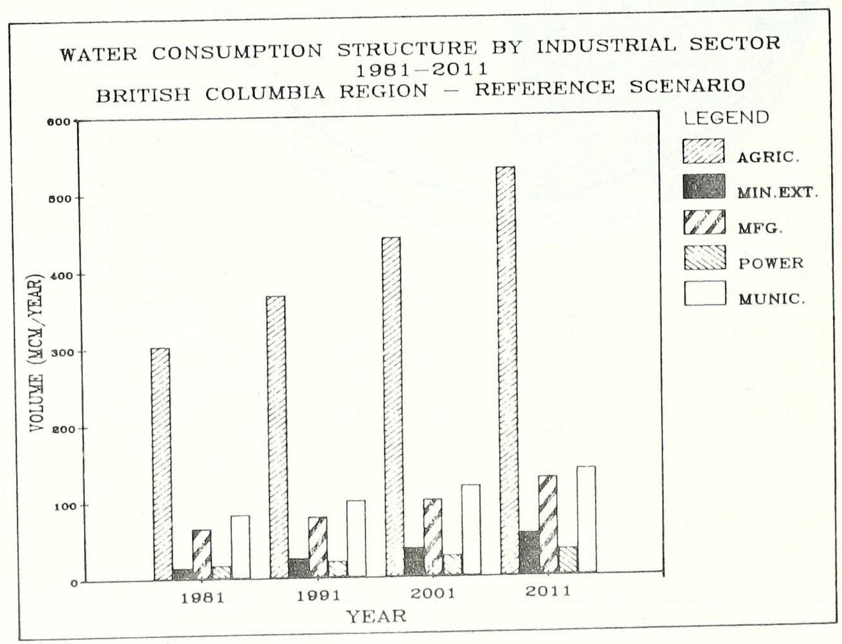
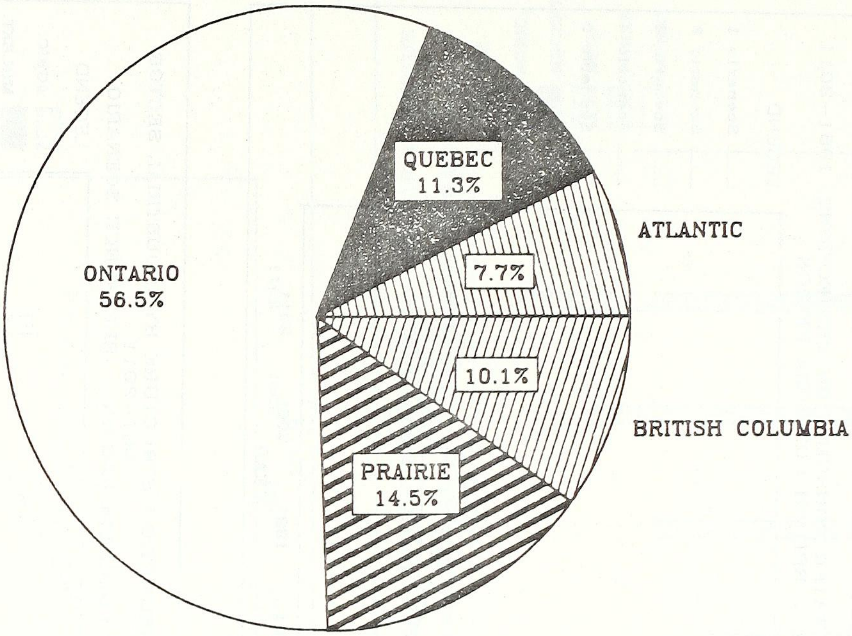
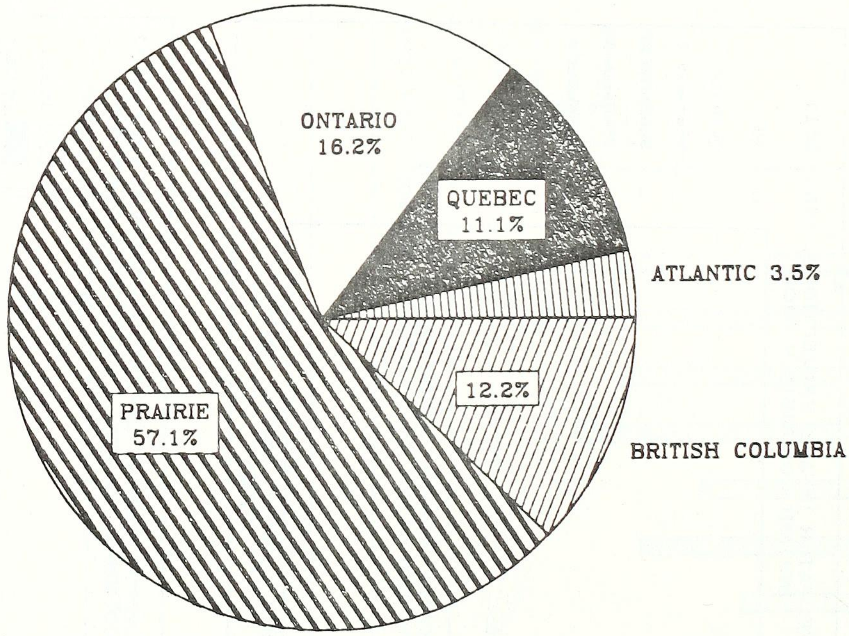


FIGURE 4.7 – WATER USE DISTRIBUTION BY REGION, 1981
CANADA

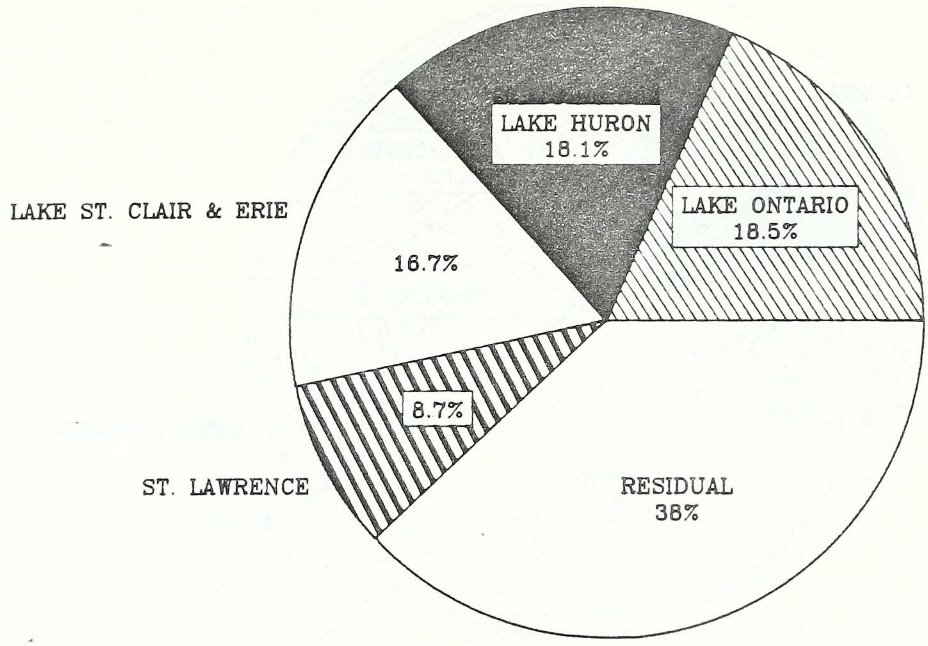


INTAKE

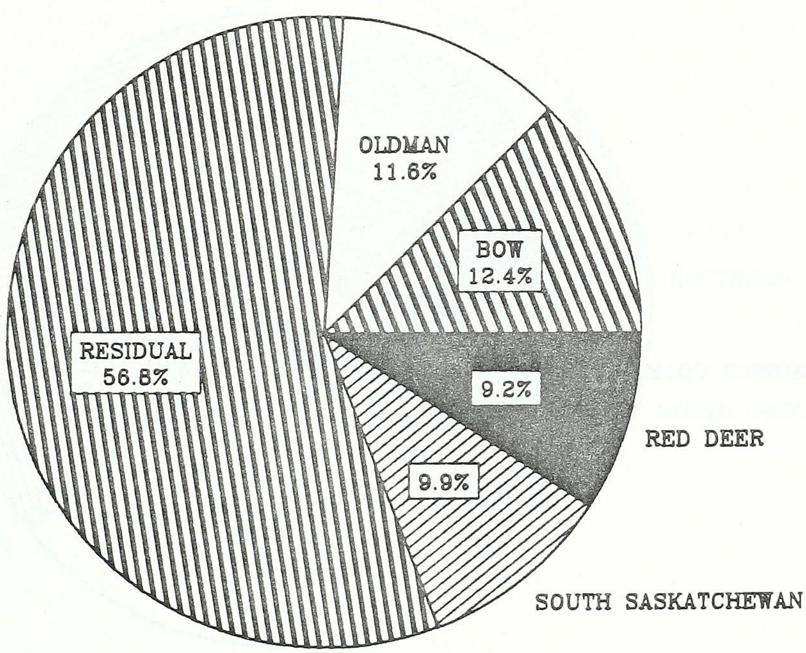


CONSUMPTION

FIGURE 4.8 – WATER USE DISTRIBUTION BY BASIN, 1981 CANADA

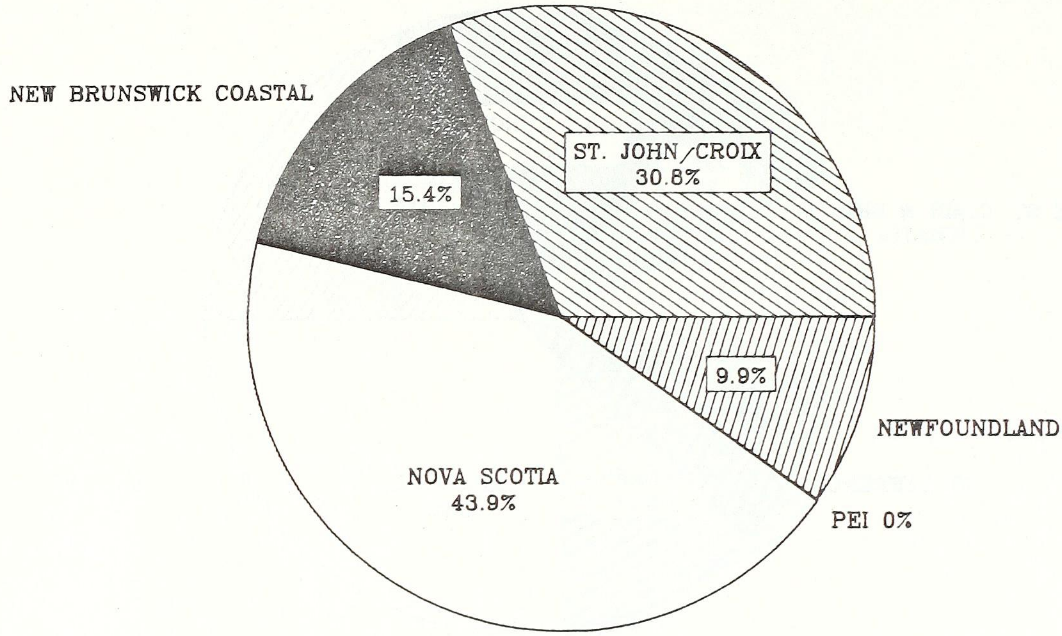


INTAKE

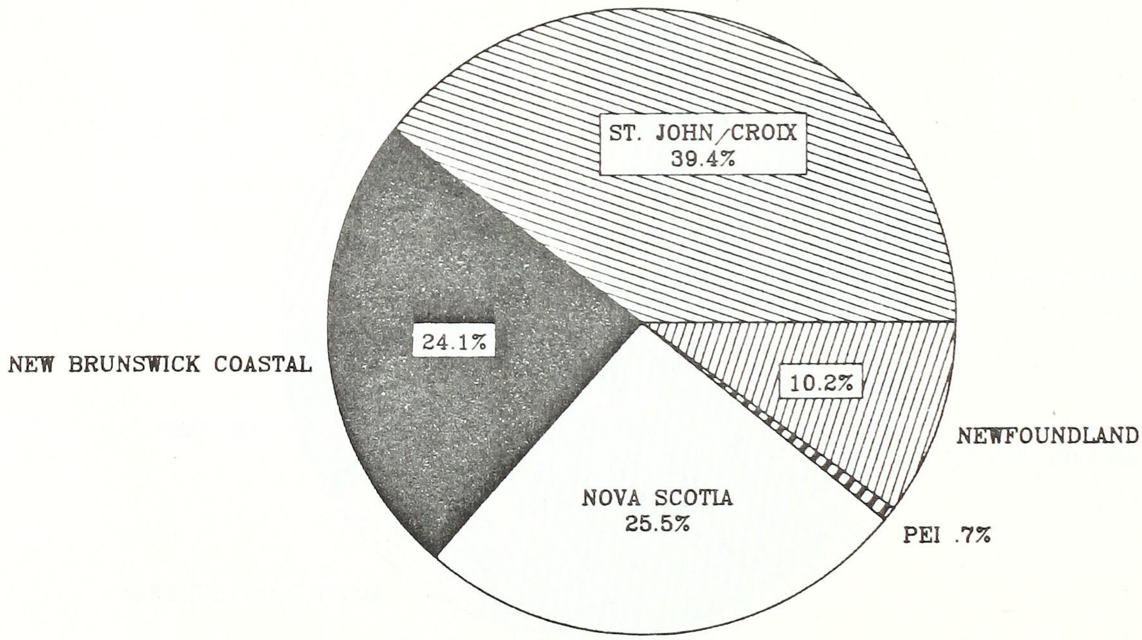


CONSUMPTION

FIGURE 4.9 – WATER USE DISTRIBUTIONS BY BASIN, 1981
ATLANTIC REGION

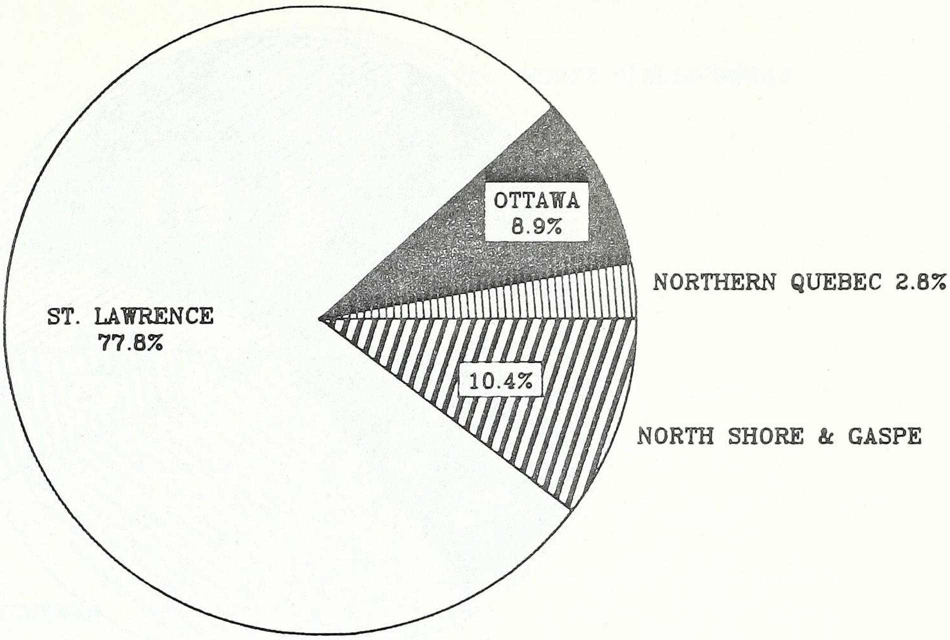


INTAKE



CONSUMPTION

FIGURE 4.10 – WATER USE DISTRIBUTIONS BY BASIN, 1981
QUEBEC REGION



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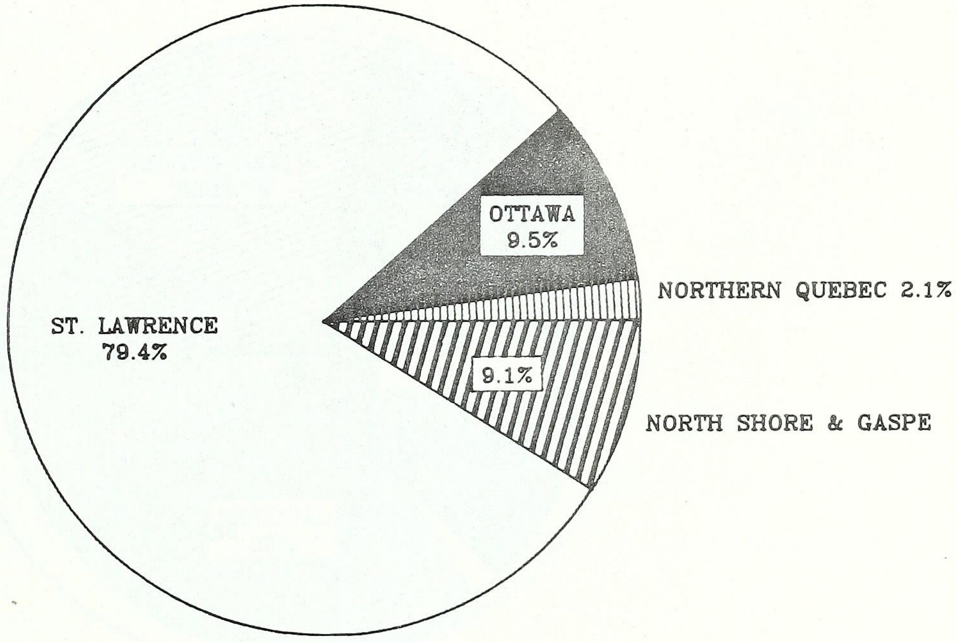
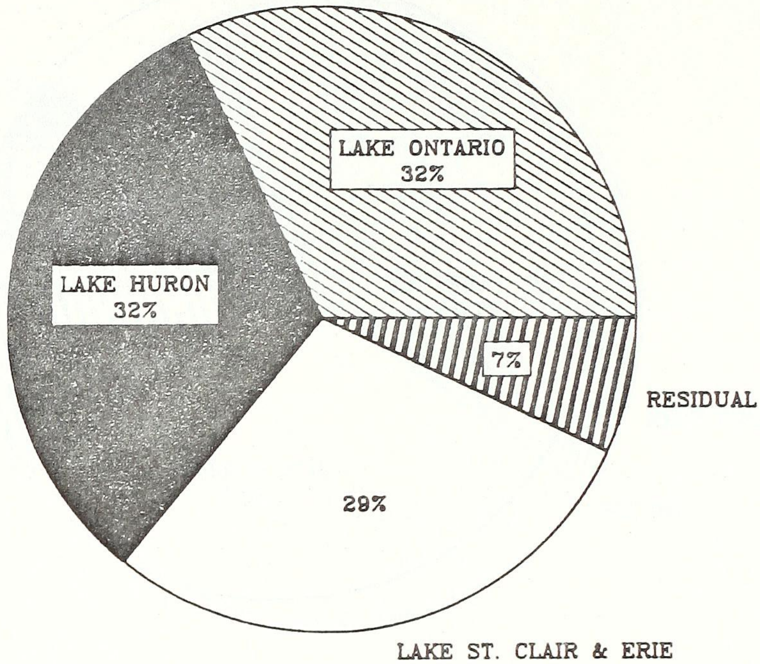


CONSUMPTION

FIGURE 4.11 – WATER USE DISTRIBUTIONS BY BASIN, 1981
ONTARIO REGION



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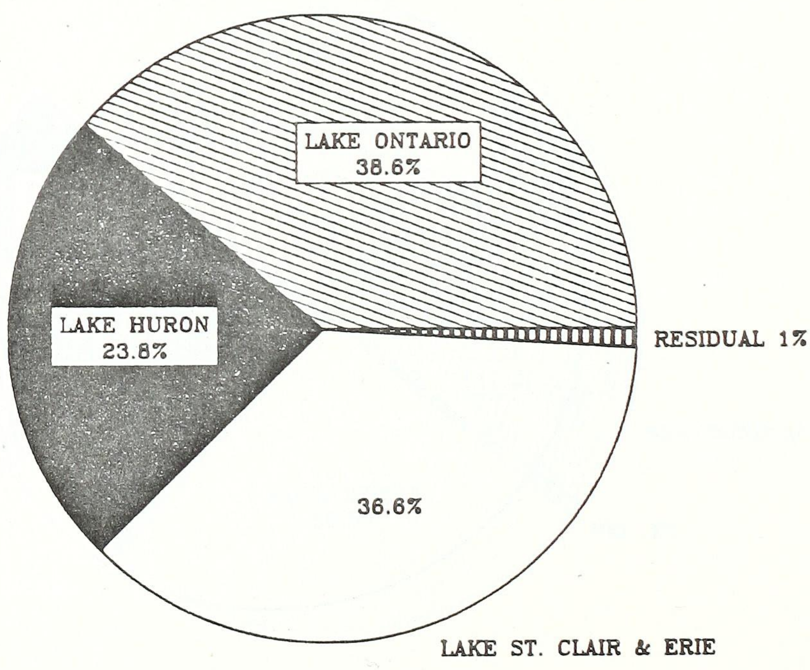
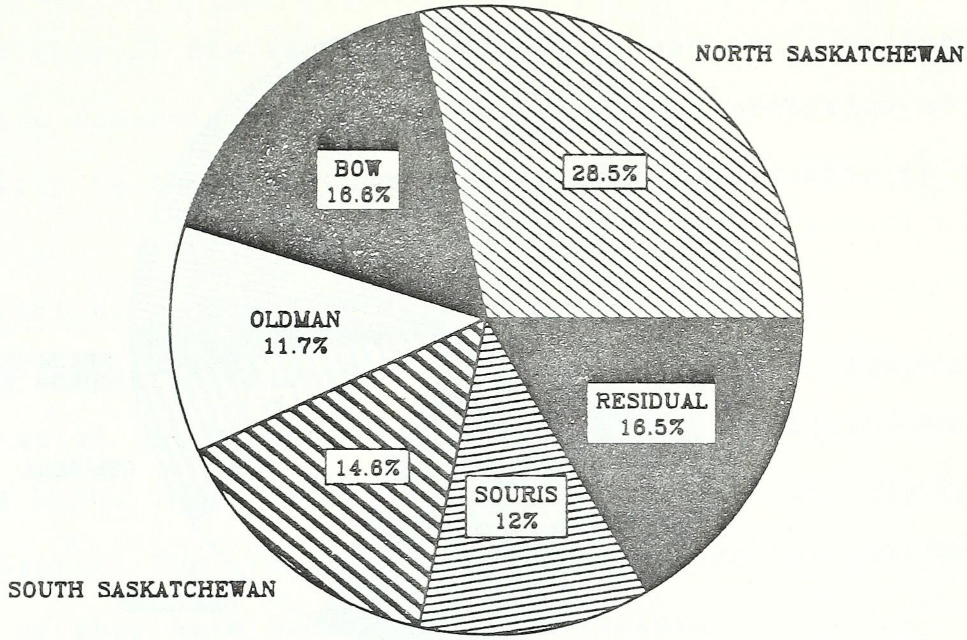


CONSUMPTION

FIGURE 4.12 – WATER USE DISTRIBUTIONS BY BASIN, 1981
PRAIRIE REGION



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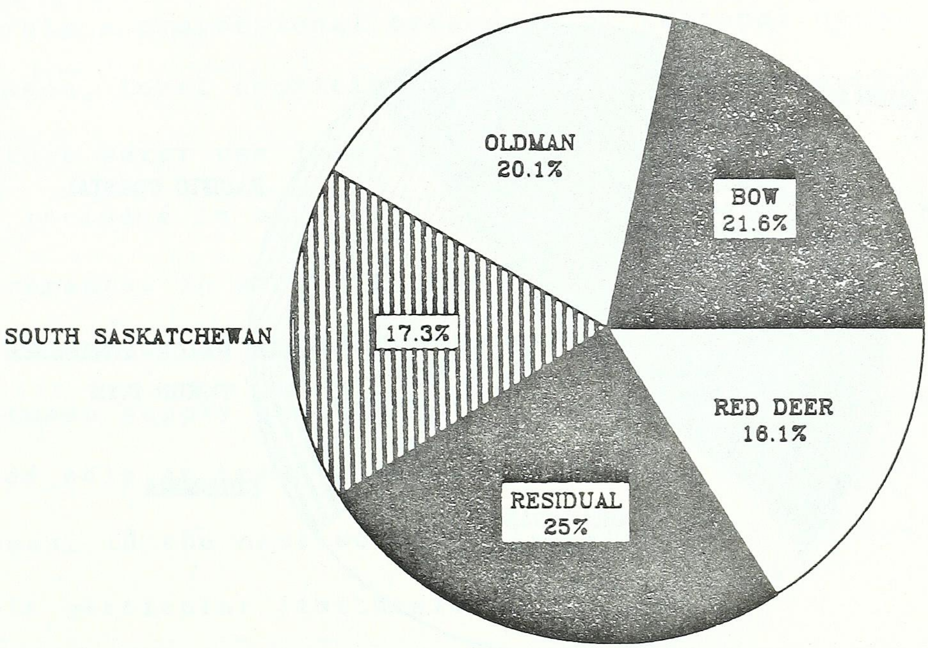
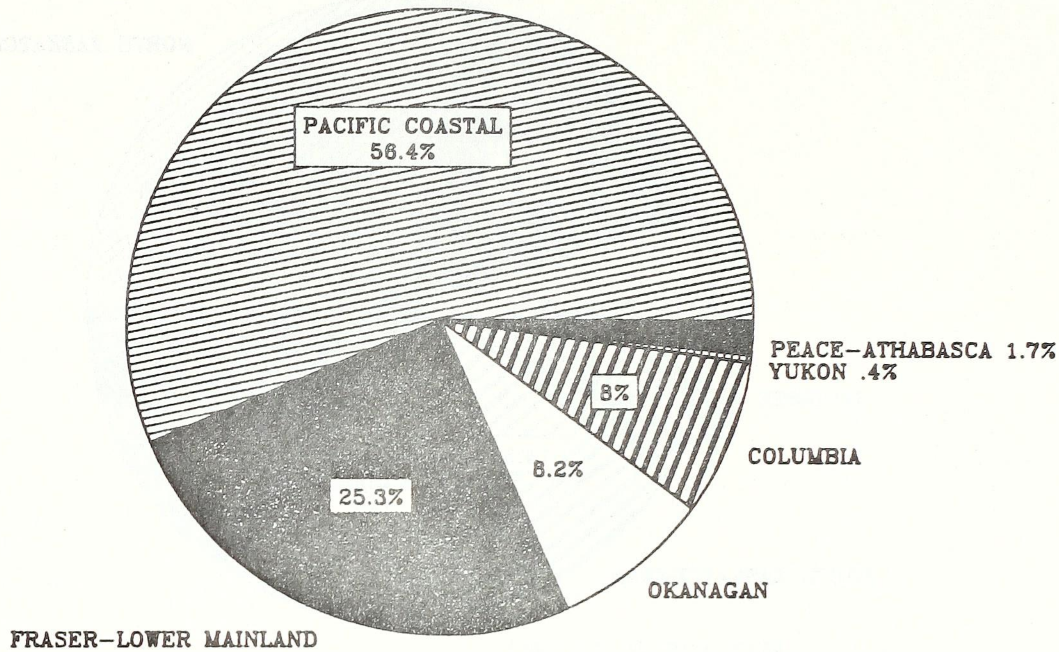
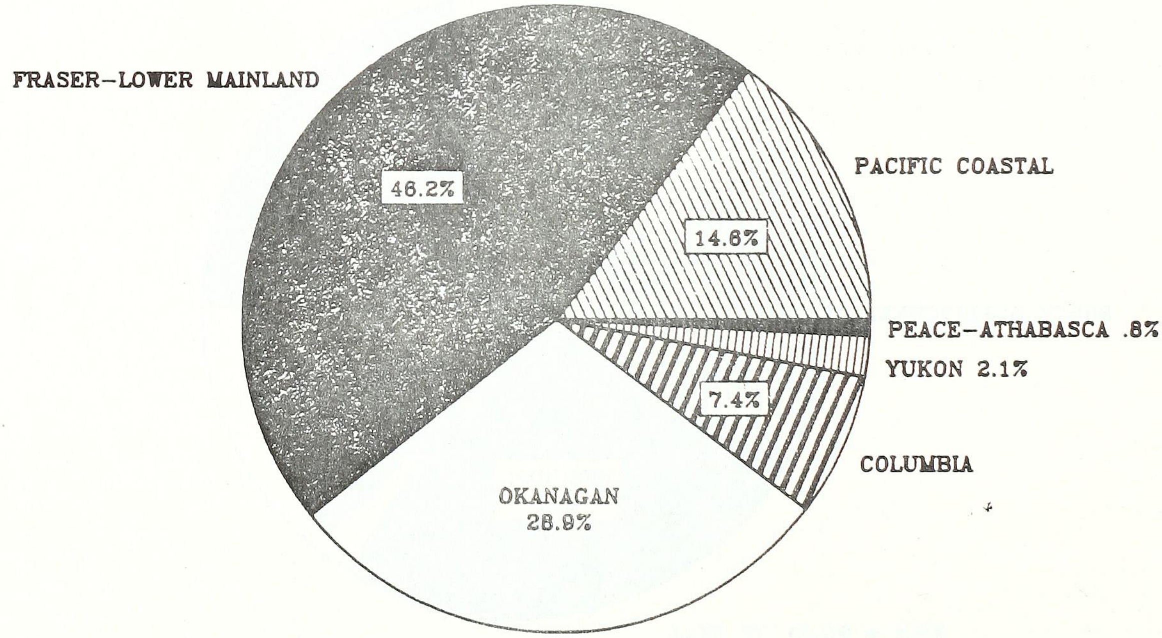


CONSUMPTION

FIGURE 4.13 – WATER USE DISTRIBUTIONS BY BASIN, 1981
BRITISH COLUMBIA REGION



INTAKE



CONSUMPTION

essentially linear in nature, the patterns shown in the regions and their river basins follow closely the characteristics given above. In general the forecasts by region and basin reflect closely the economic base of each area. Interpretation of these data is left to the reader because of time constraints on this project.

4.2 Limitations of the Forecasts

As indicated in various places throughout this report, there are substatial limitaions of the forecasts, or projections, contained here. These limitations are dealt with in this section of the chapter. The problems of uncertainty are not mentioned further, as they have been addressed earlier.

4.2.1 Lack of Consideration for Small Spatial Units

The bulk of the work in this project was carried out at the national and regional levels. The river basin projections were merely a proportional breakdown of regional data. For this reason, local conditions, which might be important in determining future water use levels, were not studied, and, if they were not be included in aggregate tends, were not incorporated into the forecasts. In many situations, it would be the local developments which would be most important in giving rise to imbalances between supply and demand. Thus, the forecasts here should be used only as broad indicators of water use conditions over wide areas. In the next section, a method is suggested for overcoming this particular limitataion.

4.2.2 Lack of Supply Considerations

In Chapter 1, consideration of supply conditions was explicitly ruled out of this project, due principally to time and resource availability constraints. While such an arrangement was required here, the implication is that the water use forecasts are divorced from any physical reality. For instance, areas where the balance between supply and use are critical now or are becoming critical cannot be defined. Water quality conditions are also missing. The integration of supply and demand is a complex task, which must be undertaken at a fairly local level, as shown in the next section. For the present, however, the water use forecasts must stand by themselves.

4.2.3 Sectoral Detail

Due to the methodology used here, each of the sectors effectively received an equivalent amount of effort during the research phase. This was done to assure a reasonably consistent set of forecasts for Canada and its regions. However, it may be argued that the more important regional industries should have received more detail than the less important ones. In fact, this very arguement was put forth by the Advisory Committee for this project with respect to irrigation in the Prairie region. However, time did not allow a full sector-by-sector examination, and this remains as a task for the future.

4.2.4 Linear Modelling

The model used in this project in essentially linear in nature. This implies a high degree of uniformity in future water use patterns between regions, as indeed can be observed in

Figures 4.1 to 4.6, and in the constant proportions of each basin's water use to total regional use. The world, however, is not linear in nature, and future work is required in overcoming the structural rigidities of the model. More work is also required on the subject of forecasting technological conditions.

4.2.5 Limited Number of Variables

The model used here considered three major dimensions of forecasting: economic activity, production technology and water use practices. Minor consideration was given to the impact of water pricing and to varying population levels. However, many other variables, such as production process mixes, product mixes, plant operating practices and rates, etc., may also have influences on the level of water use. In future investigations such variables will require consideration.

4.2.6 Data Gaps

In compiling the data base for this report, all known sources of water use data were used, and it is thought that most of the withdrwal water use in Canada (i.e. over 95%) has been included. However, there are a few basins where no information on water use was available (e.g. the Churchill River basins, the Arctic Coast). These areas are not included in this report. Finally, the most serious data gap is the complete lack of data on non-withdrawal water use. Filling this gap will be a major task for the future.

CHAPTER 5

SIMULATION MODELLING - AN ALTERNATIVE APPROACH

In chapter 4, a number of limitations were suggested to the forecasts presented in this paper. Research is currently underway within the Inland Waters Directorate, Environment Canada, to overcome some of these inadequacies, particularly to create a methododogy which accounts for local conditions, which gives greater attention to locally important economic sectors and which incorporates water supply considerations. This research and some of its preliminary results are outlined here, because it constitutes the next step thought to be necessary in water use modelling. This approach could have been taken in the current project had resources (principally time) permitted. The object of presenting this material is to examine a practical method for linking water use and demand projections to water supply conditions. Although some empirical results are given, these are for primarily demonstrative purposes at this stage, for the required research for definitive statements about basin water balances is not yet complete. In other words, the material in this chapter is presented strictly in a research context, and, beyond the adoption of such an analytical approach, has no current implications for water planning and management.

5.1 Overview of the Model

The alternative method for approaching regional water demand forecasting employs a simulation model of fairly disaggregated areas. The simulation modelling approach is based upon defining the most crucial variables underlying sectoral water uses with a river basin region, linking these in a logical fashion in a computerized model, building a forecasting algorithm and comparing forecasted water uses with available water supplies. The approach is a very flexible one, allowing a wide range of water supply conditions and alternative values of future variables. The model is outlined here, and then used to produce some projections for the Red Deer River Basin in Alberta. It is stressed here that the results given here are for demonstrative purposes only, and should not be treated with the same degree of reliability as those produced with the structural model used in the main part of the report

In contrast to the structural model, the simulation model uses river basins and subbasins as its primary spatial focus, and the areas within which to compare water supplies and uses. The region being analyzed must, therefore, be divided into subbasins, normally the area drained by a tributary or segment of a major river system. A subbasin must have a stream gauge near its mouth, with an adequate lengh of historic streamflow record. Base year (i.e. in this case 1981) data are required on the water use patterns of the various socio-economic activities in each subbasin. Water uses are projected by the model using various assumptions about economic and population growth, water use rates, specific significant developments which may be foreseen, and other forecasting parameters. These projected water use data (on withdrawal and consumptive use) are then combined for comparison with data on available water supplies, normally represented by streamflow data which have been naturalized by removing the effects of historic withdrawals/consumptions. The model results are obtained at monthly intervals, by subbasin. The subbasin results can then be aggregated to produce comparisons of water supplies and uses by major river basin or by economic region.

5.2. Computation Procedure

The model's operation can be viewed as a three-stage process: (a) determination of future water uses; (b) determination of supply availability; and (c) comparison of future uses with available supplies. In setting up the model, the hierarchical relationship of subbasins within the main basin must be defined; irrigation areas must also be placed in their proper spatial positions within the subbasins. Upstream basins are examined first, comparing uses to available supplies. The surplus water is passed to the next downstream subbasin. Local subbasin inflows, irrigation return flows from other subbasins, diversions and surplus flows from upstream are all considered in computing water availability. In this way, the impacts of all upstream water uses and water sources are accounted for in analyzing downstream basins. The model structure is presented in Figure 5.1. The calculation detail for each subbasin, or node in the model, is illustrated in Figure 5.2.

The following material constitutes a brief description of the principal methods used in the model, based upon more extensive documentation (Canada, 1983, 1984).

FIGURE 5.1 - MODEL STRUCTURE

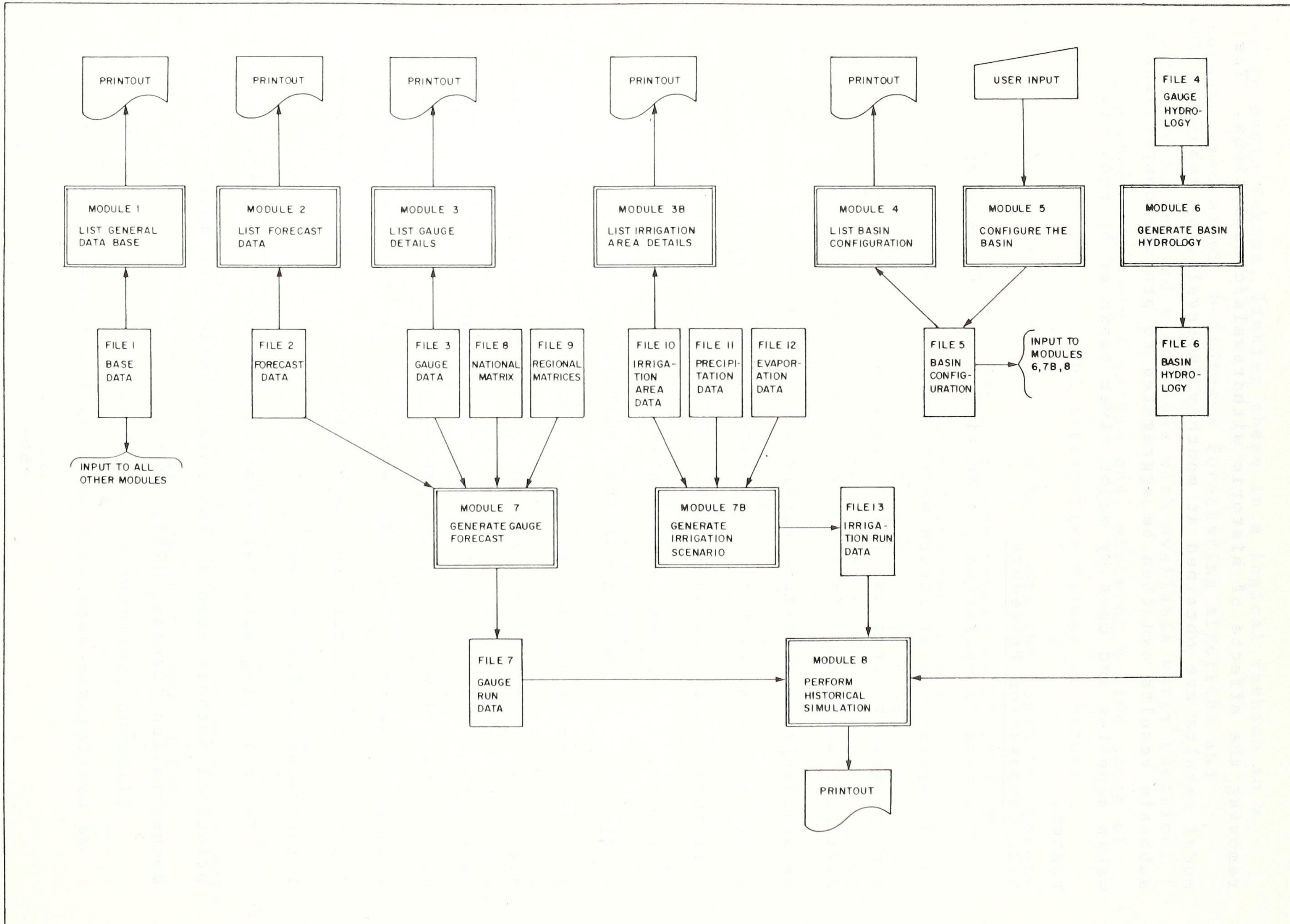
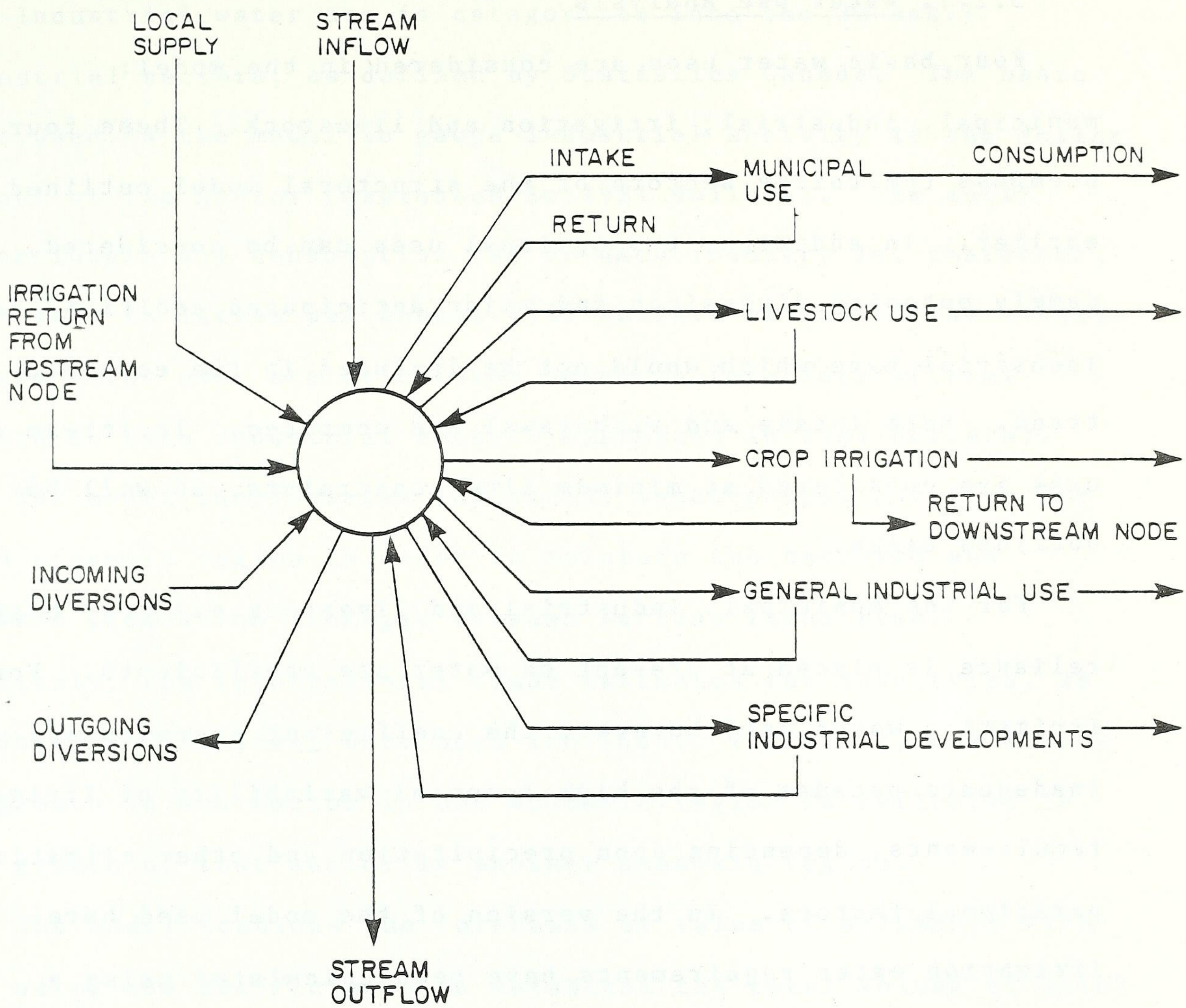


FIGURE 5.2 - CALCULATION DETAIL AT EACH NODE



NET INFLOW = LOCAL SUPPLY + STREAM INFLOW + DIVERSIONS IN − DIVERSIONS OUT + IRRIGATION RETURN FROM UPSTREAM

OUTFLOW = NET INFLOW $- \sum_{\text{ALL USES}}$ (INTAKE - RETURN) AT THE NODE

5.2.1. <u>Water Use Analysis</u>

Four basic water uses are considered in the model: municipal, industrial, irrigation and livestock. These four uses ncompass the thirty sectors of the structural model outlined earlier. In addition, two optional uses can be considered, namely outgoing diversions and major anticipated additions to the industrial base which would not be included in the economic trend. Both intake and withdrawal are computed. In-stream water uses are considered as minimum flow constraints, as will be outlined below.

For the municipal, industrial and livestock sectors, heavy reliance is placed at present on water use coefficients. For irrigation water use, however, the coefficient approach was inadequate because of the high temporal variability of irrigation requirements, depending upon precipitation and other climatic and perational factors. In the version of the model used here, irrigation water requirements have been calculated using a detailed submodel of crop water requirements. In future versions of the model, municipal and industrial uses will also be the objects of detailed submodels, but those submodels were not available for use in this project.

For the municipal sector, the model requires forecast data describing population growth. These data, available at the provincial level, are apportioned to the subbasin, based on baseline population data. The model utilizes the forecasts of future population and the municipal water use rates to establish the total municipal water requirements in each subbasin.

Industrial water use is categorized into the 30 basic industrial sectors, as defined by Statistics Canada. The basic unit used in the model to gauge industrial activity is the dollar output of the sector (expressed in 1981 dollars). The total water intake and consumption use of each industry is, therefore, expressed in litres per annual 1981 dollars of industrial output. Future water uses are calculated based on forecasts of real growth in each industrial sector (expressed in 1981 dollars).

The model incorporates industrial input-output matrices for each economic region in order to maintain the backward and forward production linkages between various industries. Similarly, the interregional trade estimates for industries, as produced by Statscan, have been included. Therefore, the impact of growth in one sector in one economic region is reflected in the growth of that sector in another economic region.

The model combines the forecasts of value of shipments with the water use coefficients to establish the total volume of water required by industries in the subbasin.

Forecasts of livestock water uses are calculated, by livestock type, following an approach which is similar to the municipal sector.

Irrigation water requirements are calculated based on detailed modelling of crop water needs, giving consideration to irrigated area under different crop types, irrigation types, precipitation (in-season and out-of-season), crop evapotranspiration, soil moisture levels and various operational factors, such as level of irrigation, application efficiency and delivery efficiency. The calculations are performed in units of millimetres per hectare, on a monthly basis within the cropping season (May to September), and for a historic period of years determined by the precipitation record.

Figure 5.3 is a flow chart of the irrigation water use submodel. More details on the submodel's computational procedure, assumptions, etc. can be found in Canada (1984).

Forecasting irrigation water needs requires information on the future area under irrigation, by crop, soil and irrigation types as well as foreseen operational factors. The model calculates irrigation water diversions and return flows for each irrigation area for combination with the other water uses.

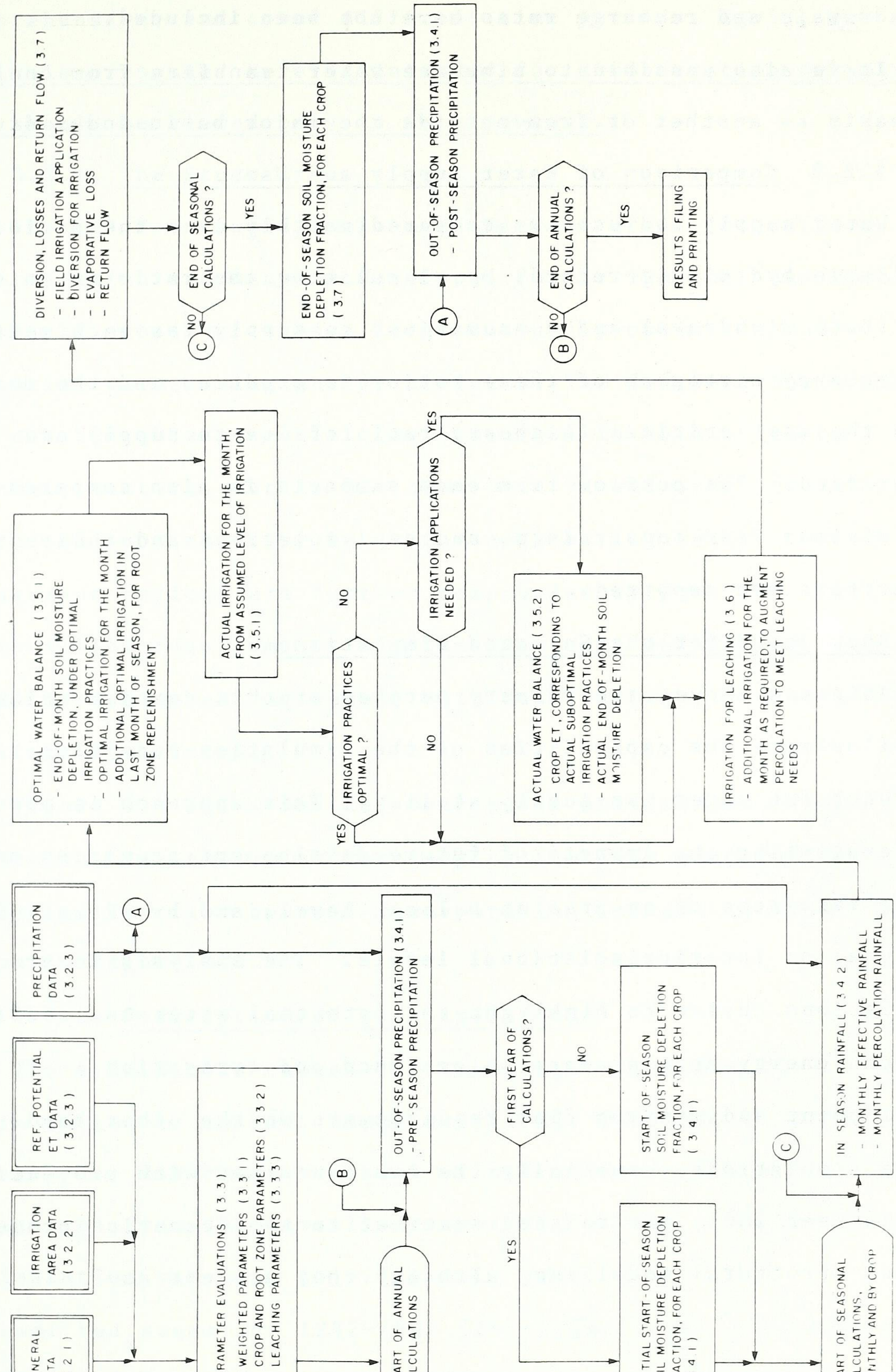
In-stream uses (e.g. recreation, water quality) are presently considered in the model based on minimum flow constraints. The model provides the option to specify monthly minimum flow constraints at the outlet from the subbasin. Months when these minimum flows are violated are flagged in the output and the frequency of their occurence is documented.

5.2.2 Water Availability

Water supplies from surface water sources are represented in the model by monthly (natural) streamflow data. The model, in its present form, requires that streamflow data be adjusted for the effects of reservoir regulations.

Provision has also been made in the model for including water supplies from groundwater sources. At this stage of model development, however, groundwater supplies are modelled using ad hoc procedure. Specific aquifers and their limitations, maximum

FIGURE 5.3 - FLOW CHART FOR EVALUATION OF IRRIGATION AREA WATER USE



withdrawals and recharge rates have not been included.

It is also possible to simulate water transfers from one subbasin to another or from outside the major basin under study.

5.2.3 Comparison of Water Supply and Use

Water supply and use are compared monthly over the period of available hydrologic record, by calculating the ratio of water use (both withdrawal and consumption) to supply for each month. A frequency histogram of these ratios is produced and the months with the most critical (highest) ratio of use to supply are identified. The outflow from each subbasin is also compared with the minimum flow constraints, and any violations and their severities are reported.

5.3. Background for the Selected Simulations

As noted above, the primary purpose of this demonstration is to illustrate the capabilities of the simulation modelling approach for water use:supply studies. This approach is most useful for evaluating the impacts of future development scenarios on the water resources of an area at a local level, and by extension at regional or interjurisdictional levels. The analysis covers four simulations chosen to highlight the potential water use conflicts between energy developments on one hand and irrigation development and minimum flow requirements on the other hand. These simulations, especially the two concerned with projections to the year 2001, are related somewhat to the scenarios produced by the structural modelling, although they are not as comprehensive, and cover different time periods. Again, the analysis presented here is intended for demonstration purposes and should be viewed only in this context.

5.3.1. The Study Area

The Red Deer basin is located between areas in southern Alberta which are heavily developed for irrigation, and more northerly areas which have large currently-operating and potential water using energy projects. The Red Deer basin itself has considerable potential for expansion in both of these economic sectors, but it has also been viewed as a possible source of supplementary water for neighboring basins. Water management options are further compounded by possible alternative minimum flow requirements for instream uses and for meeting the water apportionment agreement with Saskatchewan, the neighboring province downstream.

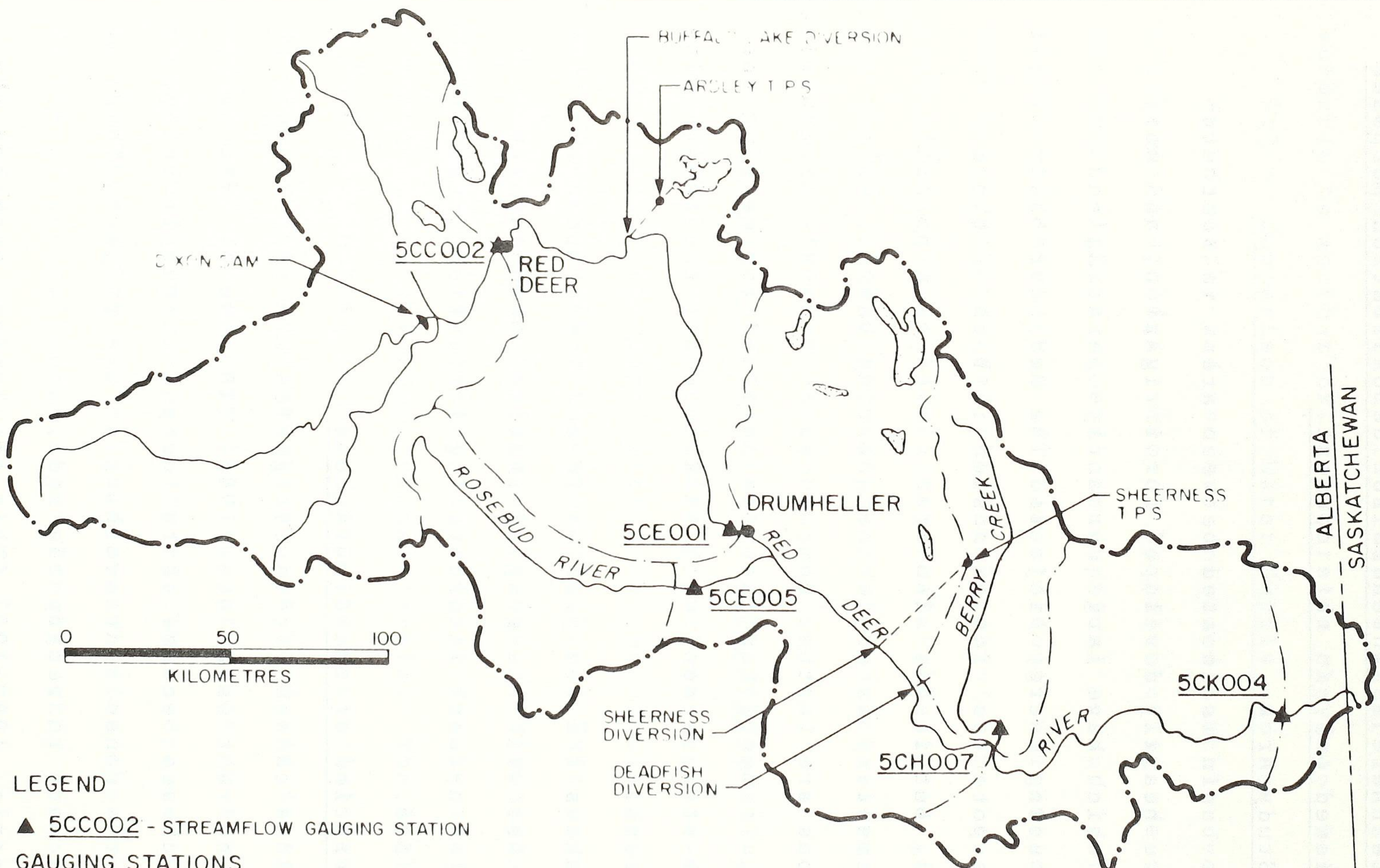
Figure 5.4 shows the Red Deer basin and its component subbasins, together with the gauging stations used for the analysis. The flow network incorporating irrigation areas is shown in Figure 5.5.

5.3.2. Description of the Simulations

The simulations chosen for investigation are as follows:

- Simulation of current water use, 1982. (The use of 1982 as a base year was chosen because of the output currently being received from the consultants working on the project. This simulation was done to verify the model).
- Committed scenario, 1982-1987 (This simulation examines the effect of developments already planned or underway for the

FIGURE 5.4 - RED DEER RIVER BASIN - SUBBASINS AND GAUGING STATIONS



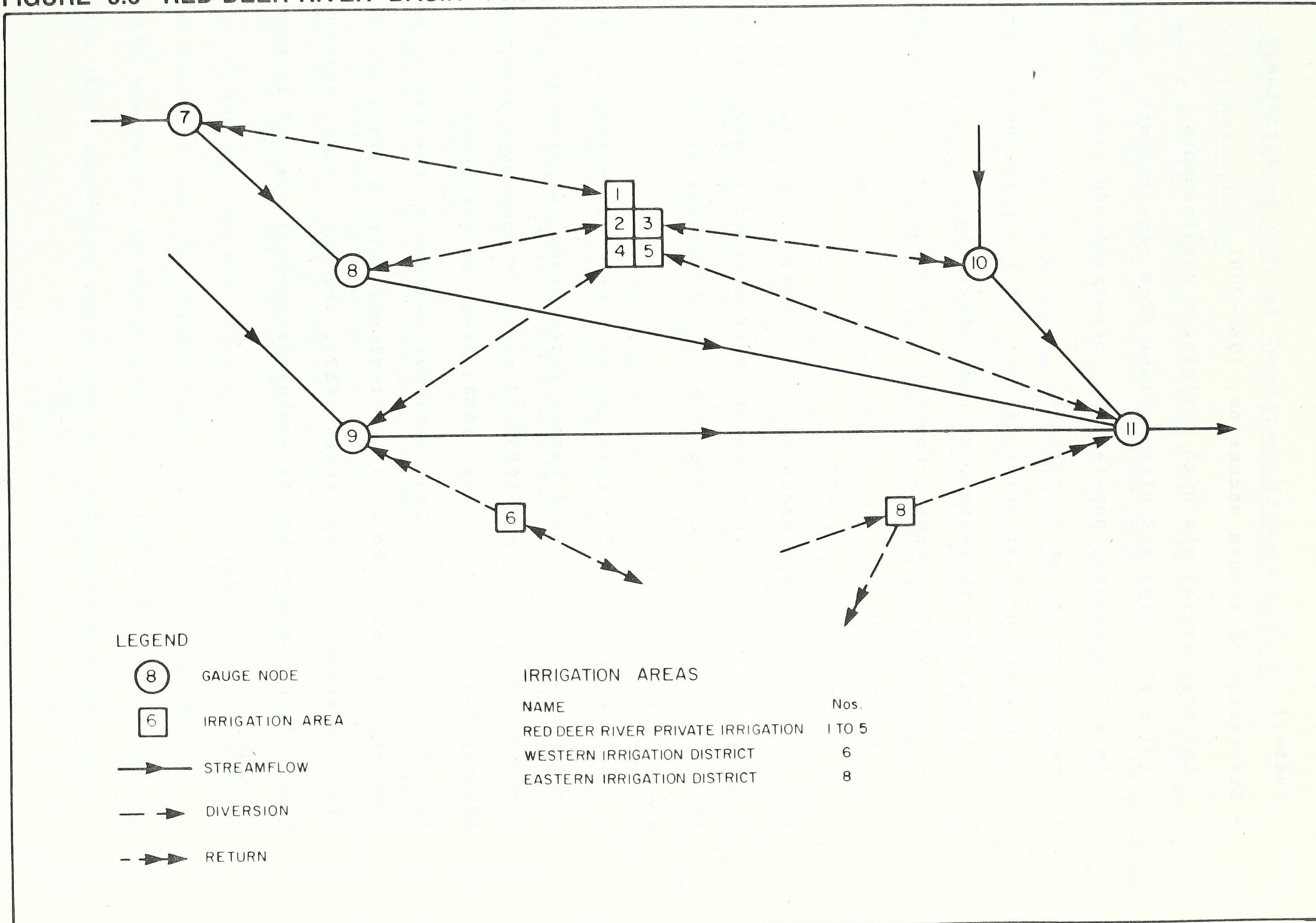
LEGEND

▲ 5CC002 - STREAMFLOW GAUGING STATION

GAUGING STATIONS

I.D. No.	LOCATION	NODE No.
5CC002	RED DEER RIVER AT RED DEER	7
5CE001	RED DEER RIVER AT DRUMHELLER	8
5CE005	ROSEBUD RIVER AT REDLAND	9
5CH007	BERRY CREEK NEAR THE MOUTH	10
5CK004	RED DEER RIVER NEAR BINDLOSS	11

FIGURE 5.5 - RED DEER RIVER BASIN - FLOW NETWORK INCLUDING IRRIGATION AREAS



basin.)

- Simulation of future scenarios, 1981-2001

  (a) High energy and high irrigation requirements

  (b) High energy and high minimum flow requirements

In all scenarios, population, industrial and livestock forecasts were chosen as follows:

- population- Statistics Canada (198) population scenario 1 (fertility increase plus some imigration);
- Industrial- Economic Council of Canada (197), 1981-1990 projection
- Livestock- Low growth

Irrigation and energy production (and their water uses) as well as minimum flow requirements were allowed to vary, as will be specified below. Thus the water use forecasts at this stage are partial in nature.

Most of the data for this analysis were taken from studies carried out at the Inland Waters Directorate, Environment Canada (Canada, 1983; 1984; and 1985). A recently completed study by Alberta Environment (Albeta, 1984) aided in the scenario formulation. Three previous regional studies by the Canada West Foundation (1982), the Prairie Provinces Water Board (Canada-Alberta-Saskatchewan-Manitoba, 1982), and the Saskatchewan-Nelson Water Board (Canada-Alberta-Saskatchewan-Manitoba, 1972) were also used.

5.4. Simulation of Current Conditions (Simulation 1)

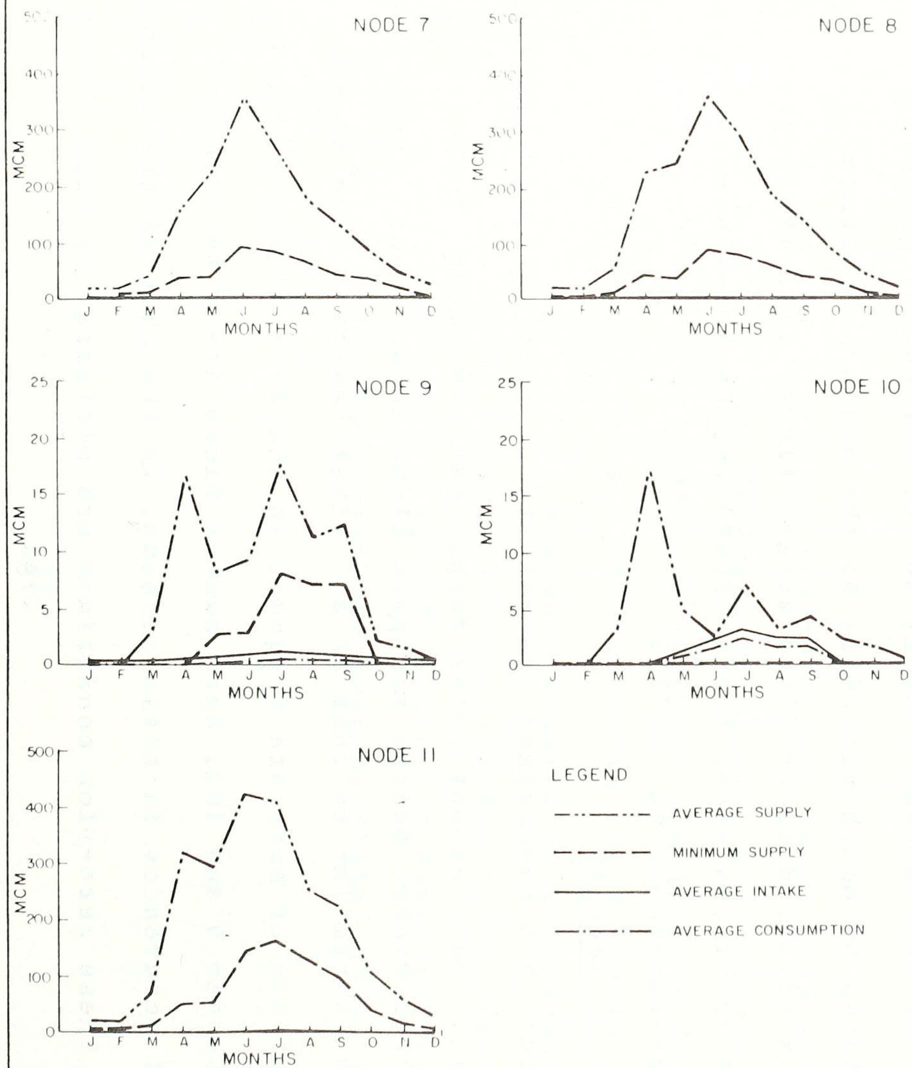
5.4.1 Assumptions

Water use for the Red Deer basin in 1982 were simulated using current population and activity levels. No special energy developments were built in, and all irrigation was set at the 1982 level (i.e. about 7 100 ha. of private development plus 115 430 ha. of public development in the Western and Eastern Irrigation Districts, located in the Bow River basin. Return flows from these two districts are routed both to the Bow River and to the Red Deer River basins. No diversions, other than the irrigation flows, were incorporated. Minimum flows were place at the level of the average apportionment flow to Saskatchewan at Bindloss (Node 11) of 18 cubic metres per second, which is approximately equal to 75% on the minimum historic natural flow. This corresponds roughly to the current situation. The flow was distributed by month according to the historic pattern. Flows were taken as adjusted naturalized stream flows, 1912-1967, produced by the Prairie Provinces Water Board (PPWB)(see Canada-Alberta-Saskatchewan-Manitoba, 1972).

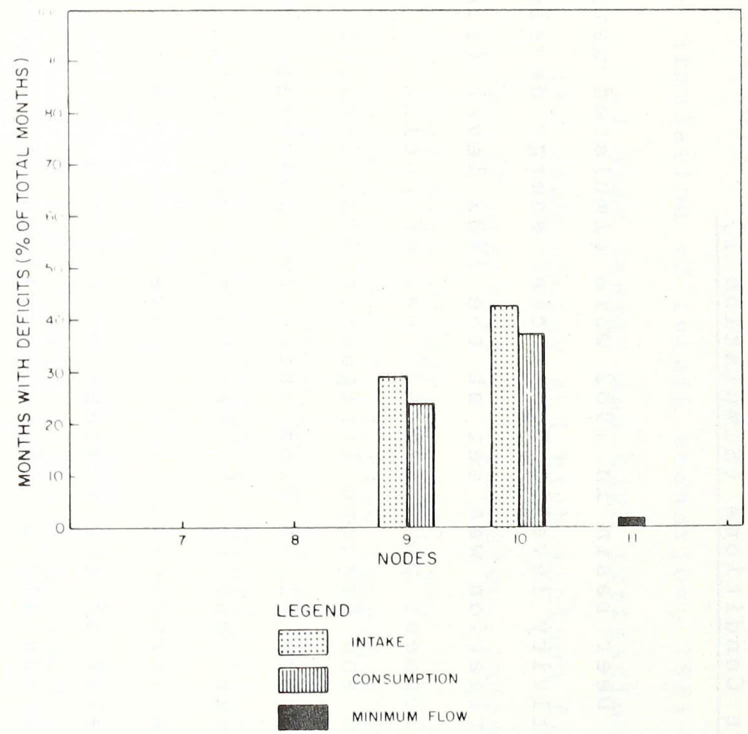
5.4.2. Results

Figure 5.6 summarizes the results of this initial simulation exercise. The dominant water supply pattern is for very low flows during the winter months and peak flows in June and July. This pattern is similar to that of all river basins in the area. Winter flows of zero are frequent in the Rosebud River and Berry Creek (nodes 9 and 10). Zero summer flows are also frequent natural occurences in these streams. In the case of the Rosebud River, these zero-flow conditions are mitigated by high return

FIGURE 5.6 - RED DEER RIVER BASIN - BASE SCENARIO 1982



MONTHLY DISTRIBUTIONS



MINIMUM SURPLUS* (% OF AVAILABLE FLOW)

NODE	INTAKE		CONSUMPTION		MINIMUM FLOW	
	S	A	S	A	S	A
7	94	92	98	98	N	N
8	96	96	99	99	N	N
9	86	81	95	93	N	N
10	D	D	D	D	N	N
11	97	98	98	99	45	46

S = SEASONAL (MAY - SEPT.) D = DEFICIT

A = ANNUAL N = NOT APPLICABLE

* BASED ON THE YEAR WITH MINIMUM SUPPLY

DEFICITS AND MINIMUM SURPLUS

flows from the Eastern and Western Irrigation Districts. Combining the withdrawal water uses with the supply conditions, substantial water surplusses occur in the Red Deer main stem subbasins (nodes 7, 8 and 11). Frequent winter supply deficits occur in the Rosebud and Berry tributary subbasins, primarily due to zero-flow conditions. It is assumed that groundwater sources are used in the winter. Frequent deficits also occur in the summer in the Berry Creek subbasin, due both to the low natural flow conditions and to a relatively high level of irrigation development. The same comments also apply to water consumption.

Occasional monthly violations of the assumed minimum flow requirements occur at Bindloss (node 11). This is due to the assumed monthly flow distribution. On a seasonal or annual basis there is a surplus supply.

5.5. Simulation of the Committed Development Program (Simulation 2)

5.5.1 Assumptions

Certain developments in the basin were assumed as committed developments, and formed the basis for the second simulation. Population, livestock and industrial production were forecasted as outlined earlier. In addition, in the energy sector, the Shearness thermal power station, located in the Berry Creek subbasin, is taken as developed to the 750 MW level, with an annual intake of 54 MCM. This plant will be served by diversion from the Red Deer River during 8 months of the year, with intake from storage only during the 4 winter months. Return flows from the power station were assumed to be held in storage for release during the irrigation season (May through September).

Full development of irrigation areas to the level of 10 400 ha. along Berry and Deadfish Creeks (node 10) was assumed, following implementation of the Berry and Deadfish diversions. Nominal expansions were assumed elsewhere in the basin to a total of 16 000 ha. overall. Also some increased developments were assumed in the Eastern and Western Irrigation Districts to 120 000 ha., with partially increased irrigation efficiencies.

Three intrabasin diversions were assumed. For recreational and environmental purposes, 1.8 cubic metres per second are diverted from the Red Deer above Drumheller to Buffalo Lake. To support the power plant at Sheerness, 2.0 cubic metres per second are diverted from the Red Deer below Drumheller. For irrigation, 1.0 cubic metres per second are withdrawn for the Red Deer below Drumheller to Deadfish Creek.

With regard to flows, the 1912-1967 adjusted naturalized flows from PPWB were use. The Dickson dam was incorporated above Red Deer, and operated to maximize minimum winter flows. In this manner, a minimum winter flow of 18.4 cubic metres per second can be supported throughout the winter. A minimum flow of 18 cubic metres per second at Bindloss was assumed, as in the first simulation. Also, a minimum release from the Dickson Dam of 16 cubic metres per second was assumed, as in the original design criteria for the dam.

5.5.2 Results

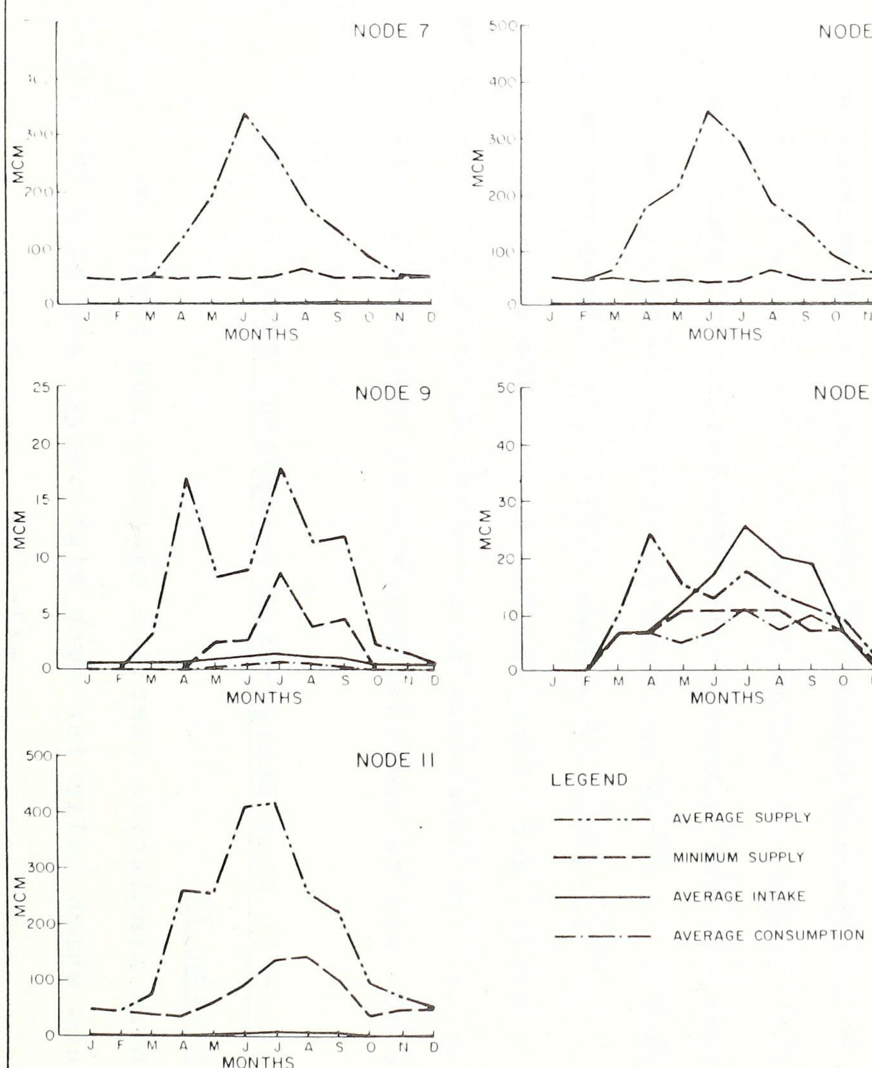
As a result of this simulation, notable improvements can be seen (Figure 5.7) in winter flows along the Red Deer mainstem (nodes 7, 8 and 11), due to the specified operation of the Dickson Dam. In the years of very low flow, an almost constant flow is maintained at the two upstream nodes, unaffected by unregulated inflows downstream. Diversions into the Berry Creek subbasin (node 10) significantly improve supply conditions in the summer months.

With regard to the impact of water use on the supply pattern, substantial surplus supplies occur along the Red Deer main stem subbasins (nodes 7, 8 and 11), as in the 1982 run. Negligible changes from the 1982 base occur in the Rosebud subbasin (node 9). Thermal power and irrigation production in the Berry subbasin (node 10) have a marked impact in increasing the frequency of deficits with respect to water intake on both a monthly basis, and on a seasonal and annual basis. The impacts of consumptive use are similar to those outlined for intake, with one notable exception. The frequency of summer deficits in the Berry subbasin decreases sharply, and there are now negligible deficits on a seasonal basis. The Sheerness power plant and related storage is seen to be the key to combined power and irrigation in this subbasin.

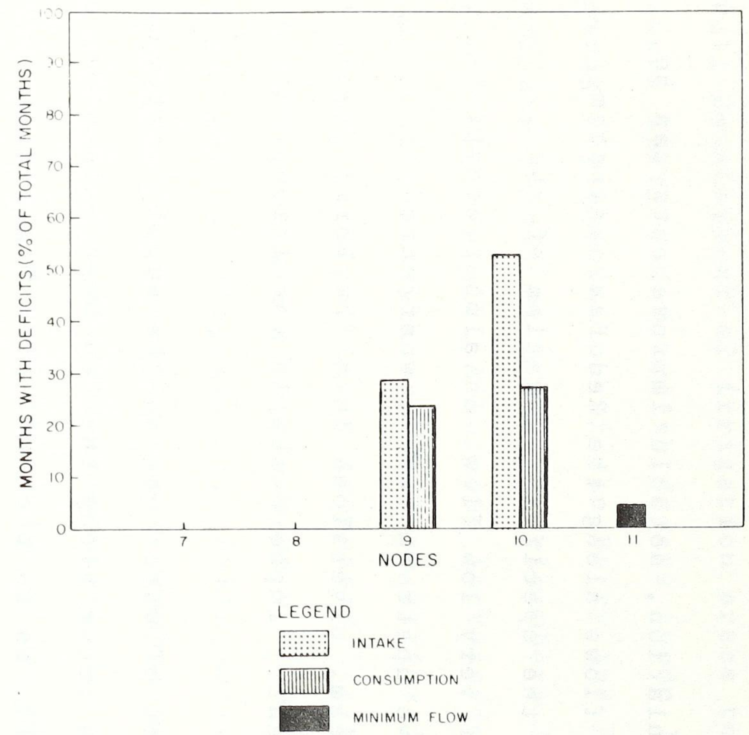
5.6. Simulation of High Energy-High Irrigation Requirements (Simulation 3)

The third simulation exercise examines the impact of developments which calls for both high energy and high irrigated

FIGURE 5.7 - RED DEER RIVER BASIN - COMMITTED SCENARIO 1987



MONTHLY DISTRIBUTIONS



MINIMUM SURPLUS* (% OF AVAILABLE FLOW)

NODE	INTAKE		CONSUMPTION		MINIMUM FLOW	
	S	A	S	A	S	A
7	92	92	97	97	38	24
8	94	94	98	99	N	N
9	83	77	93	92	N	N
10	D	D	D	12	N	N
11	95	97	97	98	34	44

S = SEASONAL (MAY-SEPT.) D = DEFICIT
A = ANNUAL N = NOT APPLICABLE
* BASED ON THE YEAR WITH MINIMUM SUPPLY

DEFICITS AND MINIMUM SURPLUS

agricultural production by year 2001 . In this manner some of the trade-offs between the two sectors can be seen as they apply to the areas's water resource base.

5.6.1 Assumptions

The flow record used here is the same as for the other simulation runs. The Dickson dam is also incorporated. Thermal power production at the Sheerness plant is doubled (i.e. compared to simulation 2) to 1500 MW, with annual intake requirement of 85 MCM. Diversion and storage arrangements similar to those outlined in the previous section are made. In addition, the Ardley thermal power station below Red Deer (node 8) is developed to 2000 MW, with a yearly intake of 88 MCM. Withdrawal at this plant take place from surface sources during 8 months of the year, with winter withdrawals from storage only. Return flows from the thermal plant are routed to Buffalo Lake, during the 8 month period in which surface withdrawals occur ; these return flows are for recreational and environmental purposes, with no subsequent return flow to the Red Deer main stem.

With respect to irrigation, full development of potentially irrigable land (outside of the two organized irrigation district) occurs, to a total of 120 000 ha. Of this total 104 000 ha. are developed in the lower Red Deer main stem subbasin below Drumheller (node 12). In the organized irrigation districts, expansion takes place to the 153 000 ha. level, accompanied by fully improved irriation efficiencies, producing relatively low return flows.

In support of these developments, 1.8 cubic metres per second is diverted from the Red Deer main stem as in simulation 2. This is in addition to the Ardley power plant diversions from the same location. The 4.0 cubic metres per second diverted to Sheerness continues as in simulation 2, as does the summertime diversion from Deadfish Creek.

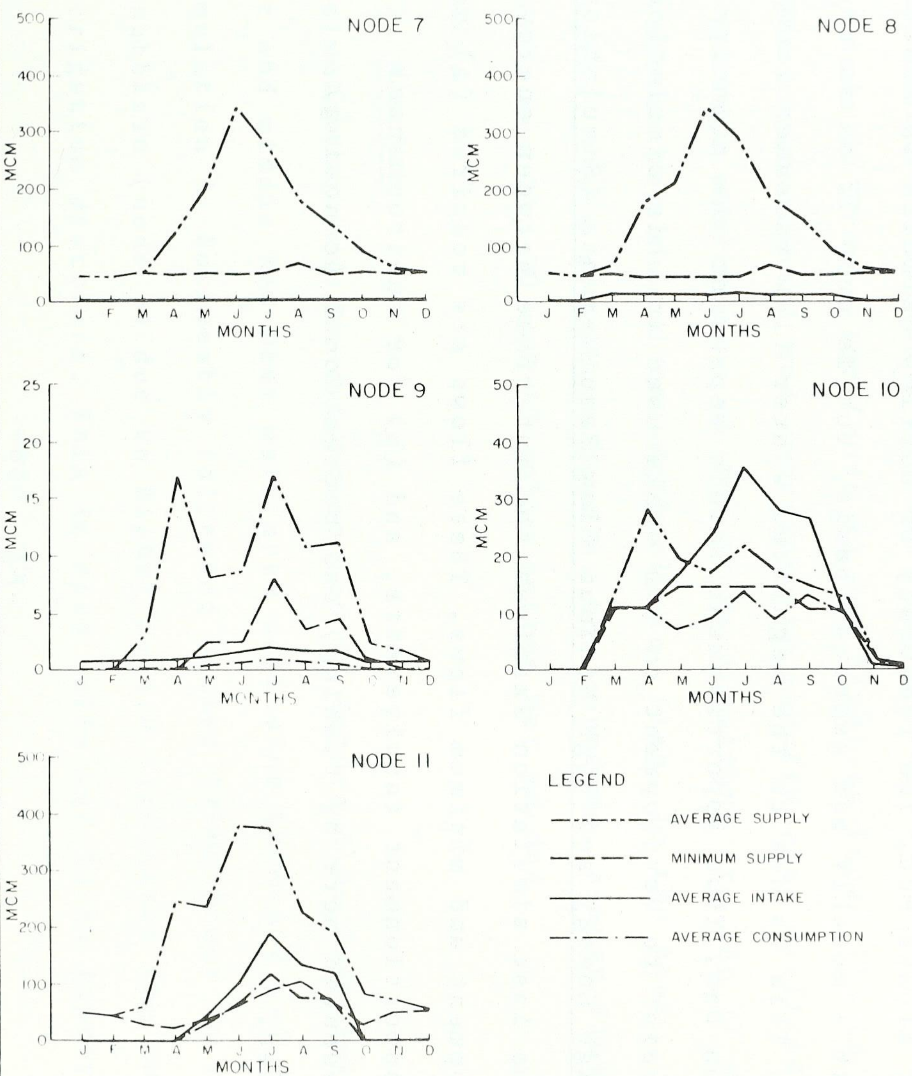
An average apportionment flow to Saskatchewan at Bindloss is reduced to 12 cubic metres per second, about equal to 50% of the minimum natural flow. This flow is distributed through the year as in simulation 2. Also minimum release from the Dickson Dam is again set at 16 cubic metres per second (node 7).

5.6.2. <u>Results</u>

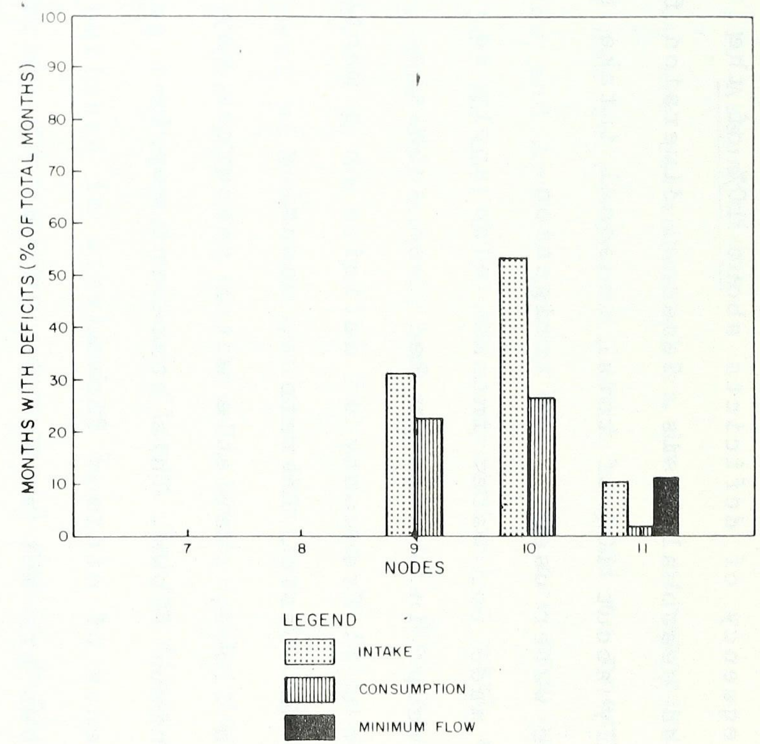
Further improvements in the summer water supply, over and above those of simulation 2, occur as a result of the increased diversion to the Sheerness power station (Figure 5.8). A noticeable reduction in summer water supplies to the lower Red Deer subbasin (node 11) result from the lower irrigation return flows from the Bow River basin, as a result of increased irrigation efficiencies.

Water intakes increase substantially above Drumheller (node 8) as the Ardley thermal power plant comes on stream. Minimum annual surplus, however, is still substantial, at 78% of available flow. Further increases in thermal power and irrigation water withdrawals in the Berry subbasin (node 10) approximately counteract the effects of the increased diversion, making the overall impact about similar to that for simulation 2. Significant summer increases in withdrawal in the lower Red Deer

FIGURE 5.8 - RED DEER RIVER BASIN - FUTURE SCENARIO 2001, HIGH ENERGY AND HIGH IRRIGATION



MONTHLY DISTRIBUTIONS



MINIMUM SURPLUS* (% OF AVAILABLE FLOW)

NODE	INTAKE		CONSUMPTION		MINIMUM FLOW	
	S	A	S	A	S	A
7	89	88	96	96	37	24
8	74	78	81	86	N	N
9	73	63	90	88	N	N
10	D	D	0	12	N	N
11	D	20	9	50	D	8

S = SEASONAL (MAY - SEPT.) D = DEFICIT
A = ANNUAL N = NOT APPLICABLE
* BASED ON THE YEAR WITH MINIMUM SUPPLY

DEFICITS AND MINIMUM SURPLUS

(node 11) result in a frequency of deficicts about 10% of the time on both a monthly and seasonal basis. Seasonal diversion for Sheerness constitutes only about 10% of total seasonal intake in the subbasin; most of the water use is for irrigation.

The same comments as made for water intakes also apply to consumptive water use, except in the lower Red Deer subbasin. Here, there is only about a 2% frequency of deficits on a monthly basis and none on a seasonal basis. Therefore, assuming appropriate use of return flows, available water resources may be sufficient to support minimum flows. This statement may be modified by the requirements of minimum flows.

Specified minimum flows are met at Red Deer (node 7), as in simulation 2. However, the reduced allocation of flow at Bindloss is not always met. The frequency of outflow deficits is about 10% on both a monthly and seasonal basis, but is only 2% on an annual basis. This is due to the regulated winter flow releases from the Dickson Dam. Thus apportionment levels represent the principal constraint to development on the scale used in this simulation.

5.7 High Energy and High Minimum Flow Requirements (Simulation 4)

The last simulation examines the interface between energy development and minimum flows. These flows are required (a) to meet apportionment requirements, and (b) for environmental (represented here by fishing) and recreational (canoeing) purposes.

5.7.1. Assumptions

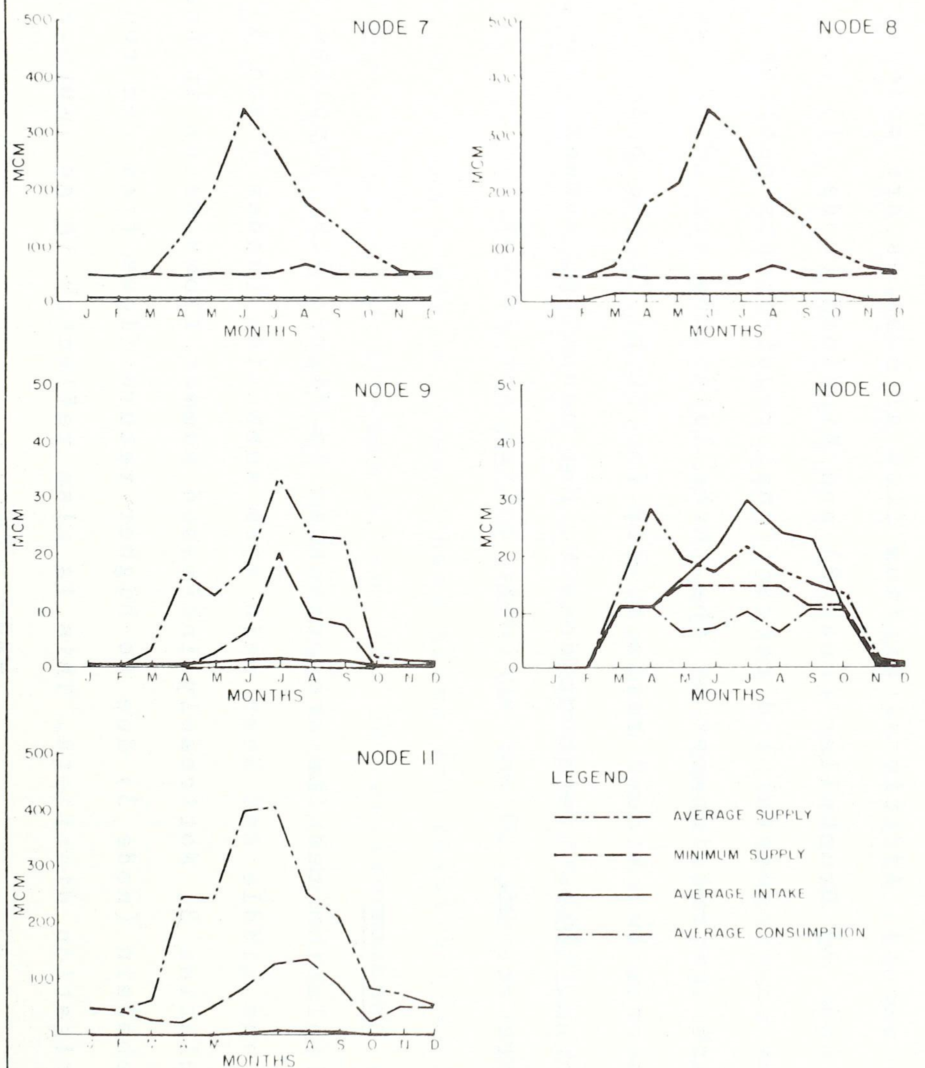
Flows are established as in the other simulations, with the Dickson Dam incorporated. With regard to energy production, Sheerness and Ardley power stations are set up as in simulation 3 (i.e. 1500 MW and 2000 MW respectively, with appropriate water use patterns and supply arrangements). Private irrigation development is held to 16 000 ha. as in simulation 2. Full development of the Eastern and Western Irrigation Districts takes place to the 233 000 ha. level, with fully improved efficiencies producing increased return flows. Water diversion arrangements are as outlined in simulation 3.

Apportionment flows average 18 cubic metres per second at Bindloss, and minimum release from Dickson Dam is set at 16 cubic metres per second. Additional minimum flow allowances are made at Red Deer (node 7) Drumheller (node 8) and Bindloss (node 11) to satisfy the environmental and recreational requirements outlined earlier. Average requirement at the three locations are 18, 27 and 36 cubic metres per second respectively for fish. In the peak summer months, these are about double. For canoeing, summer flow requirements are 25, 30 and 40 cubic metres per second respectvely.

5.7.2. Results

The simulation results are presented in Figure 5.9. Supplies in the upper and middle Red Deer main stem subbasins (nodes 7 and 8) are as in simulation 3. Noticeably increased summer flows occur in the Rosebud subbasin (node 3) due to higher return flows from the two public irrigation districts. This is also reflected in an improved

FIGURE 5.9 - RED DEER RIVER BASIN - FUTURE SCENARIO 2001, HIGH ENERGY AND HIGH MINIMUM FLOW



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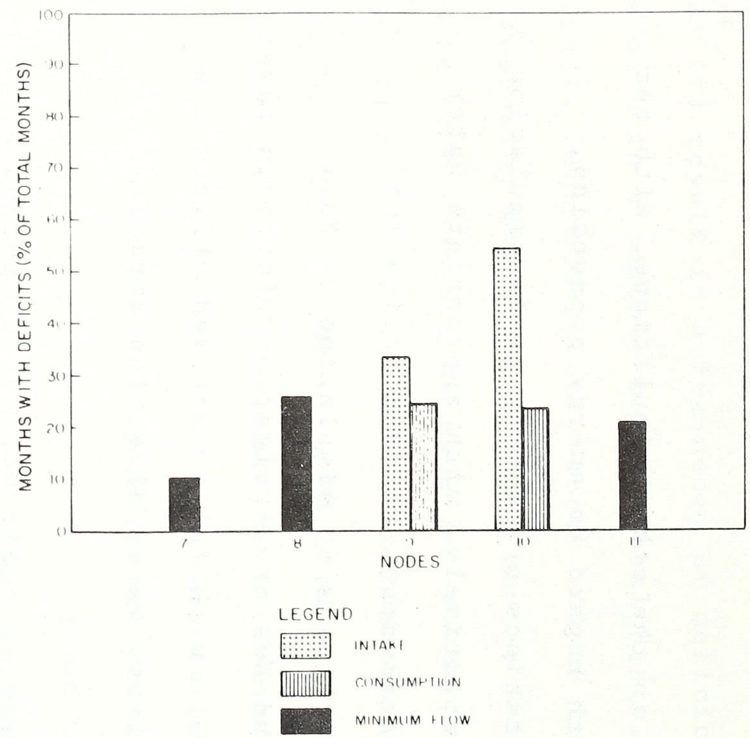

MINIMUM SURPLUS* (% OF AVAILABLE FLOW)

NODE	INTAKE S	INTAKE A	CONSUMPTION S	CONSUMPTION A	MINIMUM FLOW S	MINIMUM FLOW A
7	89	88	97	97	D	D
8	74	79	81	86	D	D
9	90	84	97	95	N	N
10	D	D	23	25	N	N
11	94	96	97	98	D	D

S = SEASONAL (MAY-SEPT.)
D = DEFICIT
A = ANNUAL
N = NOT APPLICABLE
* BASED ON THE YEAR WITH MINIMUM SUPPLY

DEFICITS AND MINIMUM SURPLUS

supply situation in the lower Red Deer (node 11).

Intakes above Drumheller (node 8) and in the Berry subbasin related to thermal power generation are unchanged from simulation 3. However, in the latter, reduced irrigation development reduces total intake. Intakes in the lower Red Deer (node 11) decrease sharply from simulation 3, as irrigation expansion here is now negligible. The same comments apply to water consumption. The net result is that the 1987 level of irrigation development, combined with higher return flows from the expanded Sheerness development, virtually eliminates summer water deficits in the Berry subbasin.

The imposition of minimum flow requirements for environmental and recreational purposes has a noticeable impact on the allocation of water resources in the basin. At Red Deer, Drumheller and Bindloss (nodes 7, 8 and 11), outflow deficits occur 10, 27 and 22% of the time respectively. The frequency of these deficits at Red Deer would probably be acceptible, particularly since some improvements , both here and downstream, could be achieved by modest adjustments to the assumed operations policy of the Dickson Dam. The frequency of deficits at Drumheller and Bindloss would probably prove unacceptible . However, these deficits are due to the levels of minimumun specified flows, and not to energy project impacts. The latter require only 10% of these flows. The minimum flow requirements exceed water availability on their own during low flow years. In environmental and recreational terms, the Ardley power station, by requiring transfer of flows to Buffalo Lake, will enhance recreation and the environment in that subbasin while reducing flows in the Red Deer River main stem.

5.8 Concluding Remarks

The analysis presented here was intended for demonstration purposes to illustrate the potential advantages of integrating water use forecasting with water supply considerations. The usefulness of such an approach is clear in that in this example the forecasts have been made functional in terms of water management decision-making. This stands in contrast to the projections which constitute the principal results of this research paper, and which require considerable further interpretation vis-a-vis water supply conditions.

The particular results for the particular basin examined are indicative rather than definitive, given that there is no consideration of the many alternative levels of development and other options such as diversions, increased storage or groundwater exploitation. As a demonstration of model capabilities and potential it has served to highlight some of the positive characteristics of the simulation model at its present stage of development. Any "conclusions" which are read into the results relate to this demonstration as an experiment in methodology, not as exhaustively researched implications for development of the Red Deer basin, which, of course, is primarily a provicial matter.

In the research context, it is necessary to recognize the current limitations of the model. The first limitation is the inability to simulate efficiently the effects of new storage reservoirs or of alternative reservoir operating policies. A second limitation of the model is the absence of a routine for estimation of groundwater use and availability. Groundwater withdrawals are substantial in some areas, and there are some indications of significant interaction between surface and groundwater sources. Some conceptual work has been done on groundwater methodology, but it remains to develop this into an adequate component of the model. This may, however, prove to be an extremely difficult task. Thirdly, more work is required in the municipal and industrial sectors to move away from sole reliance on the coefficients approach to projecting future water uses.

Another limitation of importance relates to the model's treatment of use priority. When a deficit is identified, there is no priority assigned to one sector over the other. In many cases, this approach will not be appropriate. For example, minimum flow requirements at international and interprovincial boundaries are usually given first priority to satisfy water apportionment agreements. An enhancement of the model in this regard, given its intended national perspective, is seen as important.

Several other items of work which would improve the model capabilities and accuracy have also been identified . The database in the model is now complete only for the South Saskatchewan basin. Currently, the database is being expanded to cover the entire Saskatchewan-Nelson basin, thus allowing for future analyses of almost any river basin in the southern half of the Canadian prairie region. Also, some of the techniques developed in the main part of this paper (e.g. the impact of conservation options, the implications of technological change) could readily be incorpoated into the simulation modelling context.

In conclusion, it is reasonably clear that water use studies in the future will derive their primary usefullness when used in conjunction with physical resource considerations. The model presented here is quite powerful for this integrative purpose. Further development is required in some essential areas. As development planning continues across the country, future applications of the model should serve to identify potential water supply constraints and feasible alternative development scenarios.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The principal conclusions of the study are drawn in this chapter. These conclusions relate to the quantitative findings of the research, conclusions about the sumulation modelling approach and a brief recapitulation of research limitations. Recommendations for further work will then be put forward.

6.1 Conclusions

6.1.1. National and Regional Water Use Forecasts

Forecasts of water use have been produced for Canada, its five major regions and 47 principal drainage areas, using a structural econometric approach. Five scenarios, denoting a wide range of future conditions have been analyzed with respect to their impacts of water use. The major variables included economic conditions, changes in production technology and changes on water use pactices. Table 6.1 presents the major forecasted results for Canada in terms of the reference case, with the other four scenarios denoted as deviations from the reference case.

Thermal electrric power generation accounted for the largest proportion of water intake throughout the forecasting period. There is a marked correlation between regional industrial structure and the magnitude of regional water use. Thus, Ontario, with the highest proportion of thermal power production, also dominated the water intake volumes. Similarly, the Prairie regions, with its large areas of irrigated agriculture, was dominant with respect to water consumption. Table 6.2 shows, for

Table 6.1 SUMMARY OF PRINCIPAL RESULTS

Region		Reference Case (MCM) 1981	2011	% Deviation from Reference Case by Scenario in 2011* 2	3	4	5
B.C.	Intake	3789	7085	-47	15	-23	14
	Consumption	487	893	-48	11	-23	17
Prairie	Intake	5363	11172	-40	24	-21	15
	Consumption	2339	4410	-49	7	-23	20
Ontario	Intake	21230	42861	-32	25	-21	13
	Consumption	589	1093	-43	13	-23	18
Quebec	Intake	4252	7629	-43	11	-21	17
	Consumption	435	690	-45	13	-18	17
Atlantic	Intake	2884	5584	-33	21	-18	6
	Consumption	139	244	-38	15	-17	8
CANADA	Intake	37518	74331	-36	22	-21	13
	Consumption	3906	7363	-47	10	-22	18

*Scenario 2 = conservation policy scenario;
Scenario 3 = technological change scenario;
Scenario 4 = low growth scenario;
Scenario 5 = high growth scenario.

TABLE 6.2 DOMINANT WATERSHEDS IN EACH REGION, 1981 (VOLUME IN MCM)

Region	Intake	Consumption
B.C.	Pacific Coast (2126) Fraser (952)	Fraser (219) Okanagan (146)
Prairie	N. Saskatchewan (1388) Bow (813)	Bow (483) Oldman (450)
Ontario	Lake Ontario (6946) Lake Huron (5300)	Lake Ontario (231) Lake St.Clair-Erie (218)
Quebec	St. Lawrence (3257) North Shore-Gaspe (435)	St. Lawrence (343) Ottawa (41)
Atlantic	Nova Scotia (1260) St.John-St.Croix (882)	St.John-St.Croix (54) Nova Scotio (35)

each region, the two dominant watersheds with respect to water intake and consumption.

Scenario 2 examined the effects of a conservationist management policy with regard to water use. The vehicle for accomplishing this examination was a set of water use coefficients modified from 1981 levels by an assumed set of water price elasticities, augmented with an extra allowance for non-price related measures. It was clear that these modified coefficients had a pronounced effect on water use, reducing both intake and consumption to below the results obtained using low economic growth forecasts.

Scenario 3, which examined the effects of trends in production technology indicated a trend towards increasing water use, over and above the effect of medium economic growth. The results showed that technological change acting by itself would bring forecasted water near to or above that obtained using the high growth rate set. This result was somewhat unexpected, being at variance with the results of other research. This matter has to be subjected to further investigations in the future.

Based upon all of the research taken together, the following Table 6.3 represents the ranges of water use which can be expected in the future.

TABLE 6.3 EXPECTED RANGES OF WATER USE, CANADA AND REGIONS 1981-2011

(MCM)

Region		Intake		Consumption	
		Low*	High**	Low*	High**
B.C.	1981	3789	3789	487	487
	1991	3950	5043	512	645
	2001	3989	6623	508	850
	2011	3726	8057	464	1046
Prairie	1981	5363	5363	2256	2256
	1991	6167	7569	2494	3172
	2001	6580	10158	2485	4227
	2011	6687	12895	2262	5318
Ontario	1981	21230	21230	589	589
	1991	23987	28355	711	776
	2001	26925	38146	649	1031
	2011	29235	48258	625	1291
Quebec	1981	4252	4252	435	435
	1991	4523	5514	428	525
	2001	4567	7184	417	661
	2011	4327	8901	380	804
Atlantic	1981	2884	2884	139	139
	1991	3222	3795	150	179
	2001	3529	4902	153	223
	2011	3764	5929	151	263
Canada	1981	37518	37518	3906	3906
	1991	41848	50275	4292	5298
	2001	45589	67011	4212	6990
	2011	47738	84039	3882	9025

*Scenario 2

**Scenario 5. Scenario 3 was not chosen here because of the doubt cast by the contradictory research findings.

6.1.2. <u>Simulation Modelling of Water Use</u>

An alternative approach using simulaution modelling at the river basin level was outlined, and found to be advantageous in a number of ways. First, it eliminates many of the problems and limitations associated with the regional input-output model,such as the lack of supply considerations and the structural model's inability to provide detail at the river basin level. In this manner, assessments can be made of future supply:demand imbalances and their severities assessed. Second, the model can be applied for the analysis of the water resources impacts of any conceivable future development scenario. Third, the temporal variations in irrigation water requirements are represented in the model; and by using historical surface water supply data, future water supply:use conditions are evaluated on a long term basis. Fourth, there are no restrictions in the model regarding the spatial detail of water use:supply comparison; thus it can be applied for the analysis of local problems or for overall evaluations of the water resources of a major river basin or a region. Fifth, the model provides an excellent tool to test the impacts of variables such as climatic changes, water pricing and other demand management alternatives, technological changes, etc. on future use:supply conditions.

6.1.3 <u>Limitations of the Study</u>

In Chapter 4 a number of limitations were suggested to this study, which are summarized here. First, the model used was unable to examine subregional areas, with the result that much local detail is lost. It is at the local level that problems such as water demand:supply imbalances are felt most directly. Second, there is no consideration of water supply in this project, with the result that water imbalance problems, current or potential, have not been dealt with. Third, due to the structure of the model used, each of the thirty sectors received equal attention, when, in fact, greater concentration on the larger water-using industries (e.g. agriculture) would have been warrented in some areas. Fourth, the model used is linear in nature, treating each region essentially in the same manner. This characteristic is a limitation since it fails to reflect real-world conditions. Lastly, the model was limited in the number of variables which could be considered.

With regard to the simulation model, at the present stage of development, the following limitations have been identified. First, it can only identify potentially water-short areas, and quantify the shortages. All water use sectors are given the same priority. The model does not have a mechanism for the analysis of conflict situations, reallocation of the water resources based on use priorities, etc. Second, the effects of new storage reservoirs cannot be simulated explicitly. Third, there is an over-reliance on the coefficients approach to projecting municipal and industrial water uses. Fourth, the current database in the model is limited to a partial coverage of the Prairie Region. Fifth, the model is limited to water quantity aspects. Finally, water supplies from groundwater sources and their interconnection with surface water sources are not built into the model. Current research suggests considerable interplay between surface is groundwater in influencing an area's water supply.

6.2 Recommendations

Based upon the limitations to the research carried out in this paper, a number of directions for improvement and future work can be suggested.

6.2.1. Integration of Water Use and Water Supply Studies

That some areas of Canada can be termed areas where water is in short supply, there can be little doubt. While this particular research report has not come to terms with this issue, the examination of water shortage situations is a primary goal of water use and demand forecasting. From a preliminary examination of water availability figures completed for the Inquiry, it seems that a number of areas, particularly in Western Canada, are ones of current or potential water shortage (Hess, 1985).

The real value of demand forecasting will be derived when demand and supply are integrated at levels effective in identifying and quantifying water imbalance problems. A practical methodology for achieving such an integration was suggested in Chapter 5, and it is recommended that such a methodology be refined and applied to major basins in Canada, beginning with those basins where water supply:demand problems are current or threatening or and later to the other major basins of the country Further. the development and improvement of the river basin simulation model should be given top priority in regard to water use and demand studies, and should be funded at a level higher than currently available.

6.2.2. Continued Development of Regional Water Use Modelling

The main research carried out here was concentrated on projecting water use in the major regions of Canada. A number of assessment, such as watching briefs on overall national water use, studies of future consumptive water use, and policy evaluations will continue to be based on such projections and modelling activities. It is recommended that development and application work on these aggregate models be continued.

6.2.3. Further Investigation of Conservation Measures

Scenario 2 demonstrated that significant reductions relative to other growth paths may be achieveable through improved water pricing practices and other conservation measures. The analysis here, however, was quite hypothetical, and relied upon a number of assumptions and secondary data sources. It is recommended that further research be carried out on this subject in order to investigate fully the impacts of conservation measures, not only on future water use but also upon the requirements for new water supply development initiatives.

6.2.4 Examination of Technological Change Impacts

The subject of technological change impacts on water use were examined in Scenario 3, with the indication that production technology was tending to lead to proportionately increased water use relative to current technologies. Since this finding is a variance with other research on the subject, as outlined in Chapter 4, it is recommended that further work be carried out in order to bring the technological change fully into the calculus of water demand forecasting.

6.2.5. Water Use Data

The undertaking of this project was due in part to the availability of reliable Canadian data on various aspects of water use. These data have been collected regularly over the past 10 years. It is recommended that such data collection efforts, which have been relatively inexpensive in resource terms, be continued, both to verify the accuracy of the forecasts and to provide data for improved forecasting efforts. Such data collection efforts should ensure that data are collated on a river basin basis in order to feed data to the simulation model being developed, as well as on the basis of political regions

6.2.6 Nonwithdrawal Water Uses

This report has considered only the major withdrawal uses of water. However, the nonwithdrawal water uses (e.g. recreation, wildlife, hydroelectric power, etc.), are a dimension of water use which have generally been underplayed, not only here but also in other studies. It is recommended that research be carried out to identify the most efficient method of incorporating nonwithdrawal water use considerations into investigations of future water demand. This work should be carried out in conjunction with the investigations recommended in Section 6.2.1.

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