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Irrigation water use in southern Ontario

Kenneth Iain MacDonald
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IRRIGATION WATER USE IN SOUTHERN ONTARIO

By

Kenneth Iain MacDonald

B.A., Wilfrid Laurier University, 1984.

THESIS

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ABSTRACT

The appreciation of water as a finite resource has engendered a renewed research interest in producing effective water management policies and practices in order to reduce both current and potential demands on existing reserves. Unfortunately, such research, especially in the humid regions of North America, has concentrated on water use in urban areas and has neglected the use of water in irrigation agriculture; even though irrigation is a major consumptive use of water in many localized areas. In addition, research has been dominated by physical, technological and economic viewpoints at the expense of an understanding of the human element in the management of irrigation water. This neglect results in the misinterpretation of current water use practices and inaccurate estimates of future demand. Potential consequences include the development of ill-devised water management policies, and recommendations of ineffective water management practices.

This study attempts to provide an understanding of existing irrigation management practices in southern Ontario. Specifically, 35 irrigating farms in three distinct counties were surveyed to determine the methods of securing a supply of irrigation water, delivering and applying water to fields, and the factors affecting the timing and amount of water applications. Bureaucratic regulation of water use is reviewed and found to be ineffective in controlling the use of water. Additionally, due to the proximity of water sources to the point of use, communal allocation and regulation of water use are not evident in southern Ontario. An examination of on-farm irrigation practices, including both the technical and cultural methods of irrigating, reveals a pattern of diversity and variation between farmers. This is related to the variety of circumstance within which farmers operate and the practically autonomous control over water exercised by each individual irrigator. According to yield maximizing criteria, the majority of surveyed farmers are found to be under-utilizing irrigation water in terms of seasonal need.

In practicing a form of survival irrigation, farmers deviate from scientific recommendations of optimal irrigation management practices. This is commonly explained in terms of irrationality due to a carelessness or lack of information on the part of the farmer. Conversely, this present study describes this dichotomy as one of differing objectives and characterizes existing practices as rational. In a system that is free from effective institutional constraints or controls over the delivery and use of water, farmers have the flexibility to adapt their irrigation practices to their individual operating circumstance. In doing so, they are guided by their unique experience and objectives as farmers. If they are to be effective, recommendations to improve irrigation practices and the formulation of improved water management policies, must take into account the variety of circumstance in localized areas and be based on an understanding of the rationale behind existing water use practices.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In recent years, the term water "crisis" has become increasingly prevalent in both the popular media and professional water management literature in both Canada and the United States. Several factors have brought this issue to the forefront of public attention. First is a growing realization that water is a finite resource both in terms of quantity and quality. This is in contrast to earlier attitudes which were common during the development of both nations – that Canada and the eastern United States were endowed with a superabundance of available water. Second has been the recognition that a steadily increasing population, combined with expanding industrial and agricultural activities are placing a great stress on existing water reserves in localized areas. These concerns have resulted in an increased research effort directed toward exposing the consequences of continued programs of extensive supply management, and have focused on means of reducing or managing the demand for water. However, such studies have typically focused on problems of use in urban areas and have tended to ignore the agricultural context of water use. This urban-dominated trend in research has been particularly evident in eastern Canada but has not gone totally un-noticed. Mitchell(1984), for example, noted that while water resource research has covered numerous aspects of municipal supply, interbasin transfers and demand management, research on various aspects of irrigation has been gravely neglected.

In one respect, this neglect of the agricultural situation is surprising, particularly in southern Ontario. It is certainly significant, for example, that of all the permits issued for water withdrawal by the provincial government, 67% were for irrigation purposes. This amounts to a total potential withdrawal of 5.7316 million cubic metres per day; a figure which is surpassed only by withdrawal for industrial purposes (Vallery 1987, personal communication). In addition, irrigation is essentially a consumptive use of water, meaning that little of what is withdrawn from the source is recoverable, but is consumed in the form of evaporation and transpiration or is incorporated in the final product. Conversely, urban and industrial uses, although withdrawing large amounts of water, are primarily non-consumptive. Much of what is withdrawn is returned to the source of supply, albeit seriously diminished in quality. One major exception would be the watering of lawns in urban areas. Thus, irrigation water use is an extremely important demand component in the overall framework of water management in Ontario. Indeed, Salbach and Dennis (1981) have noted that the majority of surface-water quantity problems in the province involve a stoppage or serious reduction in flow caused by the taking of water for irrigation purposes.

In other respects, the apparent research emphasis on urban water use is perhaps not difficult to understand. Urban areas tend to provide a relatively compact, homogeneous (or what is usually assumed to be homogeneous), population which can be readily studied. Although not always the greatest consumers of water, supply systems are commonly designed based upon the demands of urban users and, in turn, the "water crisis" is nominally perceived in terms of urban-industrial needs, large-scale transfer to drier regions and low-flow augmentation for polluted or recreational water ways. In terms of control, urban consumers are restricted in their use of water by the structural capacity of the supply system and do not have direct control over the source of supply. Rather, this is determined by the relevant water authorities. In addition, because of the nature of the supply and distribution network in urban areas, their exists a wealth of data with respect to water supply and use. This type of data, however exists at an aggregate level and tends to lend itself well to strict statistical analysis, as is evident in the majority of demand management literature.

In contrast, agricultural users tend to be spatially dispersed and, most notably in southern Ontario, develop their own water supplies, whether from a nearby stream, pond, or from the water table. The result is that the farmer has more direct control over the supply and use of water. These important points introduce an element of difficulty to the study of agricultural water use. The spatial distribution of agriculturalists does not allow the compact study group characteristic of urban areas. Additionally, as farmers commonly develop their own water supplies, they must be considered as individual water managers, comparable in status, though not in magnitude, to municipal water authorities. However, due to the individual nature of water development and supply in agricultural areas, there does not exist the quality and type of data that is available for urban areas. In any study proposing to examine agricultural water use, these situations convey the necessity of examination at the individual farm level, as this is the terminal unit of both supply and demand. They also point to the need to consider elements of behaviour and decision-making on the part of the individual farmer. This is in direct contrast to the majority of urban-based studies which tend to be dominated by models which aggregate the individual components of the system and by theories of economic controls, incentives and disincentives.

Another possible reason for the neglect of humid region irrigation water use studies is the general perception that irrigation is not "necessary" in these areas. Instead, there is a general tendency to associate irrigation only with arid regions where most agriculture could not exist without irrigation. Natural precipitation in humid regions is commonly considered to be adequate to meet the moisture requirements of most crops. Partly because of this attitude, the bulk of water use research as it relates to irrigation has traditionally concentrated on dry or water scarce regions. Hence when one begins to consider irrigation water use in a humid region such as southern Ontario, "It is not possible to draw extensively on research or experience" (Nonnecke 1981). This neglect is not only a hinderance to research, but also to the formulation of effective water management policy. In the face of a general ignorance of the human management of irrigation water and in the absence of any adequate descriptions of the conditions under which irrigation water use occurs in Ontario, there is a persistent danger that recommendations to improve water management policy or practice will be misled by the results of studies conducted in the traditionally arid or semi-arid regions of the continent.

Yet, as the present study shows, rather than emulate these dry-region studies, it is necessary to realize that there is an important divergence of concerns and conditions which exist where irrigation is practiced in a temperate humid climate.

In addition to this arid-region domination of irrigation research, most agricultural water use research — due in part to the priorities of research-funding agencies — is physically oriented, or focuses on aggregate and macro-processes while neglecting the crucial importance of the micro-behaviour of the resource user. This emphasis has tended to limit our knowledge of the behaviour of individual resource users and in particular their decision processes. Yet, more than 20 years ago, some writers were stressing the need to focus research efforts on the behaviour of water users and the many social restraints which influence the use of water in localized areas. White (1961) for example, stated that the formal strictures of political agencies, and societal attitudes and traditions are all factors which influence the use of water on the part of any individual and suggested that there is a benefit in acquiring information which allows us to understand how the customs and conditions of individuals and their communities or societal structure influence the use of resources such as water. In the ignorance of such knowledge, it can be expected that policies and programs designed to improve water management will be adopted without full appraisal of their consequences. The detrimental effects of ignoring such factors in the development of water projects and policies have been elucidated on by many researchers; especially in less-developed countries (excellent reviews are Widstrand 1978, Widstrand 1980).

In a similar vein, White, as chairman of the U.S. National Academy of Science Committee on Water (1966), produced, along with other members, the statement that:

> "there is little precise understanding of the circumstances in which people make their choices and of the factors that affect their decision to overirrigate their crop ... Because public policy often is based on a belief as to how such decisions are made, a better understanding of their determinants and rationale could assist in the formulation of sound policy."

The need for this user-based approach to research was also guided by a realization that the gap between scientific knowledge of "optimal" water management methods, and their applications by users such as farmers was widening rather than narrowing. The intervening years since this call for user-based research have not seen much improvement. Professional water managers, agro-scientists, and even social scientists seem largely to have ignored the reasons that farmers follow prevailing irrigation practices in Ontario. Yet, these are the same agents who are recommending improvements to water management policies and practices. These efforts have increasingly focused on physical inventories of existing reserves of water, and quantitative estimates of present and potential uses of existing supplies. This is all worthwhile and necessary research. However, the premise of this thesis is that physical inventories of water supply, use, and potential demand are not an adequate basis for establishing recommendations as to future water management policies, plans and practices. The way in which water is being used, the existing practices in local areas and the influence of the unique physical, institutional and socio-economic circumstance within which users live and operate must be understood as factors which act to create the overall demand for water, and will determine the success or failure of attempts to modify water use. Gaining an insight into the irrigation water management practices of farmers augments the physical inventories of existing reserves and quantitative estimates of present and potential uses of water, all of which are required for the effective formulation and implementation of practical water management policy and planning.

1.2 PURPOSE OF STUDY

The above discussion has identified several gaps in knowledge relevant to water management in Ontario. First is that irrigation water use has been a neglected subject of research. The primary purpose of this study, then, is to describe the nature of irrigation water use in southern Ontario. Specifically, the study examines the irrigation water management practices of a set of farmers and attempts to relate the circumstances which affect water use and variations in water use in a localized area. An underlying theme of the study is the divergence of concerns regarding water use between irrigators and both the water management bureaucracy and the agro-scientific community. This dissimilitude is observed as a function of the control over water exercised by each individual irrigator and the resulting objective rationality of their water management practices.

1.3 ORGANIZATION AND SUMMARY OF CHAPTERS

Essentially, there are four phases to the investigation. Following a description of the methodology in Chapter two, Chapter three outlines the physical and agricultural parameters of irrigation land-use in three counties of southern Ontario. The development of irrigation is initially related to widespread drought but subsequently maintained due to seasonal moisture deficiencies which are particularly detrimental on coarse-textured soils producing high-value crops. Irrigation was not intended as a means of settling marginal agricultural lands or creating a new type of agriculture but was essentially adopted to maintain the viability of an existing ;ricultural system.

Chapter four examines the institutional means of regulating irrigation water use in Ontario and how it affects or influences a farmers use of water. The discussion concludes that neither governmental nor communal institutions effectively control the flow of irrigation water nor do they have any practical means of enforcing the regulation of water use. A front of control and allocation is maintained through a system of formalized "paper" rights which have little influence on water use except as a dispute settlement mechanism. Quantitative inventories of water use, or projections of water demand, based on bureaucratic records are misleading and contribute to ill-devised water management plans and policies. With no effective bureaucratic or communal regulation of water use, expedient control of water is in the hands of each individual irrigator. As such, efforts to change the behaviour of farmers or develop water management plans for rural areas must be cognizant of existing patterns of resource use and base their plans on conditions of reality.

Chapter five presents the main findings of the field work and describes the methods of irrigation water use on a set of farms in three distinct political, physiographic and agricultural regions of southern Ontario. The chapter is composed of three primary sections. Section 5.1 discusses irrigation water supply in terms of the source of water used on the farm, the means utilized by farmers to attain a secure source of water supply and the adequacy of that supply for the purposes of irrigation. Section 5.2 discusses the technical methods of delivering and applying water to irrigated fields. Section 5.3 examines the cultural practices which affect the scheduling of irrigation applications. Diversity rather than similarity in the irrigation management practices of farmers is found to be prevalent. A distinction is made, however, between technical practices and cultural practices. Technical methods of managing water are dynamic over time and open to change where advanced technology offers a practical solution to problems encountered in irrigating. Cultural practices are, for the most part, static and have evolved through time and experience to relieve the farmer of the need to actually make decisions regarding the scheduling and application of irrigation water.

The fourth phase of the investigation, presented in Chapter six, suggests that there is a great discordance between actual water management practices and recommendations of optimal practices put forth by the technical agro-scientific community. This discordance is not so much related to a resistance to change on the part of the farmer as it is to a divergence of objectives between "experts" and farmers, the internalization of "expert" knowledge among professional agencies, and a general lack of communication between researchers and farmers.

The final chapter identifies the benefits of the study for water management in Ontario and defines the risks of ignoring the importance of local circumstance in a system where the irrigator exercises almost autonomous control over the use of water. The prevalent assumption that "experts" know what people want,or more specifically, what people need must be modified to include the farmer's knowledge of the physical environment and the rationale behind existing irrigation practices. By failing to recognize the opportunities and constraints unique to localized areas, "experts" typically fail to see the essential rationality of existing practices and misinterpret the actual benefits accruing from "optimal" water management practices. The chapter concludes with a discussion of the limitations of this study and suggestions for future research.

1.4 RELEVANT LITERATURE

Generally, most irrigation research can be separated into two perspectives. One is concerned with land-use as it relates to irrigation agriculture. In the case of geographical studies, there is a common focus on explaining the spatial distribution of irrigation agriculture and its relation to the physical and economic features of the agricultural landscape of any region (Bajwa 1983, Bowden 1965, Cantor 1970). In a slightly different vein, economic studies are commonly concerned with the production efficiency or allocative efficiency of water use in agriculture. These studies are typically critical of the subsidization of water for irrigated agriculture and compare the production value of water under a variety of uses (Easter 1980, Timmons 1983, Supalla 1981).

The second perspective is related to irrigation technology and is generally concerned with the question of the physical efficiency of irrigation equipment and distribution systems (Bos and Nugturen 1983, Cannell 1962, McKnight 1979, Wittwer 1979). This concern with physical efficiency has commonly neglected the individual farmer as the final resource manager and has discounted the importance of farmer behaviour as the primary element in determining efficiency. Exceptions to this technocratic view include studies by Weatherford et al.(1982) who suggested that the important issue in improving efficiency is not that technical aid or advice is available, but rather it is the discovery of appropriate inducements or incentives for incorporating this technical knowledge in the farming operation. Keller et al. (1980) added that it is necessary to understand the decision-making processes and knowledge level of farmers in order to define programs which will improve management decisions. These unique comments still contain an element of positivism in assuming that change is indeed needed or desirable, and is reliant on "expert" knowledge. In spite of the views of these authors, however, Coward Jr. (1980) has noted that, for the most part, irrigation management problems continue to be dealt with in a variety of ways. First and foremost has been an attempt to improve irrigation technology and engineering structures. Some attention has also been given to the influence of economic incentives such as water pricing in dealing with management problems (Apland et al. 1980, Ayers and Hoyt 1980, Easter 1980).

A number of authors, primarily anthropologists, have expressed concern with these dominant approaches to irrigation management problems.

Chambers (1980) stated that, to a remarkable degree, many writers on irrigation ignore and even appear unaware of the relationships between people and irrigation water. Attention is usually fixed on the hydrological, engineering, agricultural and economic aspects and there has been little research into the human side of the organization and operation of irrigation systems. Levine (1980) echoed this concern that our knowledge of the interrelationships between water and plant growth far exceeds our knowledge of the interrelations between water and the human element in delivery and utilization. Of necessity, as increasing demands are placed on diminishing supplies of available water, understanding the relations between people and water becomes a more and more vital priority (White 1961). In short, irrigation studies have tended to neglect the "human situation" and have primarily fallen within the domains of technology and economics. Typically, the literature pertaining to irrigation has not considered the role of the individual farmer as the final decision-maker controlling the use of water, nor the conditions within which that farmer operates. The early concerns of White (1961) that the conditions in which irrigators apply different amounts of water to their fields are largely unknown, remain true today.

It seems surprising that few geographers have addressed themselves to this problem, for it lies at the heart of what various authors have termed the man-land tradition of the discipline. Pattison (1964) stated that this tradition centres on resource use and conservation, while Guelke (1979) went further and suggested that one of the major goals of man-land relations is to understand how people of different circumstances and cultures have used the resources available to them. In a widely cited address, Barrows (1923) maintained that geographers have a responsibility to ask, and attempt to answer the question, "how does 'man' use the land and its resources and why does he use them as he does?" In recent years, several other geographers have echoed the need to study this interaction (Chorley and Kates 1969, Hart 1982, Morrill 1984). With respect to the use of water as a resource, it follows that geographers should consider the question -- how do humans use water and why do they use it as they do? The importance of such an understanding seems to be of little concern to many researchers, yet such an approach tends to fill a gap not often considered by economists, engineers, or agronomists. As Chorley and Kates (1969) have noted, there is strong evidence to suggest that the ways in which water resources receive technical appraisal rarely coincide with the appraisals of resource users and hence, research that seeks to characterize the environment as its inhabitants and exploiters see it provides valued insight for the understanding of resource use.

Therein lies the geographic justification for this study as it attempts to provide examples of the "real world" conditions under which irrigators use water in southern Ontario. In doing so, it is guided by the notable work of Hudson (1962) and Holmes (1986). Hudson examined irrigation water management practices and factors which influence water use in the Utah Valley of the western United States, and evaluated his findings in terms of the factors which hinder the adoption of efficient water management practices. His conclusions stress the influence of institutional controls on water use. Holmes (1986) discussed irrigation water management in the Chili basin of southern Peru and emphasized the lack of communication between government engineers and farmers as the most important factor blocking the adoption of "improved" water management practices. The present study compliments the approach established by these two authors by examining irrigation water use in a humid environment and isolating conditions which account for deviations between actual and "optimal" water management practices in an industrialized agricultural setting.

CHAPTER 2

METHODOLOGY: QUESTIONNAIRE DESIGN AND ADMINISTRATION

2.1 INTRODUCTION

As Hart (1982) has stated, a regional geography which considers resource use must begin with the visible features of the earth's surface, but quickly transcend them and attempt to understand the factors which motivate the human behavior that is related to them. This understanding can only be accomplished through talking to people and gaining an appreciation of what they think and an insight into why and how they do things. Much of the data required for the present study, then, is not readily available or documented in any form. Although a rough background picture of the shape or pattern of irrigation land and water use in Ontario can be painted using statistics and records of government agencies, any practical information relating to the actual use of water in agriculture must rely on consultation with individual farmers. These are the people who are effectively using and managing the resource and hence, any attempt at understanding that use and management must rely on information extracted from this valuable source.

Given this need to talk to people, the obvious method of acquiring data in relation to this study is through the use of a questionnaire. The benefits of using the questionnaire technique of data acquisition are many. These have often been expounded by researchers such as Whyte (1977) who noted that asking questions of people provides information that could not be systematically observed, such as questions about the past and future and questions on attitudes, feelings and beliefs. The "attitudes, feelings and beliefs" of irrigators are of particular interest to this study as they aid in the determination of how a user appraises the resource that he is employing. It has often been stated that the ways in which water and land resources receive technical appraisal rarely coincide with the appraisals of resource users (Chorley and Kates 1969, Weatherford et. al. 1982). Although the basis and assumptions utilized in technical appraisal are well known and commonly accepted, this cannot be said to be true for the converse case of user appraisal. Is it important to the farmer how someone unknown to him determines the adequacy of his water supply or is it his own definition that will determine his response to a condition of shortage? Is it important to the farmer how someone else believes he should use his water supply or will he decide this based upon his own objectives in using that supply?

The following pages will describe the design and formulation of the questionnaire (included as Appendix I), the method of sample selection, administration of the questionnaire and a discussion of the limitations of this form of data collection.

2.2 QUESTIONNAIRE DESIGN

The design of the questionnaire used in this study was based upon a number of precepts suggested by Saarinen (1977):

i) Whenever possible, questions should be taken from other studies to maximize comparison with previous works in other geographic areas.

ii) Open-ended questions should be used to allow the respondent to structure replies in his or her own words.

iii) The problem should not be mentioned until the researcher is ready to deal directly with those topics. This prevents one question from influencing the response to subsequent questions.

A list of questions to be used in this survey was generated from previous irrigation studies which dealt with water use at the individual farm level. These include a landmark study by Hudson (1962) which examined on and off-farm water management in the Utah Valley; Bowden (1965) who described the diffusion of pump irrigation in the high plains of Colorado; and Weatherford et. al. (1982) in a discussion of irrigation efficiency in the Tulare Basin of California. Unfortunately, questionnaires used in these studies were not included in the published reports, so questions could not be extracted for the direct comparison of results. Additionally, as is typical in irrigation research, these studies were concerned with conditions of arid and semi-arid regions where the agricultural practices and the nature of water supply, conveyance, distribution application and regulation differ markedly from humid areas such as southern Ontario. Nonetheless, the broad range of topics covered by these authors to account for variations in water use can be applied to irrigating farmers in southern Ontario when the conditions under which these farmers operate as opposed to arid or semi-arid regions are understood. These conditions are outlined in Table 2.1.

TABLE 2.1 Features of Humid vs. Arid Region Irrigation

VARIABLE	Conditions	
CLIMATE	Humid	Semi-Arid and Arid
CROPS	Primarily high-value crops	All crops

DIVERSION OF WATER	Individual	Co-operative, Company or District
POINT OF WATER SUPPLY	On-Farm	Spatially distant from farm
POINT OF USE	On-Farm	On-Farm
DELIVERY TO FARM	Natural Flow	Regulated or controlled flow through canals
SOURCE OF SUPPLY	Surface Water Ground Water Conjunctive	Surface Water Ground Water Conjunctive
TECHNIQUE OF APPLICATION	Primarily Various Forms of sprinklers	Primarily Surface Methods such as various forms of flooding
POLITICAL AND LEGAL NATURE OF WATER RIGHTS (ALLOCATION)	Riparian to transitional form of Riparian (eg. Equable)	Appropriation Various forms of prior appropriation

Based on these differences, questions made specific reference to the conditions that were applicable to Ontario.

2.2.1 Form of Questions

Most of the questions used in the survey were of the open-ended variety These were used to permit the respondents to formulate their own answers and to eliminate the research bias associated with pre-determined responses. Where alternatives were noted on the questionnaire, they were merely for the convenience of the interviewer and were not meant to be seen by the respondent. In all cases where alternatives were listed, an "other" category was included to capture any responses which the author may have overlooked. In all cases, although responses could not be recorded verbatim, specific comments that directly related to any particular question were recorded in full to be used in the analysis of the data. Closed questions, those with defined categories of response, were included only where specific answers could be given. Examples of these questions would include the amount of acreage owned, leased or irrigated and specific sources of water.

2.2.2 Arrangement of Questions

Questions in this survey were arranged according to guidelines recommended by a number of sources (eg. Converse and Presser 1986, Rarten 1966 and Young 1966). These guidelines suggest the following arrangement:

> i) Questions placed first on the questionnaire should be those that are the easiest to answer. Such factual questions make it possible for the respondent to participate early in the interview.
>
> ii) Questions that could possibly affect the answer to a later question should not be placed early in the questionnaire.
>
> iii) All questions pertaining to one subject should be grouped together.

Based on the information presented in the preceding pages the questionnaire was divided into nine sections most of which are inter-related but have been isolated for the sake of discussion. These nine sections are outlined and described below:

1) Background Information

2) Irrigation Organization

3) Response to Irrigation

4) Source and Use of Irrigation Water

5) Irrigation System

6) Irrigation Policy

7) Marketing of Crops

8) Future Plans

1) Background Information

Questions 1 and 2 determine the length of occupancy on the farm and the length of time that the farmer has been irrigating. Question 3 asks for the reasons for adopting irrigation. These questions can be used to determine whether the farmer had experience in farming prior to irrigating and whether that experience had any affect on his decision to irrigate. It might also determine whether later irrigators adopted the practice in response to conditions of environmental uncertainty or viewed the practice as a necessary production input. This could have implications for the amount of water used, depending on the rationale for irrigating. Questions 4, 5 and 6 relate to the physical features of the farm including the amount of land farmed, irrigated and owned or leased; the presence or absence of a windbreak on the farm and the type of soil on which the farm is located. These questions were asked to enable a comparison of farm size with the presence of irrigation on the farm and to relate irrigated acreage to the amount of water used in irrigation.

2) Irrigation Organization

Questions in this section relate to any organization of farmers in the study areas that have developed or cooperated in an attempt to reduce the initial cost of irrigation or secure a source of water supply for use in irrigation. These questions supplement other information used to describe the development of irrigation in the study area and are of particular interest as such organizations are found in many parts of the world where irrigation is practiced and have commonly evolved in response to a shortage or insecurity of water supply. They have also had a profound affect upon the manner in which irrigation water is allocated and the use of water on irrigating farms.

3) Irrigation Response

Questions in this section refer to changes in acreage under irrigation or the alteration of crops that have been irrigated. These questions were asked to determine whether the benefits of irrigation in the form of increased yields are responsible for an increase or decrease in the amount of irrigated acreage or whether other factors such as marketing agencies, contract agreements or labour availability affect the amount of land under irrigation. Questions such as these have implications for water use as the factors which control acreage will have differing affects on the amount of water used on any specific crop in any specific area.

4) Water Supply and Use

Questions in this section are related to a farmer's supply and use of water. In particular, questions 4 and 5 were left open to gain an understanding of how farmers in Ontario define efficiency in use and no definition of efficiency was supplied for them.

Responses to these questions on water supply and use can aid in satisfying a number of concerns of this study including:

i) determining whether the availability of water has an effect on the amount of water used;

ii) determining if farmers have experienced shortages of water, whether these shortages are infrequent or recurrent, perceived reasons for these shortages and whether these shortages are related to a specific source of supply (eg. surface water, groundwater etc.);

iii) determining how farmers define the adequacy of their supply and the response of farmers to frequent or infrequent shortages;

iv) how farmers define and perceive efficiency in their use of water and recognized opportunities for increasing efficiency or conservation of irrigation water; and

v) what indicators respondents use in timing their application of water.

In addition to the water supply questions outlined above, an irrigation application chart was completed with the respondent's assistance. Information on this chart yielded specific data regarding the following variables:

i) acreage of each specific crop irrigated (1987 figures);

ii) depth of water application for each crop;

iii) the number of applications for each crop per year. This data relied on the memory of each farmer and was supplied on the basis of the least number of applications he had experienced in any year, the maximum number of applications he had experienced in any year and the average number of times that he would expect to irrigate a specific crop during the growing season;

iv) primary dates of watering which were defined in terms of the period of greatest demand; and

v) capability of the irrigation system. This was defined in the respondent's terms and was usually stated in terms of time. For example, with my system, I can irrigate x acres to a depth of x inches in x hours. I usually irrigate for x hours per day so I can irrigate all of my crops in x days.

Data supplied through the analysis of these charts yields useful information that aids in the clarification of:

i) how farmers define their water requirements as opposed to water management agencies;

ii) the amount of water used per day of irrigation as opposed to the amount allocated by water management authorities;

iii) the most frequently irrigated crops and the amount of water applied to each crop; and

iv) the timing of water application compared with the most frequent periods of moisture deficit during the growing season.

5) Irrigation System

Questions dealing with irrigation systems dealt primarily with the method of water application, fixed and operational costs of the irrigation system and reasons for changing systems since irrigation was initiated. These questions were asked to determine:

i) whether the method of application has any effect on the amount of water used or the frequency of applications;

ii) why farmers have changed methods of application and whether these changes are related to a desire for increased efficiency in water use or other reasons such as cost of irrigating, labour availability or cropping patterns;

iii) the time and location of these changes could point the way toward problems in water use in future years.

6) Policy and Information

Questions in this section deal with a farmer's sources of information and knowledge of government programs or agencies dealing with various aspects of irrigation. Question 1 asks for a farmer's sources of information on any aspect of irrigation. If more than one source was mentioned, the respondent was asked to rank them in terms of most to least important. Questions 2 - 4 dealt with the farmer's knowledge and use of government programs that benefited irrigation agriculture, his perception of government support of irrigation, the need for support and what form it should take.

Responses to these questions can be analysed to determine:

i) the nature of a farmer's concerns about irrigation agriculture. For example, are they related primarily to equipment, water supply or water use;

ii) what support of irrigation can any of these sources provide to the farmer;

iii) what programs to aid the farmer with irrigation activities such as the development of supply, purchase of equipment, or increase in efficient use are available to the farmer. Are they being used. Presumably, if the farmer does not know of any programs or if he feels that government support of irrigation is less than adequate, he will not look to that source for information concerning irrigation;

iv) the mention of specific forms of support or reasons given for not desiring this support would also indicate concerns of the farmer. Are they related to water use and supply, education or research, or equipment and management systems.

Question 5 in this section deals primarily with water regulation or allocation under the Ontario Ministry of the Environment Permit to Take Water Program. Farmers were asked whether they had a permit or not and if so, how they calculated the amount of water to apply for. The first part of this question could be considered redundant as only a list of farmers who held permits was used for sample selection. However, due to the abundance of similar names in rural areas, this question provided a cross-check to ensure that the person contacted was actually the same person who was selected from the preliminary list. In only one case did this not turn out to be the case so that in the sample, there is actually one person who did not hold a Permit To Take Water. The second part of this question allows a comparison of water demanded under the program with water requirements calculated using data supplied on the irrigation application chart mentioned earlier.

This question also asked whether farmers thought that the permit was an effective method of managing irrigation water and what changes they felt should be made to the program. These questions were asked to determine the degree of compliance or non-compliance with permit requirements and to determine whether farmers were desirous of changes to this program.

7) Marketing of Crops

Questions asked in this section included whether the crop was intended for the fresh or proc ssed market, the distance to the immediate market, whether a contract with any processor or marketing agency existed and the reasons for following a specific cropping pattern. These questions inquire as to whether the market of a particular crop influences the amount of water used on that crop. For example, do vegetables or fruits that are grown for a fresh market receive more water than those grown for a processed market? Does a contract or guaranteed market result in a higher or lower use of water on a particular crop and does this arrangement influence the type or variety of crop being grown? Similarly, responses to these questions can help to determine whether a contract with a specific market or processing plant has any localized affect on the demand for irrigation water. For example, do localized colonies of irrigators appear to be related to the capability to market a specific crop in the local area? These suggestions would appear to be inter-related with the farmer's decision to grow any particular irrigated crop. Are these decisions related to a best return situation, the provision of a stable market through contractual agreements, the optimization of labour and other resources, or is this decision based on other factors altogether? These decisions may have implications for water use in irrigation in that if any of these conditions change, can we expect a consequent change in the amount of water demanded for irrigation. For example, if there is a decline in price of an irrigated crop, if a farmer closes a contract, or if a packer or processing plant closes, can we expect a reduction in the amount of land demanding water for irrigation or do other factors affect the decision to grow a particularly irrigable or high-value crop?

8) Future Plans

In this section, two questions were asked of the farmers interviewed; these being whether they planned to alter their acreage or irrigation system and whether they had any foreseeable plans to switch crops. Responses to these questions might indicate trends in these specific farms toward more or less land under irrigation or a maintenance of the status quo. Reasons given for these changes might also indicate the importance of irrigation to the farm or farmer rather than to a specific crop or vice versa.

2.3 GENERATING THE SAMPLE UNIVERSE

Two problems were encountered in selecting a sample to interview for the purposes of this study. First was the generation of a list from which to select a sample and second was ensuring that the sample selected for study would be sufficiently diverse to reflect any conditions that might influence or account for variations in the use of irrigation water over space. These questions will be dealt with in more detail herein.

Generating a sample universe when one is considering any specific agricultural practice is a particularly difficult task. Typical sample selection such as random extraction from telephone books or the use of an opportunity sample cannot be employed without considerable expenditure of time and money. Fortunately, early in the preliminary research for this thesis, it was discovered that anyone withdrawing more than 50,000 litres of water per day from any source in Ontario required a permit to do so from the provincial Ministry of the Environment. Recognizing that this would include withdrawal for the purpose of irrigation, officials of this agency were contacted and permission granted to examine these permits.

The permits issued for individuals included the following information:

i) Name and address (lot and concession)

ii) Purpose of withdrawal

iii) Source of water

iv) Gallons per minute withdrawn from source

v) Hours of withdrawal per day

vi) Days of withdrawal per year.

A sample permit is included as Appendix II. In total, three Ministry of the Environment regional offices (Toronto, Hamilton and London) were visited and data collected for 35 counties in southern Ontario. Only permits issued for the purpose of irrigation were considered, however in some cases the irrigation of golf courses or turf and lawns may have been included when the exact nature of the enterprise was not clear from data contained on the permit.

On quite a number of permits, specific data were missing, particularly hours of operation, gallons per minute, the number of days of withdrawal and in some cases, the permitted amount. However, using the data available a determination was made of the number of irrigators per county, percentage, source of supply per county and the total potential withdrawal per day in each of the counties listed. Complete analysis of this data was prohibited by time constraints and would not necessarily have been reflective of actual conditions due to the limitations of this data source discussed later in this section. Use of the location data recorded from the permits allowed the compilation of a "master list" of irrigators in south-central and south-western Ontario. This list was later used to facilitate the selection of the sample population used in this study.

2.4 SELECTION OF THE SAMPLE AREA

Weatherford et. al. (1982) suggested that in selecting a sample area, an effort should be made to include areas which vary in age and size, in source of water supply, size of farms, capitalization, soil types, distributional systems, crops and location. These guidelines were developed for studies of irrigation water use in arid environments but are just as applicable to humid areas where geographic variation in patterns of use is important. Although the permit data did not include physical or agricultural data such as soils or irrigated crops, it did provide an estimate of the intensity of irrigation and the source of supply in each of the counties examined. Based on this data and agricultural and physiographic data, three counties were selected for closer examination in this study. It was assumed that the variation in distance and physiographic conditions would be sufficient to produce a significantly different sample population and eliminate any bias of homogeneity. As Lounsbury and Aldrich (1986) have suggested,

> "the researcher must bear in mind that the primary objective of geographical fieldwork is to collect data pertinent to the problem and not to create a complex and theoretical sample design."

The counties selected are described in some detail later in the thesis and are illustrated in Figure 2.1. They are Kent County, Simcoe County, and the Regional Municipality of Haldimand-Norfolk; formerly the separate counties of Haldimand and Norfolk. As the majority of irrigation occurring in the Regional Municipality of Haldimand-Norfolk is located in the former county of Norfolk, it was decided to concentrate on this area and not include the former county of Haldimand in the analysis.

2.5 SELECTION OF THE SAMPLE

The selection of the sample population to be interviewed was completed using a stratified random sampling technique. The lists of irrigators for each of the three counties were organized by township. All pertinent data had been hand-recorded on separate sheets of paper. Two pages were selected at random from each of these townships and depending on the number of names per page, a standard interval was assigned for selecting potential candidates. For example, if there were nine names on one page, the third, sixth and ninth names were selected. A provisional list of 20 names were selected for each county. It was desired to interview 15 farmers in each county. This was not to guarantee the representativeness of the sample, indeed, the sample is not

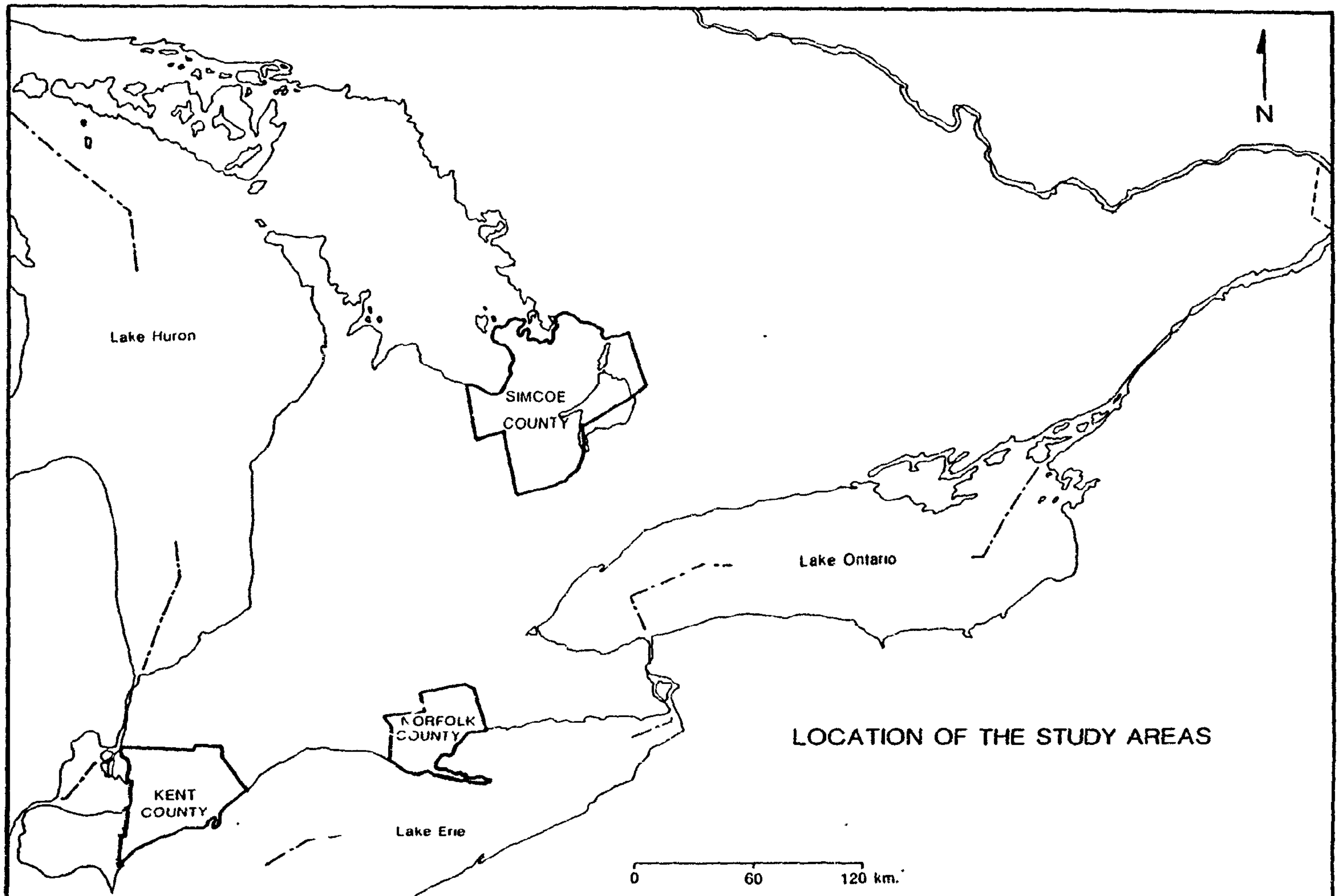

N
Lake Huron
SIMCOE COUNTY
Lake Ontario
NORFOLK COUNTY
KENT COUNTY
Lake Erie
LOCATION OF THE STUDY AREAS
0 60 120 km.

FIGURE 2.1

presented as representative. It is the individual worth of each sample that is of import to this study and projections based on this sample cannot be considered as concrete. The sample size is actually quite small and the study must be considered as exploratory and the analysis as descriptive.

Lot and concession locations were recorded for each selection and the closest town to each sample location was recorded. Telephone directories for each area were then consulted and the accordant telephone number for each selection was noted. Often times, a particular name could not be matched with a number in the directory and the process of selection was repeated.

Potential respondents were subsequently contacted by telephone, informed of the nature of the study, the length of time that an interview was likely to consume and their participation requested. Response to this technique was generally favourable and Table 2.2 lists the response figures for each county. The average response rate for all three counties was 68% of the potential candidates. This breaks down to 64%, 75% and 68% respectively for Norfolk, Kent and Simcoe counties. It should be noted that the number of respondents interviewed was actually less than the number consenting to an interview due to the absence of these respondents from their homes at the agreed upon time of the interview. This is likely due to unforeseen circumstances on the part of the respondent and does not necessarily reflect an unwillingness to comply.

TABLE 2.2 RESPONSE TO THE SURVEY QUESTIONNAIRE

	KENT COUNTY	SIMCOE COUNTY	NORFOLK COUNTY
No. of Calls Made	19	34	45
No. Contacted	19 (100%)	29 (100%)	33 (100%)
No. Consenting to an Interview	12 (63%)	15 (51.7%)	16 (48.5%)
No. Interviewed	9 (75%)	12 (80.0%)	14 (87.5%)
No. Not Home at Scheduled Time	3	2	2
REASONS FOR REFUSAL			
a) Too Busy	4	6	7
b) Do Not Irrigate	3	6	2
c) No Longer Farm	0	2	6
d) Not Interested	0	2	2
Response Rate*	75%	68%	64%

*Note: Total response rates for each county were calculated as:

$$R\% = \frac{C.I.}{P.I.C.} \times 100$$

Where C.I. = No. of people consenting to an interview

P.I.C. = Potential interview candidates defined by their ability to respond (ie. persons no longer farming would not be considered as a potential interview candidate).

Although the response rates are high when compared to the normal response of 30% to 40% for mail questionnaires (Lounsbury and Aldrich 1986), they do seem low for the personal interview technique. This could be the result of two factors. First the respondent had the opportunity to refuse over the phone without having met the interviewer and secondly, the timing of the survey was poor. In the case of this study, the second condition would prove to be most likely. Late May and early June are particularly busy times for farmers in southern Ontario as they are involved in land preparation and spring planting activities. This is reflected in the number of persons contacted who suggested that they were "too busy" to take part in the survey. Outright refusals however, were minimal and the most common reasons for not taking part in the survey were that persons had discontinued farming or were no longer irrigating. These two factors provide a warning for interpreting the permit program as a definitive data source. Permits need only be renewed every five years for a surface water source of supply and every ten years for a groundwater source. Obviously much can happen to change a farmer's need for and use of water within those time periods and thus the permit does not necessarily reflect current water use practices. With this in mind any references to data from the permit program used throughout this thesis should be viewed and treated with caution.

2.6 ADMINISTRATION OF THE QUESTIONNAIRE

All interviews were conducted in the home or on the farm of the respondents at an agreed-upon time and date. The time to complete the interview averaged between 45 minutes to one hour, although some were completed in as little as 25 minutes and others over 90 minutes. These time frames generally reflected the interest of the respondents in this study. In general, the shorter the interview, the more "no comment", "don't know" or "couldn't say" responses. Conversely, the longer interviews reflected the specificity of response, although in some cases, this was evidence of the interview "getting off- track". When this occurred, an attempt was made to bring the conversation back to the specific concerns of the survey.

In this vein, it is of some note that interviews often took the form of general discussion and in the course of that discussion, respondents provided the answers to a number of questions without those questions having been asked. This was the most agreeable form of interview both for the researcher and apparently for the respondent.

Respondents typically seemed "more at ease" when the interview discourse took the form of "just another chat". Young (1966) noted the benefits of these "free-flowing accounts" where respondents might suggest explanations of their behaviour which may account for their motivation and actions and provide new insights not afforded by other explanatory techniques. Many of the ideas and suggestions contained in this thesis are a direct result of these "explanations".

Although the personal interview particularly in rural areas, is costly both financially and in terms of travel time, it proved in this case to be the most effective means of obtaining information, both quantitatively and qualitatively. Lounsbury and Aldrich (1986) have noted the benefits of the personal interview technique as:

i) the ability to clarify ambiguous answers while in the presence of the respondent.

ii) allowing the interviewer to control the question sequence and probe for additional details.

iii) the personal interview is not as dependant on the educational and literary level of the respondents as other methods.

2.7 PROBLEMS AND BIAS IN THE DATA BASE

This particular study could be considered to have a biased sample due to the methods used in generating a sample "universe" and in sample selection. Although all irrigating farmers are required to have a permit to take water, in all likelihood, this is not the case. Indeed, it is estimated that the program captures only 66-75% of all major agricultural water users (Vallery, personal communication 1987). To confirm this, a brief survey was conducted in a small portion of one of the study areas. In this area, a road follows the route of the source of water, in this case a drainage canal, and the irrigated properties are visible from the road. Pumps are located close to the road and lines are run underneath the road to siphon water from the canal. A traverse was conducted along this road and the number of pumps recorded. Only one pump for each individual property was counted, and each individual property was designated as such by the presence of a house adjacent to the road. It was found that 41 pumps were taking water from this particular source while only 18 permits to take water from this source were uncovered in government files. This isolated reconnaissance would suggest that less than 50% of the withdrawals from this source are permitted.

These examples indicate that the data used to generate samples for this study does not include all of the potential sample population. This problem might have been remedied by obtaining lists of growers of commonly irrigated crops from marketing agencies. It was assumed, however, that the time expended in generating these lists would not necessarily have provided a more detailed or representative inventory. To quote Lounsbury and Aldrich (1986) once again,

> "all geographic field research problems are sample studies in the sense that it is not possible to obtain information for the entire spectrum of a given area, no matter how small... any given research area is a portion of a larger area, and even if all the data in a research area were obtained, they would represent only a sample of a larger universe."

Bias is also evident in the selection of case studies. Farmers were chosen on the basis of their willingness to cooperate with the project. After the initial random selection of candidates, the list was not subdivided any further. If the first five and last five names on the list consented to an interview and those in between did not, then those 10 consenting were interviewed; although they were not necessarily representative of all those potential respondents on the list. No matter how one attempts to avoid it, some bias is inevitable, and time the limiting constraint.

2.8 COMMENTS ON THE METHODOLOGY

Although the 35 cases are an extremely small proportion of the total number of irrigating farms in Ontario, each can be considered as a specimen farm with some conditions peculiar to that farm and some conditions or operating practices that would be held in common with other farms. Given the range of crops grown, farm sizes and personalities of farmers interviewed for this study it seems improbable that a truly representative sample could ever have been obtained.

Reasons for a low response rate for this sample have already been cited, but the matter of timing deserved further comment. Given that the survey was conducted at a busy time of year for farmers, initial contact was often difficult to make and many repeated calls were necessary. The most successful times for contact were, perhaps predictably, during the early afternoon (12:00-2:00 p.m.) and the early evening (6:00-9:00 p.m.).

On a broader scale although the sample size was limited by the activity of the potential candidates it is suggested that the time span of the survey may actually have enhanced the knowledge level of respondents. At this time of year many of the farmers were beginning to think about a new growing season, of which irrigation is an important component. In fact, owing to a particularly dry spring, a few of the respondents had already used their irrigation equipment. It seems logical to assume that answers to questions relating to a particular practice would contain a higher degree of accuracy when that practice is being used or thought about, than at a time when it is far from mind.

CHAPTER 3

THE DEVELOPMENT OF IRRIGATION AGRICULTURE IN ONTARIO

Although this study is primarily concerned with the water use practices on individual irrigating farms, the current pattern of water use in any area cannot be understood in isolation from the pre-conditions which have created the "need" to irrigate, and influenced the spatial and temporal pattern of irrigation agriculture. This chapter serves as an introduction to the study areas mentioned in Chapter 2 and provides a basic geographical foundation for understanding the water management practices described in later chapters. Discussion is organized in a progressively focused order; beginning with a general description of the evolution of irrigation agriculture in Ontario; proceeding to a consideration of the physical and climatic parameters of each of the sample counties; and ending with a description of the land-use characteristics of the surveyed farms.

3.1 BACKGROUND

The practice of supplemental irrigation is a relatively recent addition to the agricultural landscape in southern Ontario; having first appeared in the early 1900's. The subsequent pattern of adoption exhibits the classic sigmoidal form common to most technolcgical innovations in agriculture. Although no official statistics were recorded prior to 1950, an early study by Roger (1920) estimated that no more than 20-30 hectares of arable land were under irrigation in 1920. Roger (1920) suggested that whereas early market garden farmers had sought out heavier soils adjacent to urban areas because of their ability to retain moisture, later entrants to the commercial garden business were forced onto more distant marginal soils because of the price of , and intense competition for, garden land near the cities. These growers, Roger suggests, saw the benefits of irrigation in combatting the poor moisture retention characteristics of sandier soils and producing a marketable crop early in the growing season. Thus, they were assured of a premium price for their produce which tended to ameliorate any of the disadvantages associated with a greater distance from the main market.

The adoption of irrigation increased slowly over the next 30 years and by 1950 almost 500 farmers were irrigating 2063 ha. of land (Table 3.1). Even though some irrigation was present in most of the counties of southwestern Ontario by this time, expansion of the practice was primarily concentrated around the "golden horseshoe"— those rapidly urbanizing counties surrounding the western tip of Lake Ontario — and Essex County, the southwestern most point of the province(Figure 3.1). Unfortunately, specific irrigated crops were not identified in the 1950 census of agriculture. It can be assumed, however, that irrigation was still largely confined to high-value market garden vegetable and fruit crops. Although the growth of irrigated land between 1930 and 1950 represented a relative increase of 4900%, the following ten years saw a remarkable increase to 32,645 ha. of cropland and over 3000 irrigating farms.

TABLE 3.1

IRRIGATED LAND IN ONTARIO
1950 - 1981

Year	Total Improved Land (ha.)	Irrigated Land (ha.)	Percentage of Land Irrigated	Total Number of Farms	Number of Irrigating Farms	Percentage of Farms Irrigating
1950	5,136,887.9	2,053.82	0.04	149,920	488	0.33
1961	4,869,657.6	32,645.49	0.67	121,333	3,114	2.57
1971	4,396,843.8	40,255.77	0.92	94,722	3,880	4.09
1981*	4,518,552	32,127.48	0.71	82,448	2,638	3.20

*note the 1981 Census of agriculture asked only for acreage under sprinkler irrigation. Although this may have been meant to exclude flood or furrow irrigation techniques, it is possible that respondents interpreted this question to exclude volume guns and centre pivot techniques of irrigation. Such an assumption would seem to be supported by the survey carried out for the purposes of this investigation. Respondents made a clear distinction between sprinkler, gun and centre pivot systems. Thus, the 1981 Census results should not be considered as accurate in terms of irrigated acreage and should be treated with caution.

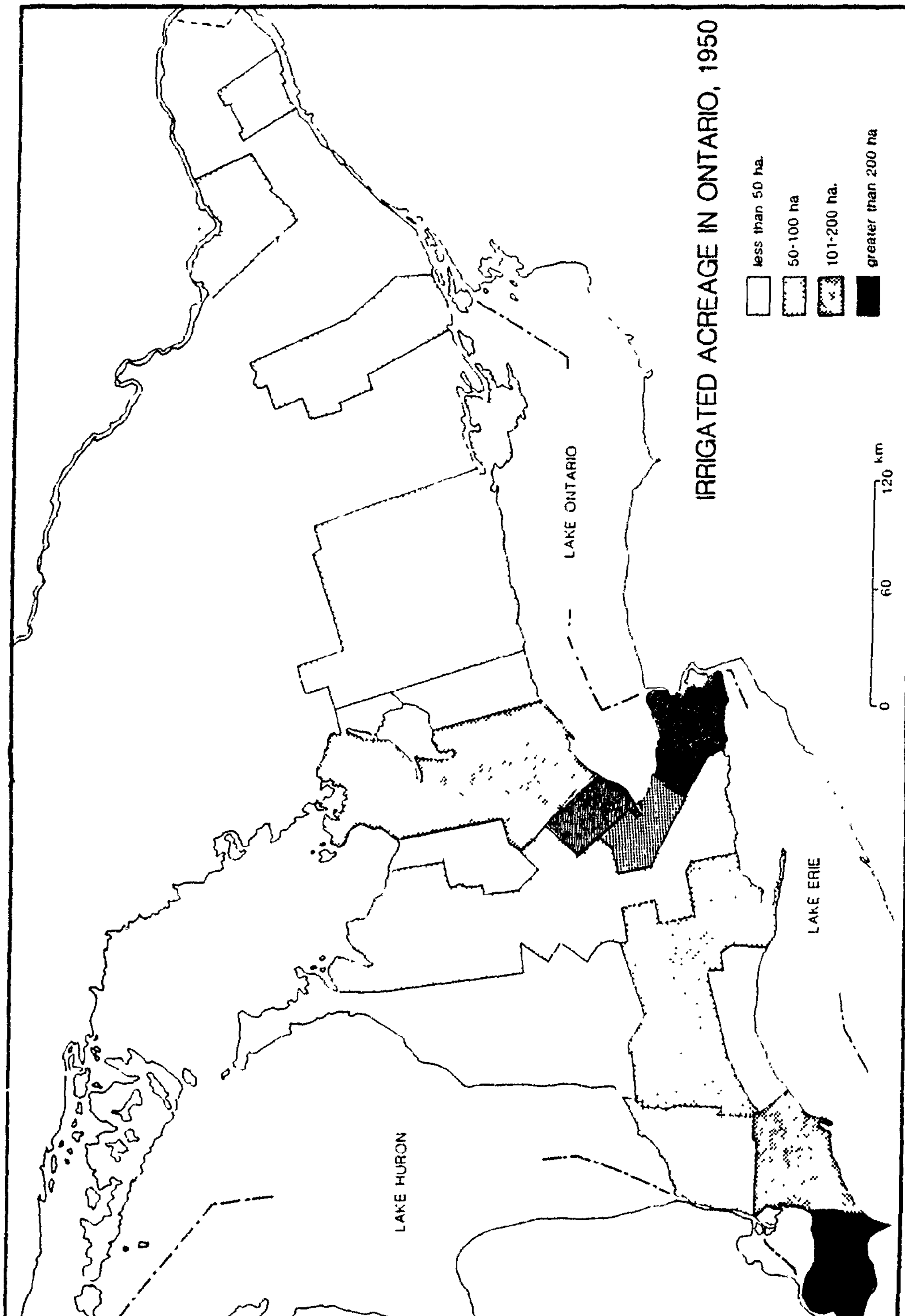

IRRIGATED ACREAGE IN ONTARIO, 1950
less than 50 ha.
50-100 ha
101-200 ha.
greater than 200 ha
0
60
120 km
LAKE ONTARIO
LAKE ERIE
LAKE HURON

FIGURE 3.1

Although this increase is significant, it is important to note that irrigation was not, and is not, a widespread practice among Ontario farmers. In 1960, irrigated land represented only 0.67% of the improved land in the province and 2.6% of the total number of farms. Even at its peak in 1970, less than 1% of the cultivated land in the province was irrigated on less than 5% of the farms.

The decade between 1950 and 1960 saw most counties in Ontario experience a notable growth in irrigated acreage(Figure 3.2). The most significant increase during this period occurred in the tobacco belt of southwestern Ontario, and in particular, Norfolk County. By 1960, over 30% of Ontario tobacco growers were irrigating 25,000 ha. of land or almost 50% of all land under tobacco (Table 3.3). Several inter-related reasons have been put forth for the expansion of irrigation during the 1950's. Perhaps the most important was a series of particularly dry growing seasons during the first half of the decade. During the growing seasons of 1952 through 1955, precipitation was as much as 40-50% below monthly means in some areas (Hore and Underwood 1957). Concern over the effects of these drought years was frequently expressed in farm periodicals of the day with headlines such as: "With Profits Being Cut in Times of Drought, More Farmers are Turning to Supplemental Irrigation" (Western Ontario Ledger 1953), promoting the benefits of irrigation. Aperiodic droughts are not uncommon in Ontario however, and particularly dry years had been experienced in 1933, 1941 and 1946 prior to the dry growing seasons of the 1950's. Why then had irrigation not been adopted earlier? Irwin (1969) attributes this to the availability of equipment, or more precisely the lack of equipment.

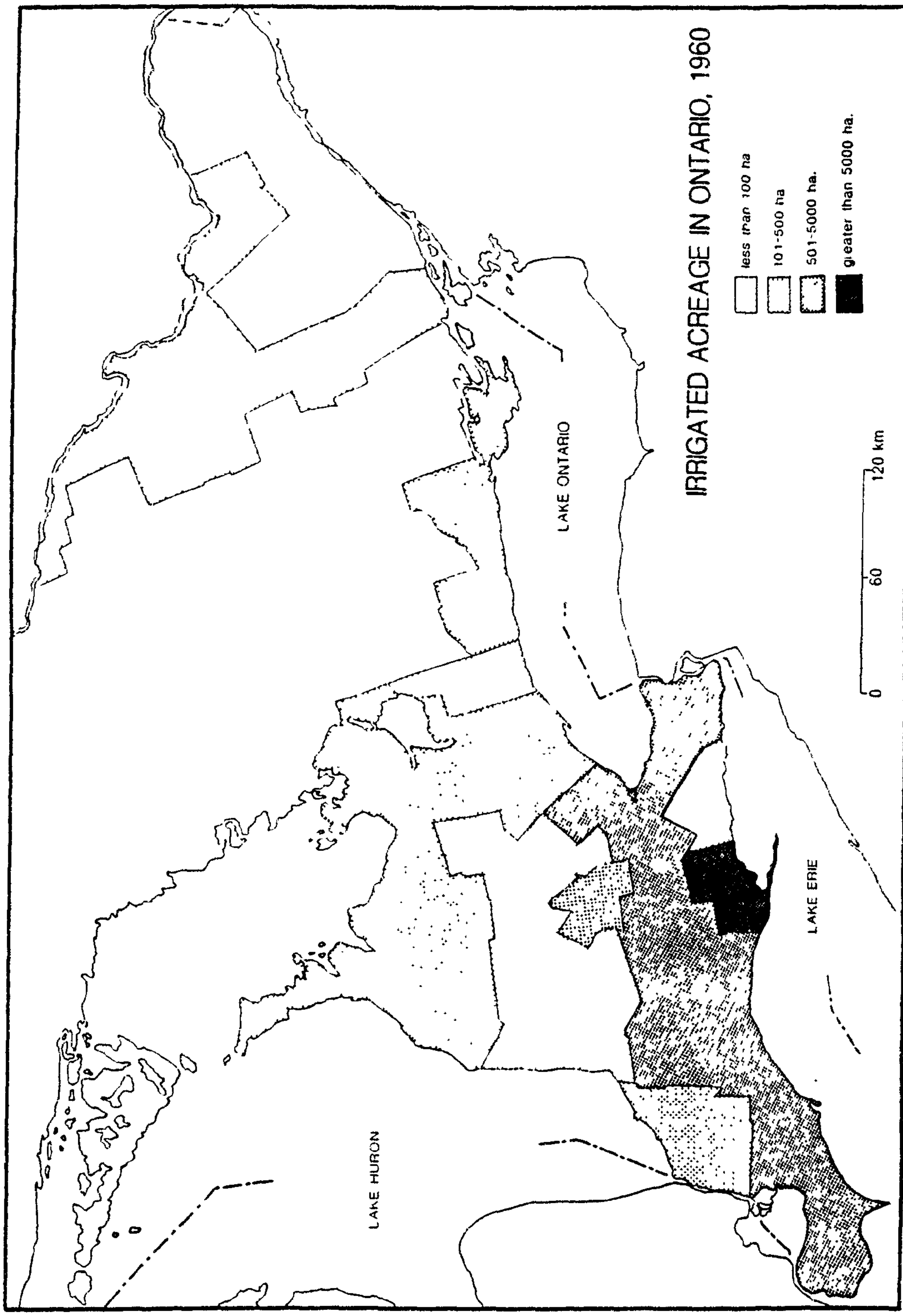

IRRIGATED ACREAGE IN ONTARIO, 1960
less than 100 ha
101-500 ha
501-5000 ha.
greater than 5000 ha.
LAKE HURON
LAKE ERIE
LAKE ONTARIO
0
60
120 km

FIGURE 3.2

TABLE 3.2

IRRIGATED CROPS IN ONTARIO,
1960 and 1970

Crops	1960 Number of Irrigating Farms	1960 Total Number of Farms	1960 % of Irrigating Farms	1960 ha. Irrigated	1960 Total ha.	1960 % ha. Irrigated	1970 Number of Irrigating Farms	1970 Total Number of Farms	1970 % of Irrigating Farms	1970 ha. Irrigated	1970 Total ha.	1970 % ha. Irrigated
Wheat	4	36,699	0.01	14.2	235,281	0.006	16	15,725	0.1	73.7	143,998	0.05
Oats	7	73,184	0.009	36.8	725,983	0.005	80	27,788	0.3	757.2	247,617	0.3
Barley	2	7,164	0.03	6.9	31,523	0.02	17	13,829	0.12	161.5	156,071	0.1
Tame Hay	32	91,079	0.04	278.0	1,327,977	0.02	93	61,409	0.15	1,635.4	1,095,512	0.15
Sugar Beets	17	990	1.7	108.5	6,791.6	1.6	--	---	---	---	---	--
Potatoes	286	34,627	0.83	1,533.8	20,826	7.4	262	2,309	11.3	1,755.2	16,210	10.8
Tobacco	1,889	5,692	33.2	25,004.9	52,049	48.0	2,206	3,814	57.8	25,667.8	35,295	72.7
Small Fruits*	300	9,008	3.3	427.0	11,821	3.6	387	1,787	21.7	714.3	1,478.4	48.3
Tree Fruits	210	8,022	2.6	1,187.8	27,814	4.3	242	4,884	5.0	1,356.1	25,437	5.3
Vege-tables	1,270	10,629	11.5	3,148.1	44,781	7.0	872	7,947	11.0	4,354.5	51,189	8.5

*Small fruits 1970 includes only strawberries

Aluminum metal was extremely expensive prior to 1945 and most crops were irrigated by hand or with discarded fire hose. However, with the availability of relatively inexpensive light weight aluminum tubing and high pressure pumps after World War II, sprinkler irrigation became more feasible and profitable. Additionally, it is not without note that supplemental irrigation gained an earlier foothold on farms in the northeastern United States. By 1949, almost 8,000 ha. were under irrigation in New York (Allee 1961), and an additional 5700 ha. in Michigan (Bajwa 1983). Early equipment dealers in these two areas apparently saw Ontario as a potentially lucrative market and established dealerships in Leamington and Grimsby in 1946. By 1955, a large number of Canadian manufacturers and distributors of American equipment had entered the market and were primarily concentrated in the tobacco belt of southwestern Ontario (Irwin 1969).

An additional factor which provided an incentive to irrigate during the dry years of the early 1950's was the favourable prices being received for fruits, vegetables and tobacco, relative to other crops. With the growth of urban areas during the first half of this century, the demand for fruits and vegetables was steadily increasing and the rapid development of the processing industry following WWII provided an extended market for producers. In addition, the increased demand for cigarettes following WWI continued into the 1950's and 1960's, providing growers with the highest per hectare value of any crop in Ontario (Spelt 1967). Thus, the decade of the 1950's combined several ingredients which triggered the rapid development of irrigation agriculture in southern Ontario — an extended period of below normal precipitation, the recent development and availability of technology and a favourable agricultural economy in which the price of production inputs was relatively low compared to returns.

The period between 1960 and 1970 saw a deceleration in the adoption of irrigation. An additional 7600 ha. was added to the irrigated land base by 760 farmers(Figure 3.3). Tobacco and vegetables (including potatoes) still comprised the greater part of this land but a noticeable increase occurred in the irrigation of grain and forage crops in eastern Ontario. The reason for this growth is not immediately clear but is likely partially attributable to a transfer of knowledge from the province of Quebec, where 73% (27,416 ha.) of the total irrigated area was under forage crops as of 1971. (The question of why so many more farmers in Quebec irrigate forage crops than do in Ontario presents an interesting problem for agricultural geographers.) A significant increase of 70% of the irrigated area of strawberries also occurred between 1960-1970. This was likely due to the adoption of irrigation as a frost prevention technique and the advent of "Pick-Your-Own" enterprises.

According to official statistics, the absolute irrigated area and the number of farms practicing irrigation decreased between 1970 and 1980(Figure 3.4).This is likely true, but must be interpreted with caution as per the note following Table 3.1. Absolute acreage and the number of irrigators both declined to levels below those reported for 1961. Although the 1961 census of agriculture did not ask for the irrigated area of individual crops, most of the decline seems to have occurred

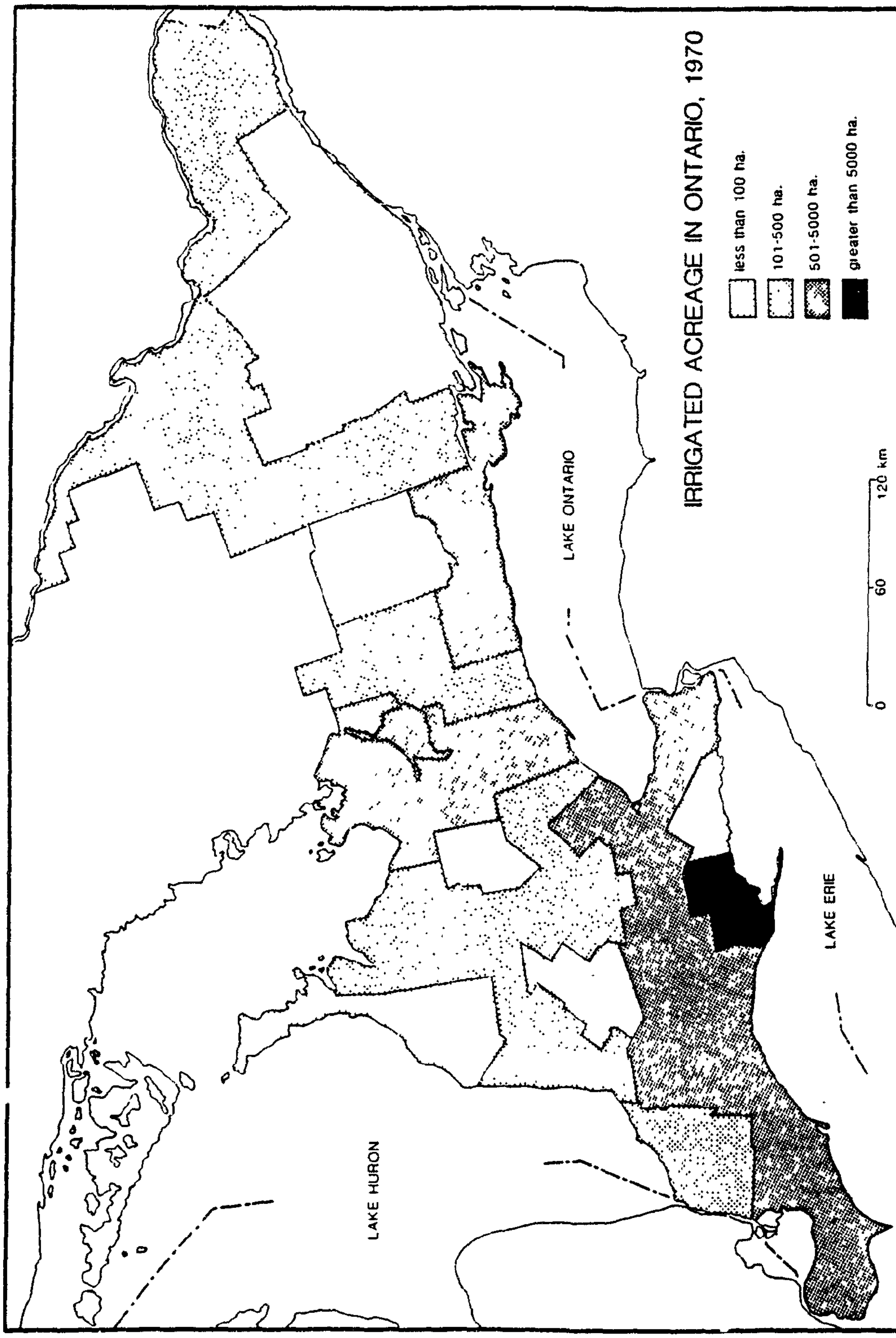

IRRIGATED ACREAGE IN ONTARIO, 1970
less than 100 ha.
101-500 ha.
501-5000 ha.
greater than 5000 ha.
LAKE ONTARIO
LAKE ERIE
LAKE HURON
0
60
120 km

FIGURE 3.3

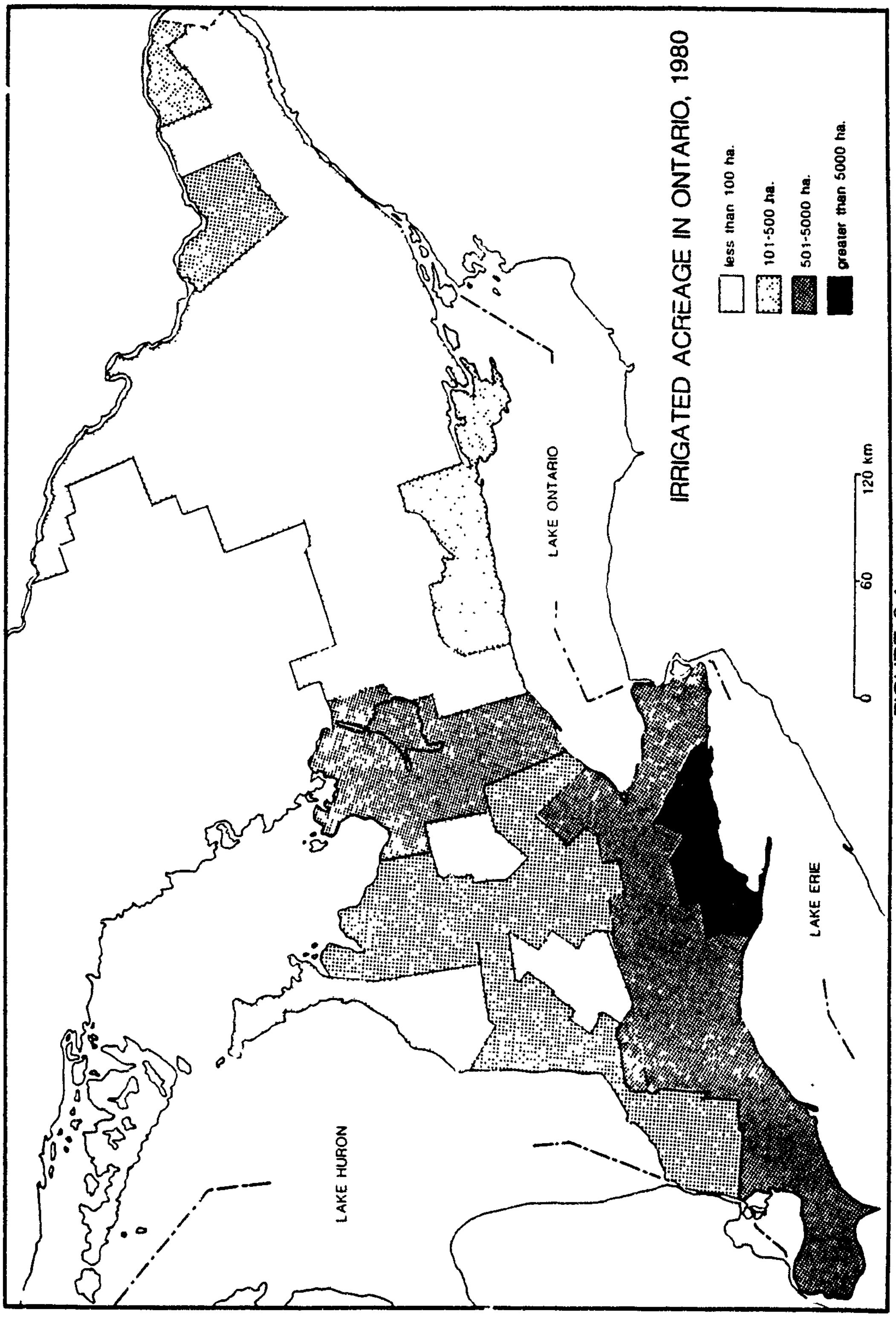

IRRIGATED ACREAGE IN ONTARIO, 1980
less than 100 ha.
101-500 ha.
501-5000 ha.
greater than 5000 ha.
0
60
120 km
LAKE ONTARIO
LAKE ERIE
LAKE HURON

FIGURE 3.4

in Norfolk County and the adjacent counties of the tobacco belt. The absolute decrease in Norfolk County alone was 3818 ha., accounting for almost 50% of the total provincial decline of 8128 hectares. This loss is associated with the general decline in the tobacco industry as a whole. With an increased awareness and publication of the deleterious health effects of cigarette smoking during the 1970's and 80's, public demand for tobacco has dropped substantially, as has the market price. Many farmers have either been forced out of the business altogether or have opted to produce alternate crops, which cannot be grown profitably under irrigation. (Again, here lies a potential area of research for agricultural geographers and rural sociologists. Changing attitudes and social preferences are significantly altering the face of what geographers would call an "agricultural region". Signs of rural decline and the process of circular and cumulative causation are present everywhere. Abandoned farms are not an uncommon site, farm auctions are ubiquitous, closed businesses in both villages and towns are becoming increasingly evident, farm implement dealers are closing their doors, a local tobacco auction house recently filed for bankruptcy. Respondents to this study reported of friends and neighbours who had committed suicide. The process of decline is also evident in physical forms; roads are often covered by the light, sandy soil blowing off of unplanted fields. Here is what McCuaig and Manning (1982) would call a "retreating margin" in the midst of an agricultural "heartland". It is not sure how such research could help the local residents, but it would certainly contribute to an understanding of the process of change in agricultural land-use, and perhaps point the way to possible future uses of this potential dust-bowl.)

A decline in irrigated acreage was also evident in the counties surrounding the expanding megalopolis of Metropolitan Toronto, and most particularly in the counties of eastern Ontario. Apparently, irrigation of forage crops in these counties did not prove profitable. A picture of irrigation land-use since 1980 cannot be presented here as the most recent census report is not yet available. However, historical analyses of this particular form of agriculture will continue to be hindered unless census categories are altered to permit a greater degree of specification and accuracy.

The development of irrigation in Ontario was essentially a crisis response to drought; in effect, a crop-saving practice. For the most part, it has been adopted for use on high-value crops and has been centred in southwestern Ontario. The amount of land under irrigation seemingly reached its peak in the early 1970's and has since declined, primarily due to a fluctuating agricultural economy. It has never been a widespread practice among farmers and barring severe climatic change, drastically altered cropping patterns or dramatically increased revenues for mainstay crops such as soyabeans and corn, likely never will be. Nonetheless, it is an important tool for those farmers who use it in localized areas. A detailed examination of all of those areas would be a prohibitively time consuming task and outside of the ambit of this study. The remainder of this chapter, then, will focus on the physical environment of those three areas selected for examination and the land-use peculiarities of those farmers selected for study.

3.2 THE PHYSICAL ENVIRONMENT OF IRRIGATION AGRICULTURE

The preceding discussion primarily focused on the spread or adoption of the practice of irrigation in Ontario but said little of the physical environment of irrigation agriculture. Although not necessarily determining factors in the use of irrigation, there are certain physical components such as topography, soils and climate which provide a framework for understanding irrigation land-use as discussed above, and provide a basis for understanding the management of irrigation water to be discussed in the following chapters.

3.2.1 Soils

The textural nature of soils play an important role in delineating the boundaries of irrigation agriculture. Specifically, two important derivatives of soil texture affect the use of irrigation in any area; these being permeability and moisture retention. Permeability is the ability of the soil to transmit water or air and is generally measured in terms of the rate of water flow through the soil in a given period of time (Foth 1978). Although other factors play a role, permeability is primarily dependant on soil texture and structure. Coarse-textured sandy soils have large pore spaces which facilitate the infiltration and percolation of moisture, whereas finer-textured clay soils have smaller pore spaces which limit the passage of moisture, resulting in poor permeability. Similarly, pore size is important in determining the moisture retention characteristics of a soil. "The percentage of the volume occupied by small pores in sandy soils is low, which accounts for their low water-holding capacity. In contrast, the fine-textured surface soils have more total pore space and a relatively large proportion of it is composed of small pores. The result is a soil with a higher water-holding capacity"(Foth 1978). Thus, coarse-textured soils, although providing excellent natural drainage, are more susceptible to seasonal moisture deficiencies than finer-textured soils. Generalized soil maps (Figures 3.5, 3.6, and 3.7) portray the distribution of soil texture classes and the location of irrigating farms for each of the sample counties.

a) Kent County

The majority of irrigating farms in Kent County are found east of the county seat of Chatham, on the coarse-textured sandy loam soils of the Bothwell/Kent sand plain (Fig. 3.5). These sands are of a deltaic origin associated with the drainage of the Thames river into proglacial Lake Warren, and are underlain by clay at a depth of 1 to 1.5 metres. Evidence of the clay plain of Lake Warren is found in the dominantly fine-textured clay and silt soils to the west of the sand plains (Chapman and Putnam 1973). The underlying clay beds throughout most of Kent county have, historically, presented problems of imperfect drainage and a network of systematic drainage canals was established during the late 1800's, relatively early in the agricultural settlem nt of the county (Lauriston 1952). For the most part, the sand plai s have a very gently undulating topography and drainage is

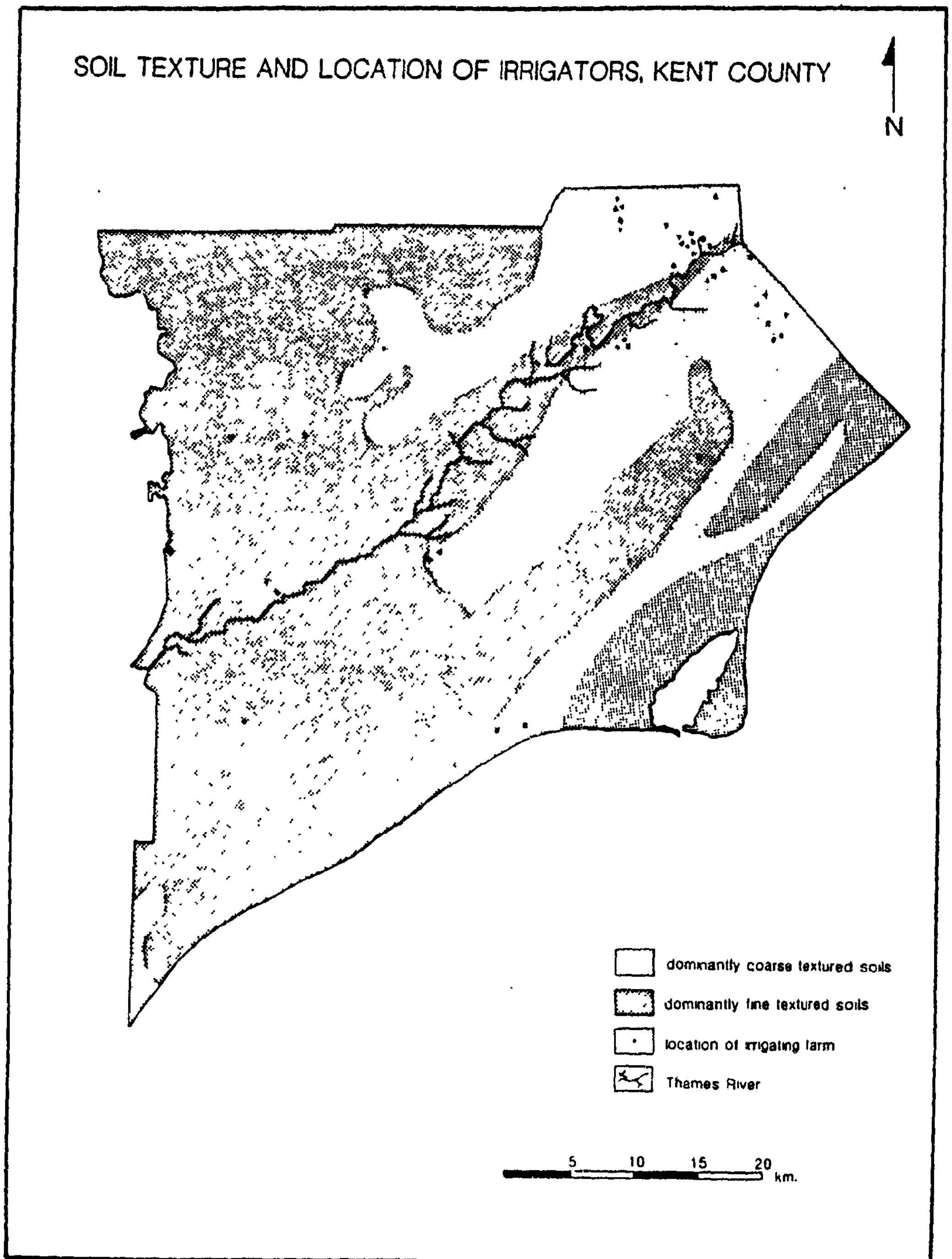

SOIL TEXTURE AND LOCATION OF IRRIGATORS, KENT COUNTY
N
dominantly coarse textured soils
dominantly fine textured soils
location of irrigating farm
Thames River
5
10
15
20
km.

FIGURE 3.5

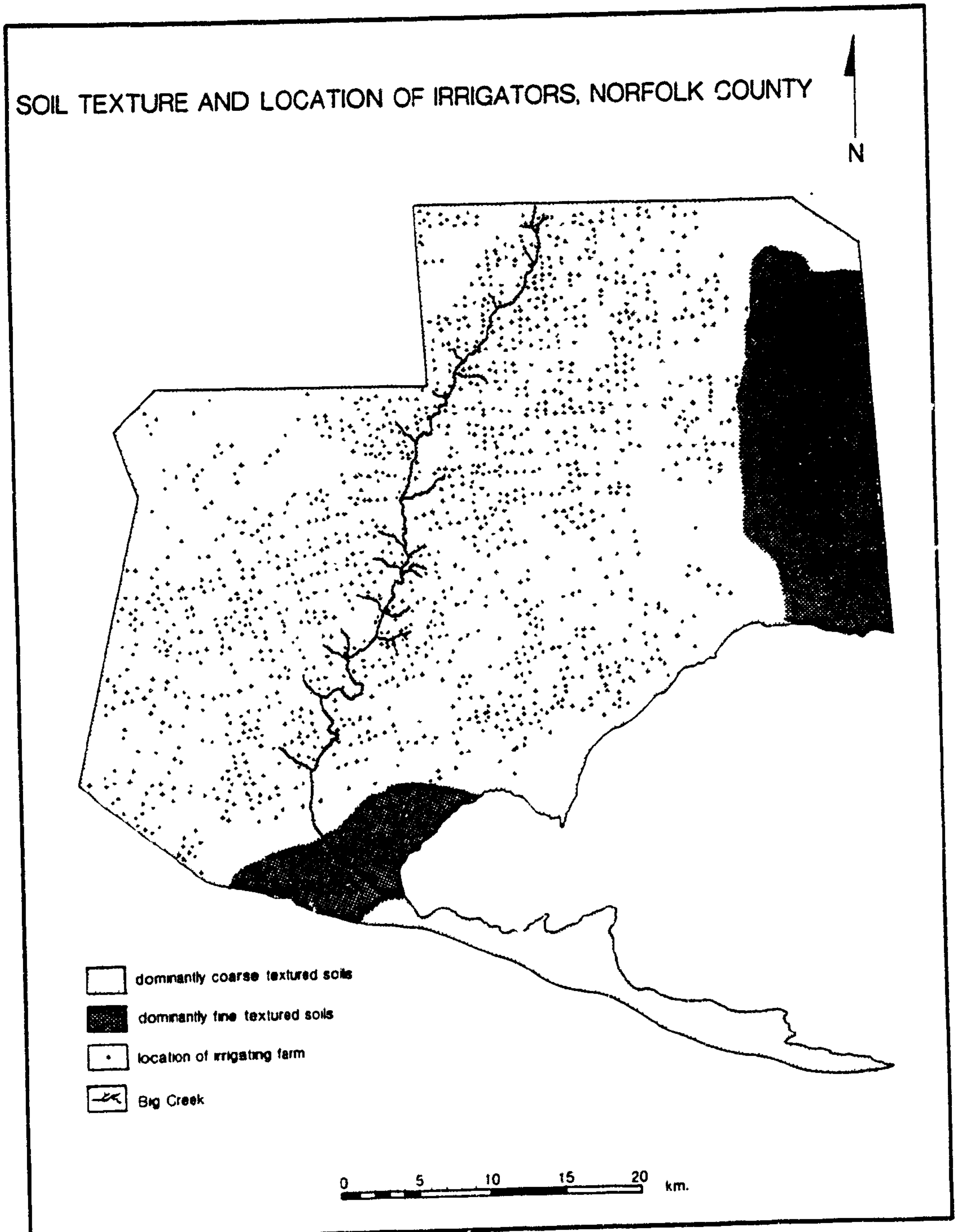

SOIL TEXTURE AND LOCATION OF IRRIGATORS, NORFOLK COUNTY
N
dominantly coarse textured soils
dominantly fine textured soils
location of irrigating farm
Big Creek
0 5 10 15 20 km.

FIGURE 3.6

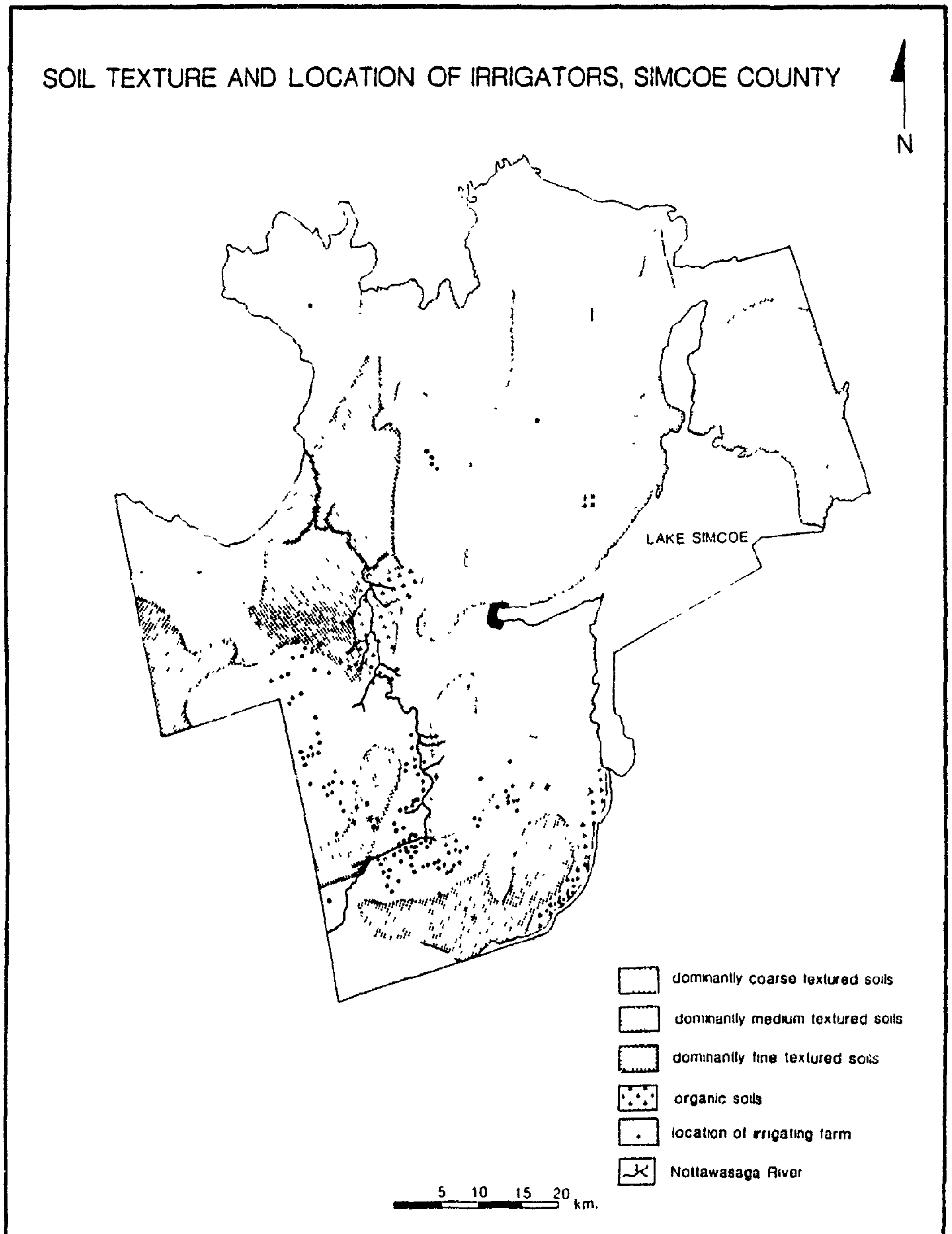

SOIL TEXTURE AND LOCATION OF IRRIGATORS, SIMCOE COUNTY
N
LAKE SIMCOE
dominantly coarse textured soils
dominantly medium textured soils
dominantly fine textured soils
organic soils
location of irrigating farm
Nottawasaga River
5 10 15 20 km.

FIGURE 3.7

oriented toward the Thames river or Lake St. Clair in the northern portion of the county. An exception to this is the morainic ridge which lies almost parallel to the present-day Lake Erie shore and extends from Ridgetown to beyond Blenheim. South of this line, short- run streams drain toward Lake Erie. Although the soils of the sand plain are predominantly Class 2 under the Canada Land Inventory classification, agricultural productivity is hindered by problems of low natural fertility and low moisture-holding capacity (Canada Land Inventory, Soil Capability for Agriculture Mapsheet: Erie 40I, 1967).

All of the farms surveyed for this study fell within this classification.

b) Norfolk County

Norfolk county is characterized by the coarse sandy loam soils of the extensive Norfolk sand plain. Exceptions include the western edge of the Haldimand clay plain which extends into the county, and a narrow band of clay soils which separates the spit of Long Point from the rest of the county. The Norfolk sand plain is generally considered to be a delta of the early Grand river system draining into glacial Lake Whittlesey (Chapman and Putnam 1973). Figure 3.6 shows that the pattern of irrigating farms is confined to the sand plain with distinct terminal boundaries at the margin of the Haldimand clay plain and above the heel of Long Point. The topography of the area is undulating and the region is dissected by a number of steep river valleys, most notably the Big Creek basin in the western portion of the county. In contrast to Kent, the sand deposits are relatively thick and natural drainage is good. The majority of the sand plain however, is considered to be Class 4 land or lower. Major limitations are low natural fertility and low moisture-holding capacity (Canada Land Inventory, Soil Capability for Agriculture Mapsheet: Erie 40I 1967). This classification, though, neglects the fact that these soils have high productivity for a specially adapted crop. Such is the case with tobacco, which thrives on light, well-drained sandy soils that warm rapidly in the spring and promote early growth. Of the ten tobacco farmers interviewed for this study, seven were located on soils of Class 4 or below. Conversely, vegetable and fruit growers were located on soils of Class 2 or better.

c) Simcoe County

The distribution of soil texture classes is more complex than those of the Kent and Norfolk areas. Irrigation however, is still largely confined to the coarse-textured sandy loam and loamy sand soils of the region. In the southern part of the county, these sands are predominantly limited to the broad flats of the Nottawasaga river basin which was, at one time, part of the floor of glacial Lake Algonquin. Surface beds are therefore of deltaic and lacustrine origin (Chapman and Putnam 1973). To the north of Alliston, however, sands have been brought into the area by the Pine and Mad rivers. These are the "loose, coarse-textured materials which have been well drained by entrenchment of rivers of the area", cited by Chapman and Putnam (1973). These soils are typically of a lower class than those to the south but the limiting factors in both cases are still low natural fertility and poor moisture retention. A significant cluster of irrigating farms is also present on the organic soils located in the southeast portion of the county. This area, known as the Holland marsh, is essentially the floor of a valley which extends 24 km. from the southern tip of Lake Simcoe and is sided by high morainic hills. Drainage of the marsh was initiated in 1925 and since that time, this reclaimed land has become one of the most intensively farmed, vegetable producing regions in the country. The organic soils are mainly a fibrous peat and irrigation is primarily used to combat soil erosion, plant abrasion, and heat stress. Of the twelve farmers interviewed in Simcoe county, four were located on organic soil, three on Class 3 or 4 land, and five on Class 2 or better.

In general then, the pattern of irrigation in these study areas, and likely in most of the province, is contained within areas of coarse-grained and reclaimed organic soils. Coarse-grained soils generally have two factors which limit their productivity: low natural fertility and poor moisture-holding capacity. Yet, they are particularly well-suited to some high-value crops such as tobacco, potatoes and strawberries. Of particular note is Norfolk county which was long considered to be a marginal agricultural region prior to the introduction of tobacco cultivation in the 1920's (Whebell 1966). Organic soils typically have excellent moisture retention capacity in the root zone but are susceptible to the drying out and aeolian erosion of their upper layers.

3.2.2 Climate

The climatic conditions of the three regions under study are broadly similar to the rest of southern Ontario which is generally categorized as having a humid continental climate. January is the coldest month of the year and July the warmest. Cultivated agriculture is primarily limited to the period between May and October, although in Kent and Norfolk, the modifying influence of Lake Erie extends the growing season longer than the inland county of Simcoe. Late spring frosts commonly terminate at the end of April along the shores of Lake Erie and 10-14 days later at more inland locations. Similarly, the first early fall frost, on average, occurs on October 15 along the lakes and two weeks earlier in the central counties (Spelt 1967). The main characteristic of Ontario's climate, however, is variability. Hare and Thomas (1979), for example, note the occurrence of a killing frost in mid-June of 1972 which devestated the tobacco crop of the Norfolk area. Perhaps as a result of this day to day variability, Hare and Thomas (1979) suggest that precipitation is unusually reliable, and there are seldom any markedly long dry or wet spells. A brief description of the climatic factors affecting the need for irrigation in each of the study areas is presented below.

a) Temperature and Sunshine

Reflecting their proximity to the Great Lakes, Kent and Norfolk counties have relatively long average frost-free periods of 161 and 154 days, respectively. Simcoe County, in its central location has a shorter average frost-free period of 133 days. For agricultural purposes, the mean annual number of growing degree days (using a 5 C minimum) takes into account both duration and warmth of the growing season and thus reflects the total amount of heat available for plant growth. The period between the average date of occurrence of a mean temperature of 5 C, however, is generally greater than the frost-free period. Growing degree days for Kent, Norfolk and Simcoe are around 4000, 3500 and 3100 respectively. Kent County, with a mean annual temperature of 8.8 C, warms early in the spring with a mean of 12.9 C in May. Norfolk County follows closely with an annual mean of 7.8 C and a mean May temperature of 12.6 C. Simcoe County lags behind with a mean annual of 6.1 C and a May mean of 10.9 C (Table 3.3). Temperatures of all three counties reach an annual maximum in July, with Kent recording a mean of 21.6 C , Norfolk at 20.6 C, and a July mean of 19.5 C in Simcoe County. Temperatures decrease through August into September, with Kent displaying a September mean of 17.6 C, Norfolk at 16.2 C, and Simcoe recording 15.1 C. Again, variability in temperature is common, but weekly means during July rarely exceed 26 C or fall below 16 C in these counties.

Radiation is not a limiting factor for agriculture in the study areas. The daily duration of bright sunshine (as a measure of radiation) is associated with temperature, evaporation, the water balance, 1 influences the photosynthetic potential of plants. The duration of bright sunshine is similar throughout most of southern Ontario. The region as a whole can expect an average of 1800-2000 hours annually with a maximum daily mean of 9 hours in July. The mean daily duration of bright sunshine for May, June, August and September are 7.5, 8.8, 8.8, and 6 hours, respectively. The low durations during the spring and fall are associated with increasingly overcast skies and a

TABLE 3.3

MEAN CLIMATIC DATA FOR THE STUDY AREAS

STATION	DATA	Unit	Annual Mean	May	June	July	Aug.	Sept.
Ridgetown KENT COUNTY	Temperature	°C	8.8	12.9	18.2	21.6	21.0	17.6
	Precipitation	mm	759	73.7	71.1	71.6	60.2	67.3
Delhi NORFOLK COUNTY	Temperature	°C	7.8	12.6	17.4	20.6	19.6	16.2
	Precipitation	mm	956	85.3	74.1	77.5	80.1	81.5
Midhurst SIMCOE COUNTY	Temperature	°C	6.1	10.9	16.2	19.5	19.1	15.1
	Precipitation	mm	747.5	68.6	68.1	75.4	70.6	65.5

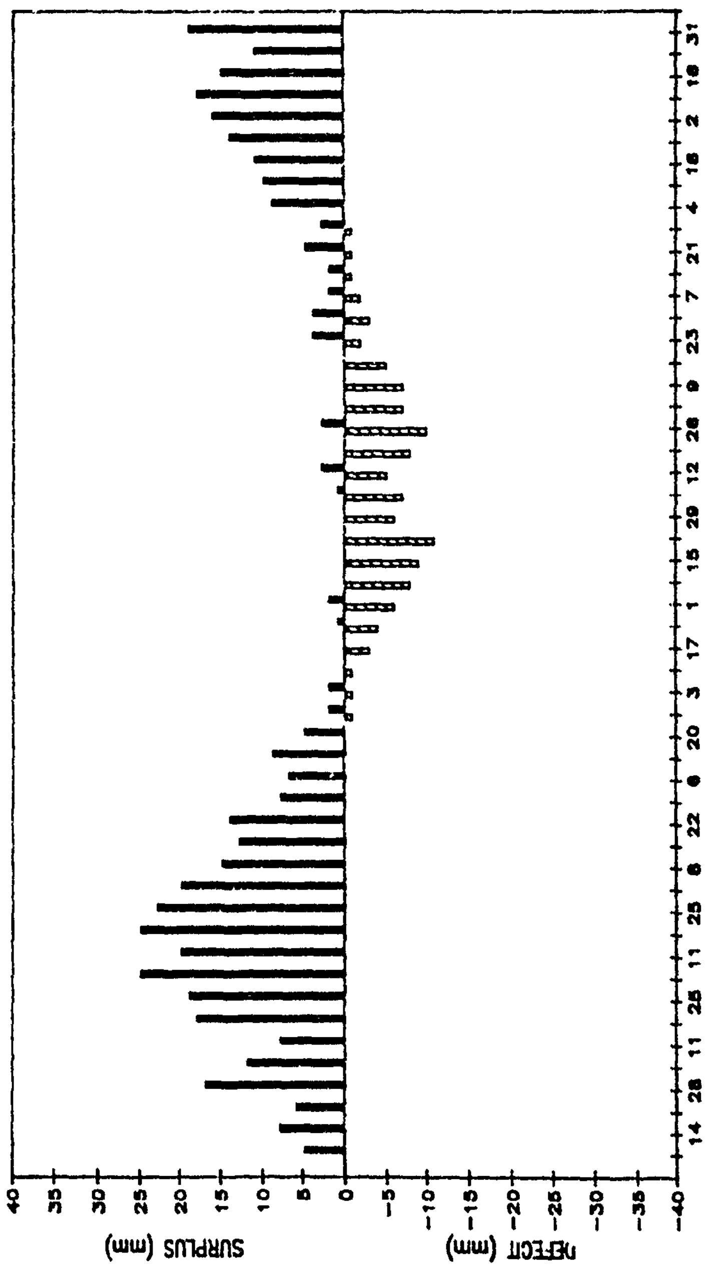
shortened daylight period. During the summer, there are very few overcast days, although completely cloudless days are also rare (Hare and Thomas 1979). Although significant rainfall occurs during this period, it is usually in the form of brief intense thunderstorms rather than the longer duration events of fall.

b) Precipitation

A common assumption with regard to irrigation in humid environments is that the addition of supplemental water is needed because of a poor distribution of precipitation throughout the year, with most of it occurring during the winter in the form of snow. This is not the case in southern Ontario. Rather, precipitation is remarkably well-distributed throughout the year and particularly, throughout the growing season. For example, the average annual precipitation in Norfolk County is 953 mm. Of this, 399 mm. or 42% occurs between May and October. In Kent and Simcoe counties, this proportion is still greater with 45.3% and 46.6% of the total, respectively, occurring during the growing season (Table 3.3). There is no consistent seasonal progression in precipitation in any of the counties. On the average, for example, the wettest month of the growing season in Norfolk County is May (85.3 mm.), while in Simcoe County, it is July (75.4 mm.). Similarly, while in Norfolk County, the months of August and September receive, on the average, more precipitation than July, the opposite occurs in Kent County.

The need for irrigation is not related to permanent or seasonal drought in the form of a skewed distribution of precipitation away from the growing season, but is more a factor of the increased rate of evaporation and transpiration during the spring and summer months. During this period, evapotranspiration commonly exceeds effective precipitation, creating a seasonal moisture deficit. From calculations of the seasonal water balance, it can be seen that a negative water balance exist throughout the growing season in each of the study areas (Figures 3.8, 3.9, 3.10: These figures are based on the calculations of Johnstone and Louie (Appendix III) who incorporate a soil water holding capacity function into their water budget model. This ranges from 100mm. for sandy soils to 280mm. for clay soils. Unfortunately, however, calculations have only been performed for a limited number of climate stations and although Figures 3.9 and 3.10 are located within Kent and Simcoe counties, they are not located on coarse-textured soils. The W.H.C. appointed to the Ridgetown station is 280mm. and to the Midhurst station, 150mm. These figures over- estimate the W.H.C. of sandy soils and consequently, figures 3.9 and 3.10 under-represent the magnitude and frequency of water deficits on irrigated soils.) The three counties studied exhibit a similar annual trend. A surplus of moisture exists during the winter months as precipitation accumulates in the form of snow and evapotranspiration is reduced. The onset of melt in February leads to moisture surplus peaks in March and April as it adds to the precipitation base. By May, the snowmelt component has typically been exhausted and precipitation is left to satisfy the moisture balance. Although precipitation remains relatively constant during this period, evapotranspirative demands steadily increase with renewed plant growth in late spring and seasonal increases in temperature and radiation.

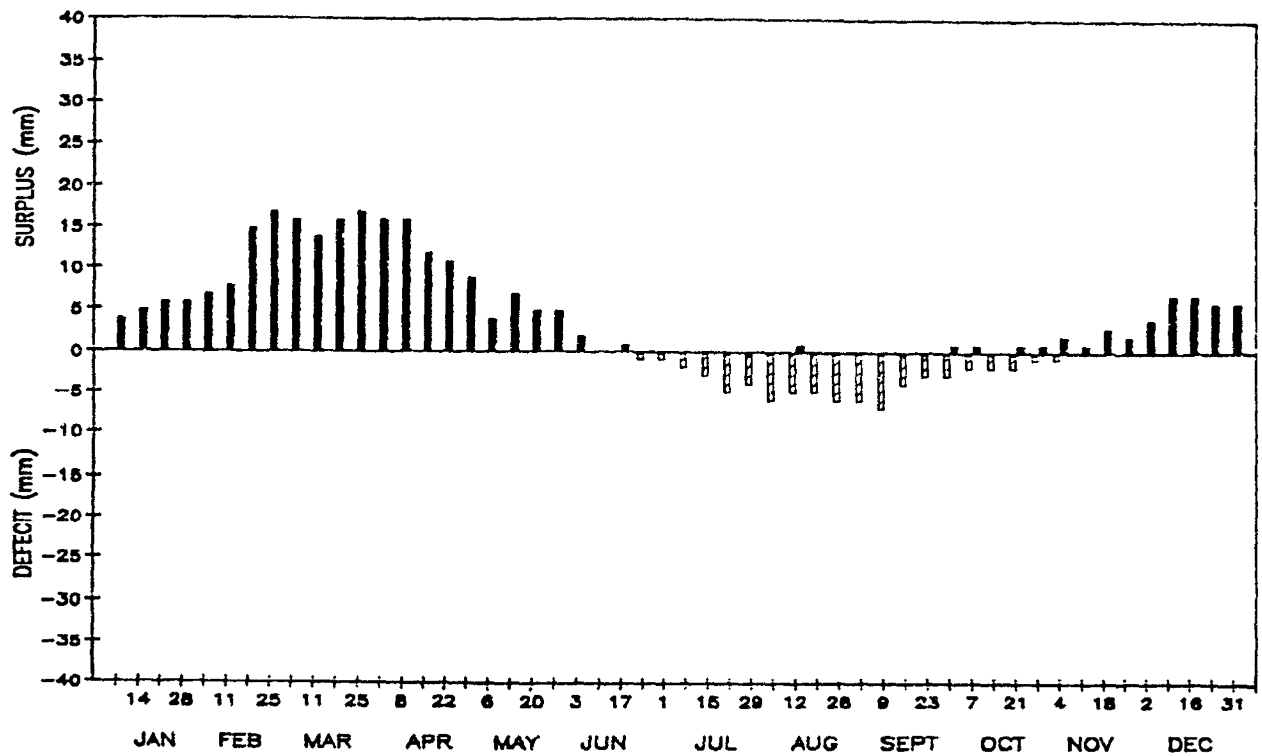
FIGURE 3.8
MOISTURE SURPLUS AND DEFICIT MEANS
FOR THE PERIOD 1962 TO 1985
NORFOLK COUNTY
(Delhi station)



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 3.9

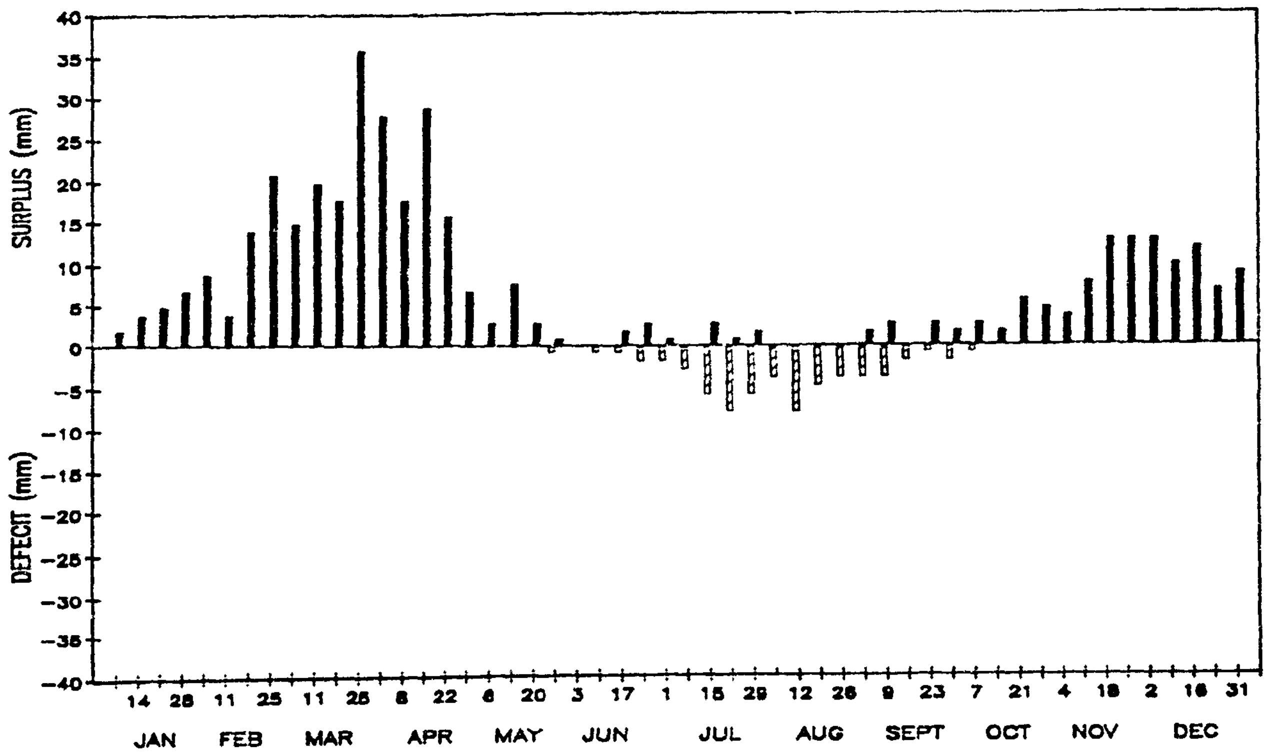
MOISTURE SURPLUS AND DEFICIT MEANS
FOR THE PERIOD 1924 TO 1985
KENT COUNTY
(Ridgetown station)



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 3.10

MOISTURE SURPLUS AND DEFICIT MEANS
FOR THE PERIOD 1967 TO 1985
SIMCOE COUNTY
(Midhurst station)



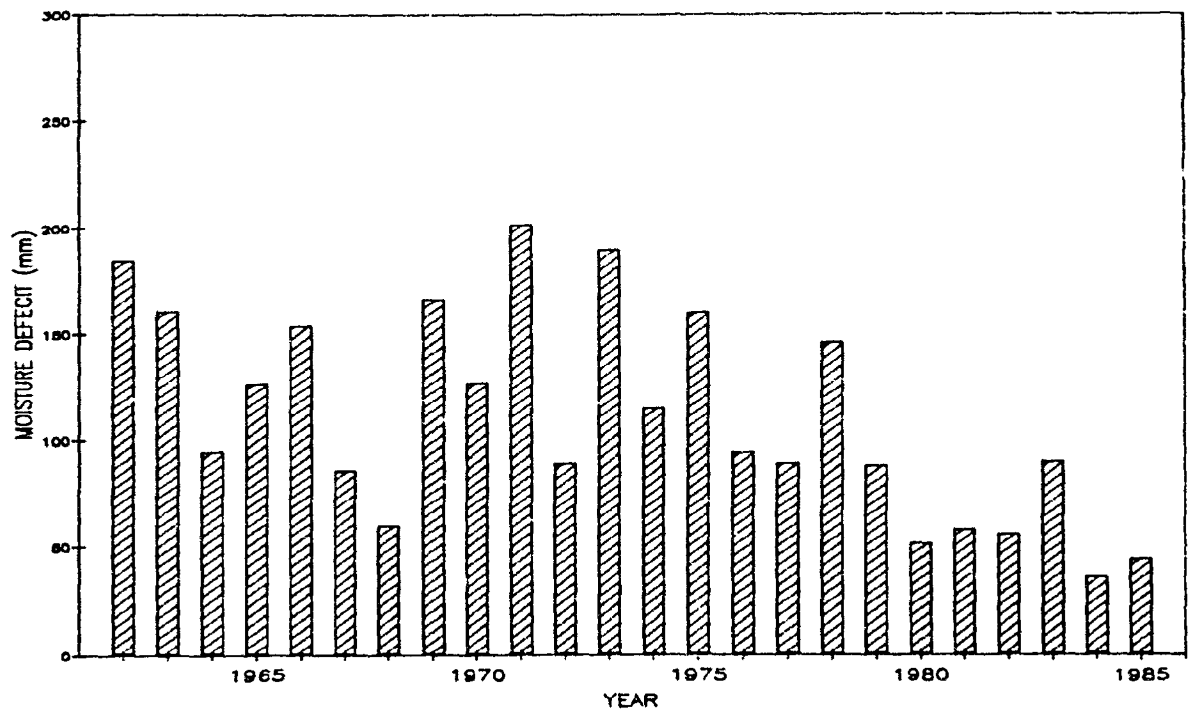
Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

Moisture deficit peaks are typically reached in July and August. While precipitation during these months is not markedly lower than any other time of year, components of evapotranspiration are at their maximum. Gradually, as crops reach maturity, temperatures decrease and day-lengths shorten, deficits subside into October and November and precipitation again exceeds potential evapotranspiration. Although this basic outline describes the annual water balance trend, seasonal variations are also evident. Figures 3.8, 3.9, and 3.10, for example, show that although moisture deficits are the dominant condition during the growing season, moisture surpluses are not uncommon. The modifying effects of the Lake Erie on the balance of Kent and Norfolk counties is also evident in these figures. Surplus peaks in Simcoe are typically reached two weeks later in the spring than Norfolk and Kent, while the onset of surplus conditions in the fall occurs two weeks earlier.

Annual variability is also evident in the magnitude of the moisture deficit (Figures 3.11, 3.12, 3.13). Norfolk County suffers the greatest deficit with an annual mean of 109mm. However, over the period of record, the annual deficit has ranged from less than 50mm. to over 200mm. The mean total deficit for both Kent and Simcoe are lower at 69mm. and 65mm., respectively, but variation is just as evident, ranging from 0mm. in both counties to over 150mm. in Simcoe and almost 250mm. in Kent (remembering that the data is not necessarily representative of irrigated soils in each area.). Not only is there considerable variability in the total moisture deficit per year, but there is also great variability in the weekly occurrence of moisture

FIGURE 3.11

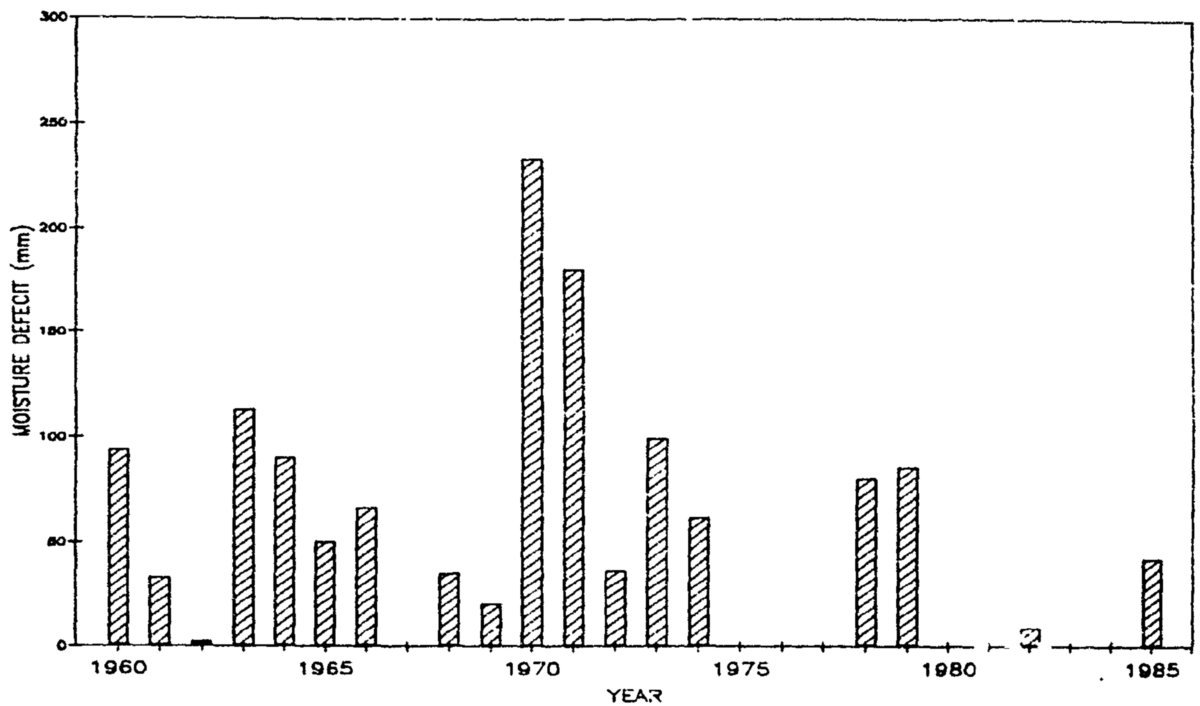
TOTAL MOISTURE DEFICIT PER YEAR
NORFOLK COUNTY
(Delhi station)
1962–1985



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 3.12

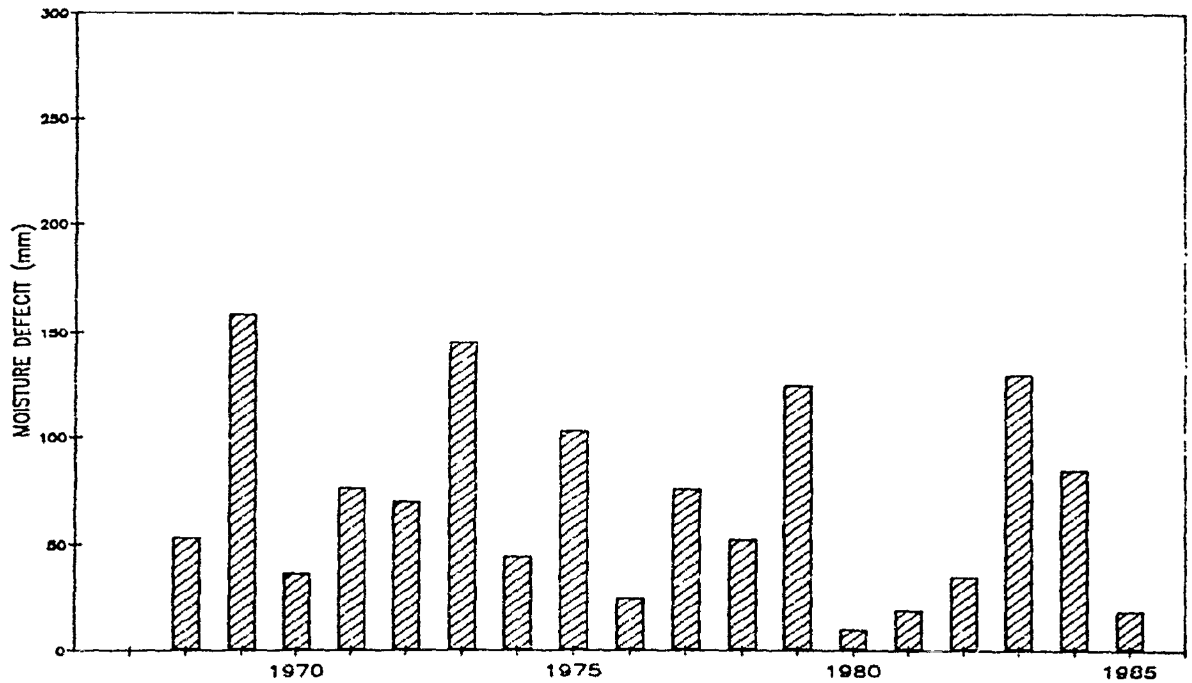
TOTAL MOISTURE DEFICIT PER YEAR
KENT COUNTY
(Ridgetown station)
1960–1985



Source: Environment Canada: Atmospheric Environment Service, Water Budget Records.

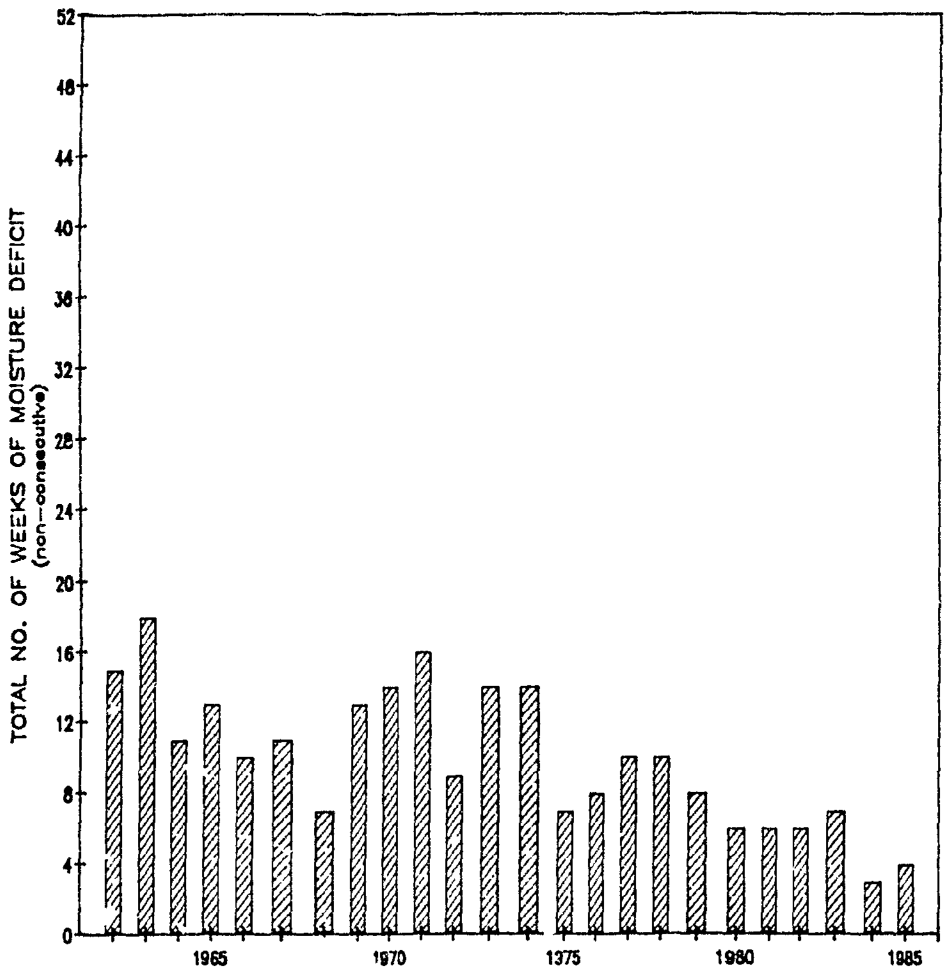
FIGURE 3.13

TOTAL MOISTURE DEFICIT PER YEAR
SIMCOE COUNTY
(Midhurst station)
1967—1985



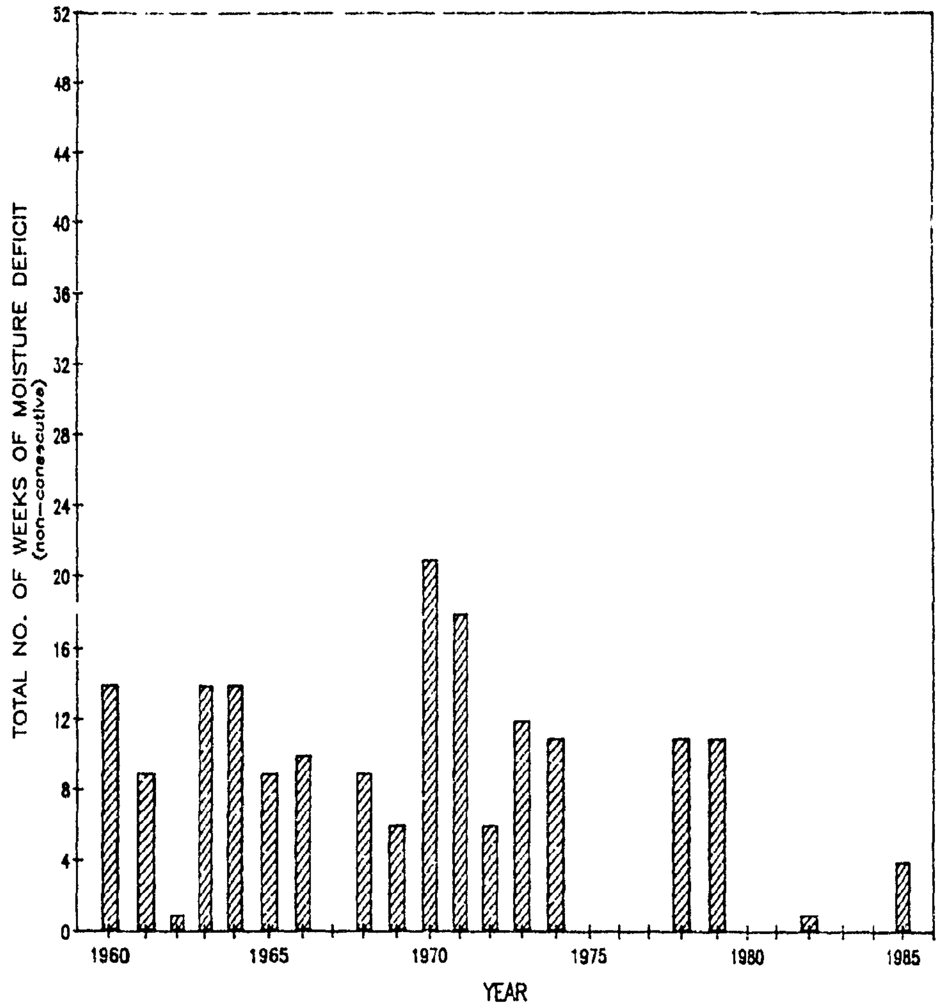
Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 3.14
OCCURRENCE OF MOISTURE DEFICIT IN WEEKS PER YEAR
FOR THE PERIOD 1962 TO 1985
NORFOLK COUNTY
(Delhi station)



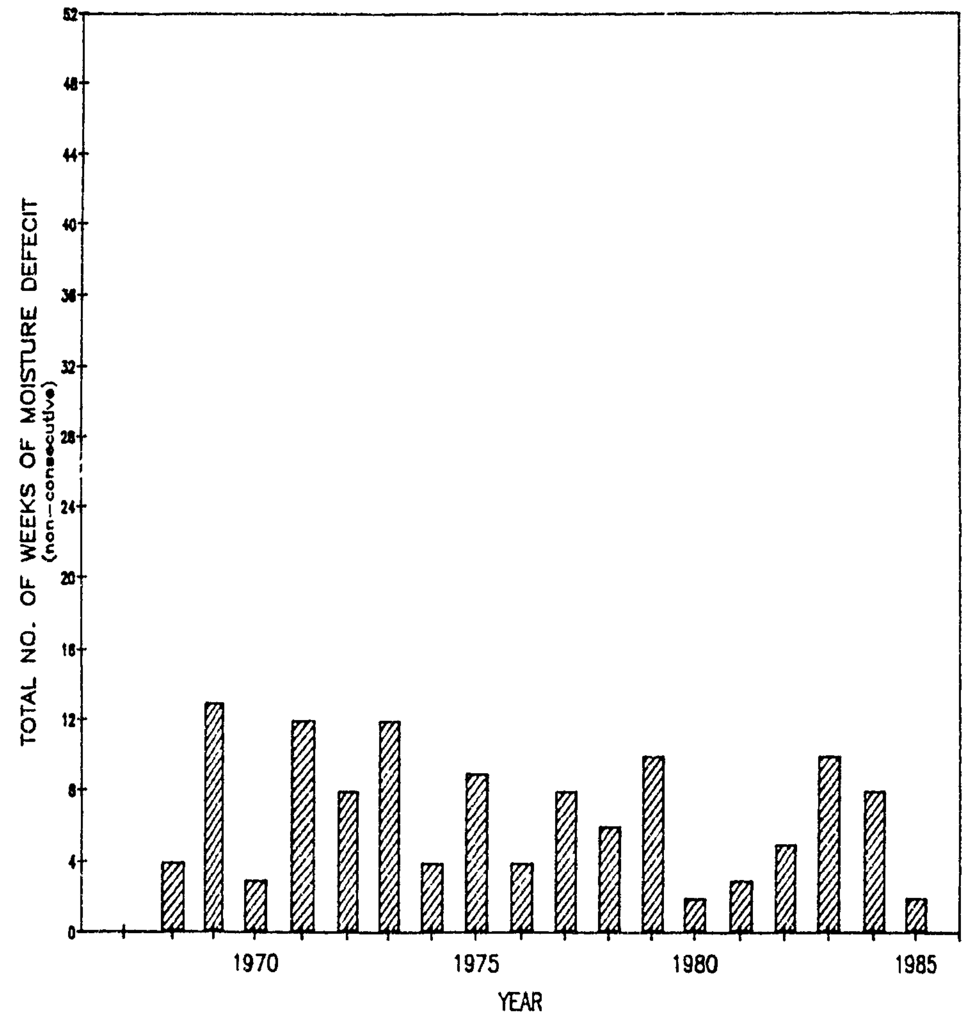
Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 3.15
OCCURRENCE OF MOISTURE DEFICIT IN WEEKS PER YEAR
FOR THE PERIOD 1960 TO 1985
KENT COUNTY
(Ridgetown station)



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 3.16
OCCURRENCE OF MOISTURE DEFICIT IN WEEKS PER YEAR
FOR THE PERIOD 1967 TO 1985
SIMCOE COUNTY
(Midhurst station)



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

deficits between years (Figures 3.14, 3.15, 3.16). Kent County for example has experienced a range from no deficit at all, to a moisture deficit in over 20 weeks of the year. Norfolk and Simcoe show similar patterns of variability. Generally, there is a consistent relationship between the magnitude of the annual deficit and the temporal frequency of deficit occurrence (ie. the greater the number of weeks experiencing a moisture deficit in a given year, the higher the total annual deficit for that year). This relationship is not as evident in Norfolk County as it is in Kent and Simcoe counties. In 1974, for example, Norfolk county experienced a total deficit of 115.5mm. over 14 weeks. The following year, however, recorded a deficit of 160mm. over a much reduced time span of 7 weeks. A more detailed analysis of the climatic data would be required to shed light on the reasons for anomalies such as this. Nevertheless, it is evident that variability is the main characteristic of both seasonal and annual water balance conditions in each of the study areas.

3.2.3 Conclusion

Climatic conditions as they affect agriculture in the study areas are locally unpredictable and variable from year to year. However, there are general factors of the physical environment which tend to delineate the boundaries of irrigation agriculture. Although precipitation is not necessarily a limiting factor to productive agriculture — as evidenced by the provincial dominance of "dryland" farming — high radiation and high temperatures during the summer growing season lead to rates of evapotranspiration which generally exceed the input of precipitation from

June to October. This condition tends to create a net moisture deficit during the growing season in most years. This moisture deficit poses more of a limiting constraint to agriculture where crops are grown on coarse-textured sandy soils due to their poor moisture retention capacities. Other characteristics of these soils, however, make them particularly suitable for the production of certain high-value crops. Their loose structure provides excellent drainage, promotes rapid warming early in the growing season and presents no textural impediment to deep-rooting crops such as potatoes and tobacco. Hence, irrigation agriculture is largely confined to areas of coarse-textured soils in an effort to realize the advantages they offer while minimizing the detrimental effects of seasonal moisture deficiencies.

3.3 IRRIGATION AGRICULTURE IN THE SAMPLE COUNTIES

Unfortunately, irrigation land-use in Ontario has received meagre attention in the agricultural census of the province. Census reports prior to 1950 make no mention of irrigation activity. The survey of 1950 recorded irrigated acreage for each county but makes no mention of irrigated crops. Surveys of 1960 and 1970 improve the data base to include areas of irrigated crops, but the 1981 census failed to distinguish between crops and again only reported the total irrigated acreage per county. In the absence of any contemporary census data reporting on the characteristics of irrigating farms, this section will present a brief description of the agricultural nature of the farms and farmers surveyed for this study. This discussion is organized under the headings of: irrigation land-use; changing land-use under irrigation; marketing; and experience and outlook of farmers, for each county surveyed.

3.3.1 Kent County

a) Irrigation Land-use

As in most of the province, irrigation is not a widespread practice in Kent County. According to the most recent agricultural census, only 578 ha., or 0.3% of the 204,932 ha. under crop were irrigated as of 1981 (Statistics Canada 1981). Generally, Kent County forms the western tip of southern Ontario's corn belt, and field crops such as silage corn, wheat and soyabeans dominate the agricultural landscape.

A total of 9 farms were surveyed in Kent County, irrigating a land base of 142.3 ha. A breakdown by crop is as follows:

–7 farms irrigated a total of 72 ha. of tobacco
–5 farms irrigated a total of 41 ha. of vegetables
–4 farms irrigated a total of 17.7 ha. of small fruits
–2 farms irrigated a total of 11.6 ha. of tree fruits

This absolute distribution is misleading. Of those farms irrigating tobacco, for example, four had land areas of between 10-15 ha., while three had between 4-10 ha. under the crop. Similarly, four of the tobacco growers irrigated small acreages of vegetables and small fruits in addition to their tobacco crop. In only one case did this acreage exceed 2 ha. One farm accounted for 57% of the irrigated land under vegetables. Diversification in production rather than single crop cultivation appears to be the norm. A mixture of irrigated and "dryland" crops was evident on all farms. This is reflected in the percentage of land irrigated relative to the total area of cultivated land for each farm. For all farms surveyed, an average of 16.3% of the total cultivated land was irrigated. This ranged from 6.7 to 67.5% but was always less than 20% on those farms where the main irrigated crop was tobacco. Thus, irrigated tobacco is only a small part of the farm operation on these properties. The remaining land was comprised of wheat or rye as a rotation crop for tobacco, and all farmers reported that hybrid corn and soyabeans accounted for a proportion of their cultivated land.

Irrigating farms in Kent County, when both irrigated and non-irrigated land is considered, are slightly larger than the provincial average of 73.2 ha. and the county average of 69.8 ha. (Statistics Canada 1981). The average size of the surveyed farms was 85.1 ha.. In terms of a range, only one farm was less than 50 ha.; two were between 50-75 ha.; three fell between 76-100 ha.; and three were greater than 100 ha.. All properties were owner-operated and only one farmer leased any land. This leased area of 141.6 ha. was used for corn production and was not irrigated.

b) Changing Land-use Under Irrigation

The temporal expansion of irrigation among those farmers surveyed in Kent County appears to follow the pattern described earlier in this chapter. Irrigation was adopted on six surveyed farms between 1954 and 1959; on one farm in each of 1962 and 1967; and on one farm in 1972. It is of note that the period between 1954-1959 and the years 1962 and 1967 were not particularly dry, while the years 1970 and 1971 experienced the greatest moisture deficit on record since 1960. All farmers, however, stated that the primary reason for initiating irrigation was to reduce the risk of crop loss due to drought. Improved quality of the crop and increased yields were given as important secondary reasons by all farmers but in particular by two orchard growers who noted the benefits of irrigation in increasing the size of mature fruit. In all cases, irrigation was adopted for use on an existing crop and was not adopted to permit the production of a crop not already grown under "dryland" conditions.

Few land-use changes have occurred on the surveyed farms in the time since irrigation was initially adopted. No farms reported crop changes but several farms had added crops in response to market fluctuations. As noted, three tobacco farms added small acreages of vegetable and fruit crops to supplement a falling income due to a declining tobacco market. One farmer expanded his corn acreage for the same reason. Farm size in all cases has remained constant although specific acreages of tobacco are subject to annual fluctuations under a controlled market.

c) Marketing

A variety of marketing arrangements exist for different crops in Kent County. In disposing of their crop, tobacco farmers have the least amount of control. All tobacco farmers in Ontario must be members of the Flue-Cured Tobacco Marketing Board which determines and allocates annual production quotas based on estimated demand within the industry. Originally, this quota was enforced by restricted acreage, but with increasing yields due to improved varieties, fertilizers, and irrigation, quotas were converted to an allowable poundage per farm. In recent years, production quotas have declined drastically. Some farmers estimated that they are currently producing only 25% of what they sold during the 1960's and 70's. Tobacco processors are not permitted to establish contract relationships with farmers and the sale of the final product is completed by auction at one of two exchange houses in Tilsonburg and Delhi. These sales centres are located within the tobacco region of the Norfolk sand plain, approximately 110 km. from Kent County.

Less stringent marketing arrangements exist for all other irrigated crops. Small fruits and tree fruits are partially marketed through "Pick Your Own" operations and the remainder sold to processing plants in Chatham or Leamington, a vegetable producing region to the west of Kent County. Vegetables are mainly grown for local processing plants through verbal arrangements rather than written contracts, although peppers are generally sold to local packing plants in Ridgetown and Blenheim. Two farmers had verbal agreements with local retail outlets for the sale of small quantities of fruits and vegetables.

d) Experience and Outlook of Farmers

The experience of the surveyed farmers in Kent County reflects its relatively long, un-interrupted, history of agricultural settlement. Only one had been in farming for less than 20 years, and five farmers were currently operating properties that had been in their families for two to three generations. This is also reflected in the reasons given by farmers for following existing cropping patterns. Whereas the more recent entrants to the farming business cited a long-term best return as the main reason for growing particular crops, those farmers who had inherited or taken over the family farm cited familiarity and experience with a particular crop as the primary reason for their existing land-use. They had grown up with a particular cropping pattern and merely taken over an established operation.

Most of the farmers interviewed were older men: five between 46-55; three over the age of 55; and one less than 25. Although most of these men are approaching retirement, they apparently have offspring willing to continue farming on their current property. The relatively stable agricultural infrastructure of Kent County has not resulted in the depopulation of the rural area common to other areas of the province. Land-use change on those farms surveyed appears to hinge on the future of the tobacco industry. Five of the tobacco farmers surveyed, stated that if their production quotas are reduced any further, they would replace existing tobacco acreage with an alternate crop. In four cases, the alternate mentioned was simply an expansion of their existing corn and soyabean acreage, while one farmer was planning to replace tobacco with a variety of vegetable crops. This farmer would continue to irrigate these vegetables, while those switching to corn and soyabeans stated that they would not irrigate these crops.

3.3.2 Norfolk County

a) Irrigation Land-use

Unlike Kent County, irrigation in Norfolk County is a dominant part of the agricultural landscape. Of the total area under crop in 1970 (75,299.5 ha.), 14,607 ha. or 19.4% was irrigated and irrigation was present in some form on 45% of the 2793 farms in the county (Statistics Canada 1972; as Norfolk County was amalgamated with Haldimand County in 1974 to form the Regional Municipality of Haldimand-Norfolk, subsequent changes to census division boundaries tend to obscure data pertinent to the former county of Norfolk. As the 1981 census report categorizes data for Haldimand-Norfolk, data from the 1971 census is used in this report. Absolute and relative figures are likely much lower today). As mentioned previously, the sandy soils of Norfolk County form the nucleus of Ontario's tobacco belt. Tobacco in turn, has historically been the primary irrigated crop in the region. As of 1970, 95% of the total irrigated area was under tobacco and tobacco farms accounted for 95% of all irrigating farms.

A total of 14 farms were surveyed in Norfolk County. By crop area, the breakdown is as follows:

- 10 farms irrigated a total of 172.1 ha. of tobacco
- 4 farms irrigated a total of 128.3 ha. of vegetables
- 2 farms irrigated a total of 10.5 ha. of small fruits.

Of the tobacco farms, six had between 10-20 ha. under the crop; two had less than 10 ha.; and two had greater than 20 ha.. Only one farm had an irrigated crop in addition to tobacco. This was in the form of 8.2 ha. of vegetables. The majority of the acreage under vegetables and small fruits was made up by two farms, one producing a combined acreage of 91 ha. of potatoes and sweet corn and 10.1 ha. of strawberries; the other accounting for 20.2 ha. of mixed vegetables.

In general, irrigated land accounted for a greater percentage of the total cultivated land than was the case in Kent County, indicating a greater reliance on a single crop and less diversification. For the sample as a whole, a mean of 42.4% of the total cultivated land was irrigated. This ranged from 6.7% to 100%, but was typically between 30-40% on farms where tobacco was produced, and greater than 50% on vegetable farms. These figures would tend to suggest a two year crop rotation for tobacco and an overlapping rotation for vegetable crops. Indeed, most tobacco farms reported that their non-irrigated land was planted in rye and/or wheat as a rotation crop for tobacco. Only two tobacco farmers were involved in diversified agricultural activities. One had a separate cattle farm while another share-cropped silage corn.

When the total farm area is considered, those farms surveyed have an average size of 85.6 ha.. Although this is much greater than the regional average of 57.9 ha., a relative distribution of the sampled farms provides a more accurate description. Five of the farms were less than 50 ha.; three were between 50-75 ha.; three were between 76-100 ha.; and three were greater than 100 ha.. With the exception of one speculative venture, all irrigated land was owner-operated. The exception was a small leased area of 6.1 ha. used to grow garlic. The operator, whose main concern is a broiler farm in the area, is actively promoting the adoption of garlic as an alternate crop to tobacco and is speculating that he will be the main source of garlic bulbs if tobacco farmers turn to that crop. Two additional vegetable farmers leased land for the production of non-irrigated silage corn.

b) Changing Land-use Under Irrigation

Among the surveyed farmers, irrigation was generally adopted earlier in Norfolk County than Kent. Eight of the tobacco growers began irrigating between 1949 and 1956; the remaining two tobacco growers and fruit and vegetable producers adopted the practice between 1967-1971; and one in 1983. Whereas those adopting the practice in the 1950's stated that reducing the risk of crop loss due to drought was the primary reason for initiating irrigation, later adopters stated the primary reason as improved crop quality and in the case of small fruits, protection from frost. Again, with the exception of two farms, irrigation was adopted for use on a crop that had previously been grown under "dryland" conditions. Only one farmer has switched crops since he began irrigating, changing from tobacco to vegetables due to a decline in the tobacco market.

c) Marketing

The marketing arrangements for tobacco are identical to those described for Kent County. Delhi and Tilsonburg are both at the edge of Norfolk County and the tobacco industry has historically been the mainstay of the regional economy since the 1930's. The long-term dominance of the tobacco industry has contributed to a lack of a processing and marketing infrastructure for fruit and vegetable produce. There are no industrial processing or packing plants in the area and all of these crops are produced for the fresh market. All surveyed farmers market their own produce. Generally this is centred around the massive food terminal in Toronto. Farmers deliver and sell their produce from this location. In the case of strawberries, one producer operates a "Pick Your Own" enterprise and runs a small packing operation on his farm. One small-scale vegetable farmer canvasses local supermarkets , within a 100 km. radius, to dispose of his produce.

d) Experience and Outlook of Farmers

Although Norfolk County has an agricultural history as long as that of Kent County, it has been nowhere near as stable and has been marked by periods of economic decline and extreme swings in rural population density. An element of stability and prosperity was brought to the area with the introduction of tobacco in the 1920's. The farmers interviewed for this study appear to be the rearguard of this stable period. Nine of these individuals had been farming for over 30 years and had grown up on or taken over family tobacco farms. A further four, mostly vegetable farmers had been in the business for between 15-30 years; while one speculative farmer had four years experience in the area. The long-term domination of tobacco is also reflected in the reasons given by farmers for following existing cropping patterns. Eight farmers gave the primary reason as familiarity. They had grown up on tobacco farms and it was "all they knew". One farmer gave a similar reason for producing small fruits and vegetables on an inherited farm. Later entrants to the business, who had no connection to a family farm in the area, cited best return conditions as their primary

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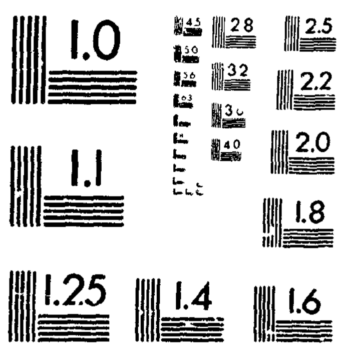

reasons for producing a particular crop. In addition, there is a general feeling among tobacco farmers that this land "is'nt much good for anything else", and they are uncertain about the future of farming in the area under alternate crops. This uncertainty is reflected in the ages of the farmers surveyed. Although five farmers were under 45 years of age, three of these were vegetable and small fruit growers. The majority of tobacco farmers were over 45; four between 46-55; four between 56-65; and one over 65. Apparently, their offspring are not willing to take over the farm and most farmers stated that they are not encouraging them to do so.

Expectedly, land-use change in Norfolk County will revolve around the future of the tobacco industry. Response to an uncertain economic climate is seen in a number of forms on the surveyed farms. Two farmers feel that expansion is the only way to remain viable in a shrinking market and are actively purchasing more land and production quotas in addition to improving and expanding their irrigation systems. On the other hand, one individual is giving up farming after this season and moving out of the region. Two farmers are considering crop changes in the immediate future. One of these is considering asparagus or grain crops, and another, peanuts or sweet corn. Most, however, stated that they have no changes in mind. There is a general "wait and see" attitude among these farmers who, in the face of uncertainty, are wary of investing in changes that could lead to economic over-extension.

3.3.3 Simcoe County

a) Irrigation Land-use

Unlike Norfolk County, Simcoe County is not characterized by the widespread practice of irrigation. According to the most recent census report, only 1326 ha. or 0.8% of the total area under crop was irrigated and irrigation was practiced on 124 or 3.5% of the farms in the county (Statistics Canada 1981). The reliability of this data is questionable at best. In surveying only 12 farms, this study covered 1092.6 ha. of irrigated land, 1088.6 ha. of which was irrigated prior to 1980.

In general, Simcoe County would be classified as a region of mixed farming. Livestock and associated large acreages of silage corn, tame hay, alfalfa and improved pasture dominate the northern half of the county. In the south, specialty crops are the norm. These include a potato belt along the Nottawasaga river flats, and vegetables on isolated pockets of reclaimed organic soils such as the Holland Marsh. Unlike Kent or Norfolk Counties, over 50% of the land is not in agricultural production.

As mentioned, a total of 12 farms were surveyed in the county. A breakdown by crop is as follows:

- 5 farms irrigated a total of 859.9 ha. of potatoes
- 5 farms irrigated a total of 208.4 ha. of vegetables
- 1 farm irrigated a total of 18.2 ha. of tobacco
- 1 farm irrigated a total of 6.1 ha. of small fruit.

Of those farms irrigating potatoes, one had less than 100 ha. under the crop; two between 100-200 ha.; and two greater than 200 ha.. The range of irrigated vegetable acreages between farms was much smaller: one had less than 25 ha.; three between 25-50 ha.; and one greater than 50 ha.. None of the potato farms irrigated any additional crops and vegetable farms produced between two to four varieties of vegetables, with each variety typically commanding an equal share of land. For the sample as a whole, the percentage of irrigated to cultivated land had a mean of 61%. This ranged from 12- 100%. In general, irrigated tobacco and potatoes accounted for less than 50% of the cultivated acreage on farms where they were grown. The remaining land was primarily comprised of wheat as a rotation crop for potatoes and rye for tobacco. Only two potato farmers produced field crops in addition to a rotation crop for potatoes. One of these had 162 ha. of silage corn, while the other farmed an additional 46 ha. of barley, rapeseed and asparagus. In contrast, the intensive nature of muck crop production is reflected in the fact that four of the five vegetable farms irrigated 100% of their cultivated acreage.

When the total farm area is considered, the average farm size for the sample is 180.5 ha., with the distribution as follows: two farms were less than 50 ha.; three between 50-100 ha.; three between 101-200 ha.; three between 201-500 ha.; and one over 500 ha.. Obviously, vegetable farms accounted for the lower extreme of this scale and potato farms, the upper extreme. All farms surveyed were owner- operated with the exception of one particularly large, incorporated farm on the Holland marsh. Although this farm had one owner, he was essentially a business manager for the farm and an attached packing plant, and retained a full-time farm manager to oversee field operations. In addition, three potato farms leased land for the production of grain crops.

b) Changing Land-use Under Irrigation

The temporal pattern of the adoption of irrigation in Simcoe County generally follows that described for Kent and Norfolk. Seven farms began irrigating between 1950-1957; three between 1963-1967; one each in 1972 and 1976; and one in 1983. Among potato and tobacco farmers, the primary reason for adopting irrigation was to reduce the risk of crop loss due to drought, while among vegetable producers, the main reason was to reduce abrasion damage due to wind erosion and to reduce heat stress in immature plants. Potato farmers generally gave a secondary reason of increasing yields, while vegetable producers stated that improved quality was of secondary importance. The primary reason of the sole strawberry producer was as a preventitive measure against frost. A significant number of individuals, and in particular, vegetable growers, adopted irrigation in the same year that they began farming. It would seem that the damages due to wind erosion are more immediately apparent than those due to moisture deficiencies. In addition, five of the farms that currently irrigate potatoes and one farm that currently irrigates strawberries initially introduced irrigation for use on tobacco in the 1950's. All of these farmers cited poor growing conditions, in the form of a short growing season and susceptibility to spring and fall frosts, as their reason for changing crops. These changes occurred between 1968 and 1974, which is generally consistent with an overall decline in the tobacco acreage in the county as a whole. With the exception of some vegetable producers, and in spite of subsequent land-use changes, all crops for which irrigation was initially adopted had been grown under "dryland" conditions. Irrigation has also had an impact on the extent of cultivated acreage on some farms. Three potato farmers stated that they had reduced their land area under potatoes by 40.5, 40.5, and 60.7 ha. respectively. Apparently, this reduction was due to increased per hectare yields since adopting irrigation. All three farmers suggested that these increased yields allowed them to satisfy existing contractual commitments on a smaller land base.

c) Marketing

Simcoe County has a strong marketing infrastructure for agricultural products. Generally, products are delivered to the final market through a "middleman". The town of Bradford, adjacent to the Holland marsh, contains a number of packaging plants for fresh produce which are utilized by most of the surveyed vegetable producers. An exception is one farmer who produces chinese greens and delivers them to specialty stores in Toronto and arranges transport of his produce to various cities along the eastern seaboard of the United States.

All of the surveyed potato farmers grew their crop under contract for a variety of potato chip manufacturers in Toronto, Kitchener and Cambridge. These arrangements are supported through brokers and storage houses in Alliston and Beeton. Although these arrangements are renegotiated annually, they generally do not fluctuate in terms of the contracted quantity of produce. As in Kent and Norfolk, the surveyed strawberry producer operated his own "Pick Your Own" enterprise which accounted for about 50% of his product. The remainder was sold through a packing house in Bradford.

d) Experience and Outlook of Farmers

The farmers surveyed in Simcoe County generally had fewer years experience in farming than those of Norfolk or Kent. Only two had been in the business for over 30 years; four between 20 and 30 years; while 5 had been farming for less than 20 years. Only four of these individuals had taken over family farms, all of which had been established for over 30 years. On three of these properties, the current operators have been responsible for changing the cropping patterns established by their fathers. With the relatively recent history of most farms, familiarity with any particular crop was not a decisive factor in establishing or maintaining a cropping pattern. Eight of the surveyed farmers cited a best return situation as the main reason for their existing cropping pattern, while three muck farmers felt that vegetables were the best use of their available land. Only one potato farmer, who had migrated to Ontario from a family farm in New Brunswick, cited familiarity and experience with the crop as the primary reason for producing potatoes. The age of those farmers surveyed is fairly evenly distributed. Although none were less than 35 years of age, four were between 35 - 45; three between 46 -55; and five between 56 - 65. Again, a relatively stable market for the crops surveyed in this county has accounted for profitable and viable farms, which offspring of those farmers surveyed are likely to continue. The relative stability and prosperity of these farms is also indicated by the immediate future plans of the operators. With the exception of one tobacco farmer no changes to cropping patterns are planned. This tobacco farmer who is nearing retirement, has begun a Christmas tree operation and is actively reforesting much of his land. In terms of physical changes however, four farmers are planning to improve and update their irrigation system. Two muck farmers who are not currently cultivating all of their owned land are planning to expand their acreage under vegetable crops. At the same time, three potato farmers are planning to reduce their acreage under crop. These farmers feel that they are over-extended with their current acreage and are attempting to reduce both risk and labour requirements to more manageable levels.

3.4 SUMMARY

The development of irrigation as an agricultural practice in Ontario was outwardly dependant on several coincident factors: the technical development and availability of irrigation equipment in the late 1940's; the occurrence of a relatively severe drought during the early 1950's which significantly reduced yields over several growing seasons; and a continuing rise in the demand and market price for specialty crops such as tobacco and vegetables. Primarily, however, the surge in irrigated acreage was initially an ad hoc crisis response to long-term drought. Since the initial growth of irrigation, the practice has largely been confined to specialty crops grown on coarse-grained sandy soils, and reclaimed organic land. Although providing unique opportunities for the production of a variety of high-value crops, these soils are subject to seasonal moisture deficiencies and wind erosion. Rather than a sporadic insurance technique, the benefit of irrigation in combatting these seasonal moisture deficits and improving crop quality yield have established it as a permanent production input on those farms where it is practiced. The future of irrigation agriculture appears to be directly linked to the general economic climate of any commodity market. This is blatantly obvious in the declining acreage of tobacco, a crop predominantly irrigated by most growers.

This study however, is concerned with how farmers irrigate, not merely that they do irrigate. Although aggregate data such as census reports aid in understanding irrigation land use, they are of little help in understanding irrigation water use. Although the nature of irrigation land management deserves greater attention from agricultural geographers, the following chapter will focus on irrigation water management in Ontario - initially within the jurisdiction of bureaucracy and then more specifically within the jurisdiction of reality as manifested in the irrigation practices of those 35 farmers described above.

CHAPTER 4

THE BUREAUCRATIC CONTROL OF WATER IN ONTARIO

An important element in understanding any irrigation system is an assessment of the ability and means of individuals, or groups of users, to control water. Control, in this sense, can be defined in a number of ways, two of which are especially important. On the one hand, it involves the techniques employed by an irrigator to command or direct the flow of water. On the other, it includes the methods used to regulate or limit the quantity of water used.

It is not difficult then, to visualize a hierarchical structure of water control. It is crowned by an individual's entitlement to exploit the resource, and based with the techniques employed by the irrigator at the field level. This structure is composed of a number of divisible parts including: an established system of water rights, a means of allocating available water supply amongst various users, and the methods used by irrigators to convey water "from the source to the goal, directing its ultimate application to the crop." (Carlstein, 1982). These procedures, according to Holmes (1986) will "reflect the interplay of the physical environment, the perceptions of this environment by farmers and the technical-scientific community alike, and the use made of perceived opportunities as these three variables affect the choices arrived at in fashioning an irrigation system."

This chapter describes the nature of bureaucratic water control in southern Ontario, initially by outlining the means of water regulation and allocation at the provincial level, and subsequently, by examining irrigator compliance with those regulations.

4.1 THE ALLOCATION OF WATER IN ONTARIO

Historically, the ability to utilize surface water and ground water has been defined by different sets of rights. These rights have typically been directly associated with the land upon which the water is being used. Until recently, however, they have remained undefined in terms of quantity. The following pages, will outline the development of allocation procedures as they have evolved in Ontario.

4.1.1 Entitlement to Water

a) Surface Water Supply.

The general governance of water allocation in Canada's humid regions has emerged historically from the English common law doctrine of riparian rights. Although this doctrine has been subject to considerable interpretation and modification, simply stated, it accords to the owner of land by or across which a stream flows, the full flow of the stream, undiminished in quality and quantity except by "normal" uses which include domestic use, watering stock, and minor gardening. It has typically excluded large-scale irrigation and industrial use. Thus, the riparian system "entitles owners of riparian land to use the water flowing past, in a reasonable manner, on their land, subject to the same rights being available to other riparians" (Gilchrist 1983). Consequently, a riparian owner does not own the water. He simply has the right to use the water. Obviously a strict interpretation of this doctrine provided little security for irrigation use as it is impossible, due to natural transfers of water, to return the resource undiminished in quantity or quality to the source. Over time, and particularly after the industrial revolution, this interpretation was modified to distinguish between unreasonable and extraordinary use. Burchill (1948) cites an 1859 decision by Lord Kingsdown, a judge of the Privy Council, which distinguished between rights to ordinary or reasonable, and extraordinary use. This decision implied that:

> "any riparian proprietor could take the water of his stream... and could use it for any extraordinary purpose, including irrigation. Other riparian proprieters could indeed prevent such use, but only if they could prove sensible damage resulting from the interruption of the natural flow." (Burchill 1948).

Until 1961, this was the system which controlled the allocation of surface water for irrigation in Ontario. Entitlement was based on location, and amount was not determined absolutely, but through the minimization of conflict as determined in a court of law. The allocation of groundwater, however, has a different story.

b) Ground Water.

The allocation of ground water for any purpose including irrigation has traditionally been subject to the rule of capture and is based on the concept of absolute ownership. Again, simply stated, the owner of overlying land has the right of free access to groundwater if he can contain the supply on his property. Thus, the rights to use groundwater for irrigation are more secure than a surface source as:

> "the owner of land containing underground water which percolates by undefined channels and flows to the land of a neighbour has the right

to use for any purpose, divert, appropriate or sell the percolating water within his own land..."(Irwin 1974).

Consequently, appropriators who suffer a loss or reduction of supply due to the actions of other appropriators have no legal recourse to claim damages or reinstate supply. They are only entitled to the amount that they can capture on their property at any point in time. As with surface ater, entitlement to water is based on location. Conversely, however, the amount is not determined by infringement on the rights of oth but is controlled solely by the availability of supply.

The conditions of groundwater allocation outlined above pertained to the withdrawal of water for the purposes of irrigation until 1961. Today, the procedures for the allocation of water in Ontario have been modified by the introduction of provincial water legislation. This modification and its application to the use of irrigation water are cutlined below.

4.1.2 Modification of Water Rights

In 1956, the Ontario Water Resources Commission was established and given a broad range of duties; primarily, the responsibility to exercise supervision over water resources in Ontario, including water supply and waste disposal and to control the use of water. On March 29, 1961, an amendment to the Ontario Water Resources Commission Act was legislated, authorizing the regulation of water takings from any source of supply. Out of this legislation, grew the Permit to Take Water Program described in Chapter 2. This legislation is now designated as Section 20 of the Ontario Water Resources Act (Revised Statutes of Ontario 1980) and the program is administered by the

Water Resources Branch of the Ontario Ministry of the Environment (M.O.E.).

This legislation and the advent of the permit program were essentially responses to the increasing demands placed on the available water supply during the 1950's. Most of this demand related to the growth of irrigation during this period and "particular attention was given to withdrawals of water for irrigation" (Canadian Council of Resource Ministers 1966). A major impetus for the program was a perceived failure of the judiciary to resolve disputes arising from conflicting uses. As Jensen (1977) suggested, the courts were available to settle disputes between users, but they were not equipped to provide the needed administration and management of the water resource. Legal decisions were not necessarily precedent setting. They were bound only to deal with individual disputes and concerned with the local circumstances affecting those disputes alone. Users not party to these disputes were not subject to the decisions resulting from arbitration. The Permit to Take Water (P.T.T.W.) Program under the Ontario Water Resources Act was an attempt to make up for this uncertainty inherent in the riparian doctrine. Specifically, the need was for an institutional arrangement to administer and control water allocation and use through a centralized office of record (Jensen 1977).

Consequently, the P.T.T.W. program was designed to satisfy these requirements but also to fulfill the role of adjudicator in the event of disputes over water rights. As such, in Ontario, the property in water is not vested in the Crown. Unlike the western provinces, the Ontario Act states that the Minister of the Environment has the supervision of all surface and ground water in Ontario, and is responsible for the administration of water law. (Beerling 1984).

The introduction of this legislation in 1961 altered pre-existing water rights in a number of ways and established a definite order of priority in the uses to which water could be put. This priority can be defined in terms of classification under the water legislation as those that are exempt from control and those that are subject to control. Under Section 20 of the Ontario Water Resources Act, a permit is not required for:

i) takings by an individual for ordinary household purposes.

ii) takings for the watering of livestock or poultry; and

iii) takings for fire-fighting.

All other uses are subject to control under the legislation. Based on an application and review process described below, the legislation also fixes an absolute amount to the withdrawal of surface and groundwater.

In the case of groundwater, the permit program is designed to provide protection to prior users of the water resource, a protection generally lacking under common law (Ontario Ministry of the Environment 1984). For example, a user procures the right to a certain amount of water that underlies his land by acquiring a permit. If a subsequent user who acquired the right to procure water at a later date interferes with the supply of the initial user, the later appropriator is responsible for restoring that supply or reducing the taking so as to eliminate the interference. Thus, all costs of restitution are borne by the later user. In essence, the legislation has borrowed the doctrine of "prior appropriation" (ie. Burchill 1948, Mead 1903 and Weatherford and Ingram 1984) from arid western lands and applied it to groundwater in Ontario. This doctrine follows the often-mentioned rule of thumb, "first in time, first in right" (Andrews 1970), so that priority of time is a basic consideration in the entitlement of an individual to a certain amount of water. Today then, the "rule of capture" still applies to groundwater and location is still a factor in entitlement. Legislation, however, protects that right by limiting the abilities of others to impinge upon it.

While the water permit legislation has effectively created a new system of water rights affecting the use of ground water, it has not had such a drastic effect on surface-water rights. Ministry of Environment publications stress the point that the legislation:

> "does not supersede the common-law riparian rights to the use of water, but is an added control. A person must comply with both and would generally be subject to the more limiting provisions. Thus while riparian rights are not superseded, they may be limited in some cases by the permit legislation" (Ontario Ministry of Environment 1984).

For example, although entitlement is still based on location and availability of supply, the permit legislation fixes an absolute amount to the right, in time and space. This amount, however, is used only as a basis to avoid or resolve conflict in the case of interference of the water supply to other users. Moreover, it is only effective when a complaint is filed with M.O.E. or visible impairment of flow is readily obvious. Until this occurs, allocation is governed by the availability of supply under the doctrine of riparian rights. As such, the P.T.T.W. program has not modified the riparian doctrine to any great extent, and as Vallery (1987) states, "it has not allocated water, but is an administrative tool that has not really been put into effect. More than anything else, it is a leverage instrument that can be used if conflict comes to the attention of Ministry officials."(my emphasis)

Thus, we have an admitted situation in Ontario similar to that which has been noticed elsewhere:

> "...water rights patterns do not accurately portray actual water demand, but rather represent a cumulative legal record of water development... (and) the principal use of these records has lain not in the comprehensive management of the public's resources, but in the resolution of private disputes by water managers in the field and water lawyers in the courts"(Wescoat Jr. 1984).

A problem arises then, when the permissible withdrawal figures recorded as water rights are used to reflect actual water demand. Unfortunately, these figures seem to be carved in stone once they are recorded and have been used to approximate the use of irrigation water in at least two Ontario river basins. Pirie (1975) in an examination of irrigation water use in the Thames River Basin utilized data "obtained from information on file with the Ministry of Environment, including applications for Permits to Take Water and records of water taking submitted by permittees." In a similar study of water demand in the Grand River Basin, Fortin and Veale (1983) assumed that:

> "the maximum daily withdrawal of water approximated the daily rate of withdrawal authorized by permit...(and) by multiplying total water takings allowed for each sub-basin by the average number of days per season required for irrigation...total water demand was estimated."

To suggest that the allowable withdrawal by permit approximates the actual use of water for irrigation in any watershed, ignores the conditions that create the demand and influence the use of water in that area. The degree to which the permit actually reflects these conditions can be clarified through:

i) an examination of the permit application process;

ii) a comparison of the actual amount of water used in irrigation with that allowed through the permit; and

iii) the extent of irrigator compliance with the permit conditions.

These issues will be taken up in the following pages.

4.2 IRRIGATOR COMPLIANCE WITH BUREAUCRATIC REGULATION

Although the Ministry of the Environment has developed a multi-step process in the issuance of a Permit to Take Water (Appendix IV), this study is primarily concerned with the application stage. It is at this point that the applicant requests permission to withdraw a specific amount of water per day, and the remainder of the permit process is based upon this request. In the case of irrigation water use, however, there exists a discrepancy between the manner in which the Ministry requests or expects applicants to define their water requirements and the manner in which the applicants themselves define their requirements. Section F of the permit application requires the applicant to specify the amount of water taken from each source that he plans to use. This calculation is based upon the maximum amount of water taken in one minute multiplied by the number of hours of taking in one day. This calculation, thereby, yields the maximum amount of water taken in one day. To complete this calculation, the applicant must have a knowledge of the rated capacity of the pump being used to withdraw water from the source.

A problem arises, however, when it is realized that this is not the manner in which farmers determine their water needs. Although not directly asked in this survey, another recent survey of Ontario irrigators (Ontario

Ministry of Agriculture and Food 1986) requested respondents to provide detailed information on their pumps. Not surprisingly, these questions had an extremely low response rate and it was found that most irrigators did not know the rated capacity of their pumps. Rated capacity is not a common parameter used in pump operation, but is sometimes used in comparing and selecting pumps and in irrigation system design. Thus, the Ministry's technical method of determining need is not in harmony with the knowledge of the farmer. Indeed when the respondents to this survey were asked how they calculated the amount of water to apply for on the permit, only 2 (6%) replied that they used pump capacity as a base. The remainder stated that they could not remember or suggested that it was a rough guess.

Conversely, most farmers know, in a sense, how much water they are using on their fields. Although not able to state a specific volume, all of the respondents operated their irrigation systems according to the time required to apply a specific depth of water to a specific area of land. These parameters, of course will vary with each individual irrigator, but it is possible, using this information, to calculate a specific volume of water used per day of irrigation. The resulting figure can then be compared with the allowable withdrawal authorized by permit for each respondent. The formula used to complete this calculation follows:

i) Litres/Day = Gallons/Day x 4.546 = (T.V./I.D)

where: 1 Imperial Gallon = 4.546 Litres.

T.V. = total volume of water required to irrigate a certain area to a specific depth.

I.D. = number of days to completely cover a certain area to a specific depth.

and:

ii) T.V. = Area x D (22,690)

where: Area = total area to be irrigated.

D = depth of water to be applied.

22690 = volume of water (gallons) required to apply 1 inch of water to 1 acre of land.

As all respondents provided their answers in imperial units, the calculations were completed using those units and converted to a metric measure once the calculation was solved. If in the future, metric measures are provided by respondents, a suitable conversion factor would be:

1 hectare centimetre equals 100,345 litres.

The results of these calculations for each of the 35 respondents are shown in Table 4.1. It should be noted that when respondents, reporting more than one irrigated crop differentiated between crops when irrigating, the calculation was completed for each crop and the maximum amount included in the Table. Similarly, when irrigators reported that they applied different

TABLE 4.1

COMPARISON OF AMOUNT OF WATER USED ON SURVEYED FARMS
AND PERMITTED AMOUNT

Location	Respondent	Calculated Use Per Day (Litres)	Permitted Withdrawal Per Day (Litres)	▲ Litres	% Use Less Than Permitted Amount	% Use Greater Than Permitted Amount
Kent	1	1,162,768	930,112	232,656	--	25.0
	2	1,031,487	872,832	158,655	--	18.2
	3	1,773,616	1,472,904	699,288	--	47.5
	4	1,160,423	668,262	492,161	--	73.6
	5	928,339	1,963,872	1,035,533	52.7	--
	6	1,060,958	576,069	484,889	--	84.2
	7	1,031,487	1,635,293	603,806	36.9	--
	8	876,764	654,624	222,140	--	33.9
	9	2,459,500	2,176,625	282,875	--	13.0
Simcoe	1	7,736,156	5,236,992	2,499,164	--	47.7
	2	1,547,231	2,454,840	907,609	36.9	--
	3	8,251,899	3,391,316	4,860,583	--	69.8
	4	928,839	3,432,230	2,503,891	72.9	--
	5	1,031,487	545,520	485,967	--	89.1
	6	12,571,253	6,546,240	6,025,013	--	92.0
	7	6,769,186	4,364,160	2,404,976	--	55.1
	8	9,283,387	10,801,296	1,517,909	14.1	--
	9	1,856,677	327,312	1,529,365	--	467.2
	10	2,475,570	2,543,789	68,219	2.7	--
	11	2,873,429	7,500,900	4,627,471	61.7	--
	12	3,094,462	UNKNOWN	--	--	--
Norfolk	1	1,211,998	UNKNOWN	--	--	--
	2	677,835	2,045,200	1,367,865	66.9	--
	3	1,909,320	1,237,785	671,535	--	54.3
	4	618,892	4,227,780	3,608,888	85.4	--
	5	593,105	2,000,240	1,407,135	70.3	--
	6	1,547,231	1,663,836	116,605	7.0	--
	7	4,641,693	2,727,600	1,914,093	--	70.2
	8	2,482,528	2,363,920	118,608	--	5.0
	9	1,031,487	1,545,640	514,153	33.3	--
	10	1,160,424	1,272,880	112,456	8.8	--
	11	825,190	227,300	597,890	--	263.0
	12	1,805,103	3,327,672	1,522,569	45.8	--
	13	1,521,444	1,022,850	498,594	--	48.7
	14	954,126	2,273,000	1,318,874	58.0	--

amounts of water at different times throughout the growing season, the maximum use figure is reported.

An examination of the data in the table reveals that very few irrigators are using an amount of water that even closely approximates the permitted withdrawal. Slightly over half of the respondents are using more than permitted while 45.5% are using less than the allowable withdrawal. The magnitude of this deviation from prescribed amounts also varies to a large extent. In relative terms, for those using more water than permitted, the variation ranges from 5% to 467% of the permitted withdrawal, while for those using less, the range is from about 3% to 85%. In terms of location, 78% of the surveyed farmers in Kent County are using more water than permitted. This drops to 55% of the respondents in Simcoe County and 36% in Norfolk County.

There exists then, a situation where, except in a few cases, the amount of water allotted by permit, does not reflect the actual amount of water used in irrigation. Thus, it can be deduced, that the use of water is not being governed by what Chambers (1977) has termed "bureaucratic allocation", but by the farmers estimation of micro-scale physical and socio-economic conditions. Chambers (1977) would account for these discrepancies in terms of the "geographical gap between the last point at which it (water) is officially controlled or measured and the point at which it enters a farmer's field." This would suggest that the ability to control water or enforce conformity with allocation procedures is limited when the agency which allocates water is not the same as the agency which controls the distribution and delivery of water to the point of use.

Unlike large-scale and arid region irrigation systems, Ontario has no controlled canal networks into which water is diverted and from which water is withdrawn for the sole purpose of irrigation. Distribution and delivery of water for this purpose occur through natural channels. Diversion and withdrawal, consequently, are controlled by the appropriator alone. They are not metered, measured or supervised by any communal or bureaucratic authority. The permit program attempts to compensate for this lack of control by basing allocation on the request of the user and modifying the permitted amount according to conditions of potential or actual conflict with other users. The resulting figure should yield the amount of water being withdrawn from the source at the point of use. The problem, as described above, is that the permit mechanism presumes a knowledge on the part of the farmer, which commonly does not exist. Based on this presumption, the permit, of course, neglects the primary factor which does influence the amount of water withdrawn from a source. That is the amount of water applied to a crop. As shown, this can easily be determined using information with which the appropriator is familiar.

Again, Chambers (1977) would attribute this problem of definition to an organizational gap "between what happens at the level of senior officials and what happens in the community which receives water." O'Mara (1984) takes this argument one step further by rightfully suggesting that farmers are better informed about their water requirements than irrigation bureaucrats or engineers. Hence, a system that is responsive to a farmer's information and demand is far more likely to "achieve an efficient allocation than any system which pre-supposes superior information and decision-making capacity on the part of the irrigation bureaucracy."

In short, for reasons outlined above, we can suggest that the permit mechanism operating in Ontario does not control or regulate the use of water for irrigation in any practical sense of the word. Thus, studies of water use and demand which rely upon data supplied through the permit program are suspect due to an ignorance of actual water use practices. In fact, studies which concern themselves with this data are not examining patterns of water *use or demand* at all; they are merely interpreting the pattern of *water rights* in an area. These "rights" have been determined by a bureaucratic agency which in turn, has not concerned itself with the operating practices of irrigating farmers.

This is by no means a recent discovery, nor is it unique to Ontario. In the early years of this century, Mead (1903), while examining the development of irrigation in the western United States, suggested that records of water rights are primarily the tool of bureaucratic institutions and in no way reflect actual patterns of use. Along the same lines, Mass and Anderson (1978) strike a note of concern against making inferences about water use that are derived from water rights analysis:

> "There is a difference between legal concepts of water rights and water practices, and many students of irrigation have overstressed the importance of rights about which they can write at length without leaving their desks"(Mass and Anderson, 1978).

In the case of Ontario, stipulations of the Permit to Take Water can be considered as synonymous with records of water rights. Their continued employment as sources of data, however biased, is not surprising as they are readily available and documented, and avoid the labour and expense of employing "platoons of recorders and vast data-handling systems" that would be required to describe actual water-use patterns (Wescoat Jr., 1984).

To this point, the discussion has suggested that the permit program is ineffective in regulating or controlling water use. But what of the farmers? How do they rate the effectiveness of the permit program? Does the permit influence their actions in using water? A consideration of these questions will be the subject of the following section.

4.2.1 Attitudes of Respondents Toward Bureaucratic Regulation

Surveyed farmers were asked if they felt that the Permit to Take Water Program was an effective method of managing and protecting the use of irrigation water, and what changes to the program they might suggest. Responses to these questions are found in Table 4.2 and 4.3. The majority of farmers thought that the program was not effective (54%) or were unsure of its effectiveness (20%).

Those respondents who felt that the permit was an effective management tool formed a definite minority (26%). This pattern generally holds true for two of the three areas under study with the exception of Simcoe County where a higher number of respondents felt that the program was effective.

Of those farmers who felt that the permit program was an effective mechanism, most simply stated that there was a need for some form of management or allocation and did not refer directly to the permit program. Three respondents suggested that there was a need to know how much water

TABLE 4.2

PERCEPTION OF EFFECTIVENESS OF PERMIT TO TAKE WATER PROGRAM ON SURVEYED FARMS

	Number of Respondents				
Location	Effective	Not Effective	Unsure	Changes to Program	
				Yes	No
Kent	2	5	2	2	7
Simcoe	5	4	3	8	4
Norfolk	2	10	2	7	7
Total	9 (26%)	19 (54%)	7 (20%)	17 (49%)	18 (51%)

TABLE 4.3

PROPOSED CHANGES TO PERMIT TO TAKE WATER PROGRAM ON SURVEYED FARMS

	Number of Respondents by Proposed Change					
Location	Discontinue Program	Should Only Apply to Surface Sources	Should Only Apply in Periods of Demonstrated Shortage	More Enforcement	More Communication	Provide Incentive to Conserve
Kent	--	1	--	1	--	--
Simcoe	2	1	1	2	3	--
Norfolk	2	2	1	2	--	1

was being withdrawan for irrigation, while two specifically mentioned that there was a need for a check on over-use or in the words of one respondent, to "protect one farmer against another." Similarly, one irrigator felt that if there were no program, there would be a greater occurrence of stream blockage or complete interference of flow. Only two of the respondents felt that the program was an effective management tool because it had modified their actions. Both of these farmers were located in Simcoe County and neither had acquired a permit until a complaint was filed with M.O.E. against their taking of water. One of these respondents had been damming hand-dug drainage ditches which he had constructed himself and although he did not know who made the complaint or why, he did not see the need for acquiring a permit to take water from this source which was the pure result of his labours. In the second case, the respondent had been blocking a natural stream and depriving a neighbour of sufficient supply for stock watering. The neighbour filed a complaint and a Ministry official attempted to resolve the problem by requiring the maintenance of downstream flow and reducing the number of hours per day that the irrigator could pump from the source. The irrigator's response to this restriction was to construct a reservoir on his property and to pump his maximum allotment from the stream into this reservoir to ensure a sufficient supply for irrigation. The respondent however, did not acquire a permit to withdraw water from this subsequent source, which would technically be required under the permit legislation. This situation then provides an example of the hazards of associating permit data with water use. According to permit data, this respondent may only withdraw 327,312 litres/day from a stream source but in actual fact, when irrigating, withdraws over 1.5 million litres/day from his reservoir. This accounts for a use that is more than four times the permitted value, as seen in Table 4.1. The authority-response relationship illustrated by this example, echoes Wescoat's (1984) observation in the Colorado River Basin, that hierarchical elements of water control tend to alter local action by "invoking strategic behaviour among participants in the allocation process."

In summary then, those irrigators who responded that the permit program was effective, generally based their answers on the need for some form of allocation and maintenance of flow and not on direct experience with resolution of conflicts or compliance with the requirements of the permit program. Only two of the respondents mentioned that the permit was effective because of direct contact with enforcement procedures. Similarly, those respondents who were unsure about the effectiveness felt that there was a need to regulate or monitor the withdrawal of water but all seven questioned the validity of the permit mechanism as a management tool. The main reason for this view was a perceived lack of enforcement of permit conditions and requirements. Two of the respondents stated that they knew of a number of people in their immediate area who did not have permits and one farmer was concerned that he did not know whether his neighbours had permits or how much they were allowed to withdraw. Another respondent insightfully suggested that until a severe shortage of water prompts a battery of conflicts and complaints, "we'll never really know if it works." This comment is similar to the view of one employee of the Water Resources Branch that the P.T.T.W. program has never been seriously tested since its inception. (Vallery 1987 personal communication).

For several years following the introduction of the P.T.T.W. program, the Ministry required irrigators to submit annual records of water taking, both to aid in resolving interference problems, and to provide data for water management and planning studies. However, these records used pump capacity as the withdrawal criteria, which casts a shadow of doubt on the validity of these records for reasons previously discussed. This part of the program has been discontinued in recent years due to what Vallery (1987 personal communication) terms a priorizing of programs within the Ministry in recent years. Tabulating these records was an extremely time-consuming task and in an effort to conserve resources within the Ministry, the filing of water withdrawal records has been terminated.

Two of the respondents who had faithfully submitted annual records of withdrawal were dismayed when told that these records were no longer needed. One of these irrigators legitimately questioned how withdrawals could be monitored and regulated when there is no knowledge of the amount of water being appropriated at any particular place or time. The other respondent, a retired school principal, was allegedly informed by the regional M.O.E. office that he might as well stop sending in records because "no one else is doing it." This irrigator wondered how an attitude of resource stewardship could be fostered if the government agency that supposedly promotes reasonable and beneficial use has adopted this position.

Generally, most farmers who were uncertain as to the effectiveness of the permit program in managing the use of water, declared a desire for some form of regulation or control over the allocation or appropriation of water. Their impression, however, is that a lack of enforcement of the terms and conditions of the permit and a lack of commitment on the part of the

Ministry does not provide this control.

The majority of respondents felt that the permit mechanism was ineffective in managing the use of irrigation water. To a large extent this reflects their perception of the need for regulation of water use and the degree to which they comply with the terms and conditions of the permit. Eleven of the respondents suggested that they have in the past, and will continue to use as much water as they need to cover their fields regardless of "what the permit says." Contrary to those who perceive the permit program as an effective management tool, most of the respondents in this category viewed the permit and withdrawal records as "just more paperwork", or "just another bunch of forms" that are only used "to keep the bureaucrats busy." Accordingly, ten of the respondents stated that, although they had received "threatening" letters from M.O.E., they had never submitted records of withdrawal. Of those few who had submitted records, all suggested that they were rough estimates which were not completed at the end of the day of irrigation but usually completed two or three months after the irrigation season had ended. Again, this attitude towards withdrawal records limits their worth as a valid data source for water-use studies. In addition, two of the respondents stated that they had not bothered to renew their permits since the original had been issued, but had continued to withdraw water and had never been bothered by Ministry officials. Another two respondents cited an observed non-compliance of other irrigators as evidence that the permit program was not effective in controlling withdrawals.

Typically then, the degree of effectiveness of the permit program is seen by the surveyed farmers to be a function of several factors that are not necessarily related to water rights. Most respondents generally perceive the permit program to be ineffective because of a lack of compliance on the part of themselves and other farmers. In turn, they feel that this lack of compliance results from a failure on the part of the Ministry to enforce the terms and conditions of the permit.

As a supplement to the effectiveness question, farmers were asked how the permit program might be beneficially changed. In response, about half (49%) of the irrigators recommended some form of change while the remainder (51%) did not. The proposed changes are listed in Table 4.3 and range from a discontinuance of the program to greater enforcement of the permit legislation. In a number of cases, respondents suggested more than one change. Four (24%) of the respondents felt that there was no need for the program and that it should be discontinued. All of these farmers stated that they would not comply with any program which tells them what they can or cannot do and that changes would not make any difference to their withdrawal practices. Six (35%) of the respondents suggested that the permit conditions should only apply in certain situations. Four of these farmers, who relied upon groundwater sources of supply, felt that the permit should only apply to those irrigators using surface water supplies where it was likely that the stream would run dry and conflicts could arise. Similarly, two of the respondents suggested that permits should only be enforced in periods of demonstrated water shortage. Perhaps surprisingly, five (29%) of the respondents called for more enforcement of the program. These irrigators, however, generally referred to cases of other appropriators who had consistently blocked streams for irrigation purposes. Interestingly, their concern was not that they were being deprived of water but was based on the belief that a continuous flow should be maintained for instream uses. An additional three (18%) respondents suggested that there should be better communication between the Ministry and farmers. Two of these respondents did not acquire permits until after they had received a "nasty visit" from a Ministry official and the other did not have a permit at the time of the interview. In the words of one respondent, "how was I supposed to know that I needed one." An additional respondent who felt that the permit program was ineffective thought that it should provide some incentive to conserve water although he could provide no method by which this could happen.

Although respondents were not asked why they would not suggest changes to the program, it could be presumed that at least some irrigators are satisfied with the status quo. Their use of water is not being hindered by the existing means of bureaucratic allocation and they see no reason to change that system. In the words of one of these irrigators, "I'm happy with the way things are." Although not directly complying with the permit requirements, it is possible that some irrigators find security in the permit as a means of protection against someone impinging on their "fair share".

In summary then, the majority of irrigators do not view the permit program as effectively managing the appropriation of water for irrigation. This is based on a perception that the permit is an attempt to control their use of water which through a lack of enforcement, fails to accomplish this goal. Of those farmers suggesting changes to the program, the majority saw a need for enhanced enforcement or control over the abuse of water resources, but few saw a need for enforcement of the permit in their individual and collective cases. An example of this is the recommendation of groundwater users that the permit should only be enforced in areas where there is a heavy concentration of withdrawal.

In general, there seems to be a misunderstanding among irrigators of the nature of the Permit to Take Water Program. The majority see it as an attempt to limit their use of water, when in fact it does not, nor can it hope to do any such thing. This confusion and misunderstanding can be clarified by examining the institutional content of the program.

Through legislation, the mandate of the Permit to Take Water Program is "to control the taking of water to promote its efficient development and beneficial use" (Ontario Ministry of the Environment 1984). With this statement in mind, the perception of surveyed irrigators that the permit program is an attempt to control their appropriation of water would be correct. However, as Orsburn (1977) has suggested, although legislatures pass water laws which government agencies must enforce, rapid implementation of these programs is rare. Even assuming that these agencies and programs have been adequately funded and staffed, Orsburn argues that administrative procedures, stated objectives and justification statements can be technically incorrect and often represent physical impossibilities in the real world.

The notion that the taking of water can be controlled, in any practical sense of the word, represents a physical impossibility in the "real world" of irrigation in Ontario. The reasons for this, as they relate to the absence of any structural form of water delivery, have been described previously. Thus, as the stated objective of the permit program is a physical impossibility, the administrative procedures have evolved accordingly. Instead of controlling the taking of water, the permit mechanism has developed into a means of controlling the abuse of the taking of water. The "front" of control is maintained by requiring all irrigators to obtain a permit which legally allows them to appropriate water but enforcement is only enacted in situations of conflict. Hence, the permit mechanism is "utilized to prevent water-supply interference problems where possible, and to resolve them when this is not the case" (Ontario Ministry of the Environment 1984).

The activation of enforcement is based on the receipt of a complaint of interference, and in the case of a conflict, the Ministry utilizes one or a combination of options to resolve the problem. Typically they would involve requiring the instigator to: acquire a permit, if not in possession of one; reduce his taking; or, in the case of several affected persons, establish a schedule of withdrawals at different times or on alternate days to eliminate the interference. Complaints of interference, however, are rare. As one irrigator put it, "what do you do? Sue your neighbour?" It would seem that the social bonds in rural communities are strong enough to overcome these problems. Even during a severe drought in 1963 when water was at a premium, few complaints were filed with the government. "It was found that, along many streams, users had scheduled their takings so that needs could be met without causing interference." (Ontario Water Resources Commission 1964). Allee (1960) reported similar arrangements, prior to government regulation, on upstate New York streams in the late 1950's. These situations would also appear to lend support to Chambers' (1977) claim that, often times, government is liable to be doing for communities what they could and would otherwise do for themselves.

Given that enforcement of the permit terms and conditions is based on complaints arising from affected parties, a lack of willingness to file complaints on the part of irrigators could partially explain the general perception of a lack of enforcement. This program itself, however, has occupied a low rung on the priority ladder of the Ministry of the Environment in recent years. Vallery (1987 personal communication) agreed that the P.T.T.W. is not really an active program and that it has been down-graded in terms of priority over the last few years. Enforcement has been left to the regional offices who decide on allocations of staff and budget for enforcement of the program. More often than not, the enforcement effort is minimal.

In light of the above discussion, the perception of irrigators that the permit is an ineffective management tool is understandable. There exists some confusion regarding the purpose of the permit and a general lack of commitment on the part of the surveyed farmers to comply. The Ministry, however, has apparently made little effort to clarify matters, either through an extension program or some form of education. This, combined with a lack of commitment towards enforcement has resulted in a sizeable number of "violations" due to a general lack of awareness and sheer indifference.

4.3 CONCLUSION

Recall the hierarchy of control outlined in the opening pages of this chapter. It was suggested then that control of water involved, among other things, an entitlement to exploit the resource through an established system of water rights and a means of allocating water among users. Initially both of these functions existed in the form of riparian rights as interpreted through common law. For all intents and purposes this is the situation that exists today. Few if any practical changes have occurred in the water rights systems governing the use of surface water. Although the rights to ground water have been altered, this has not arisen out of any great concern for the promotion of "efficient development or beneficial use" but merely to guarantee some form of protection of available supply to those who have made the investment in capturing the resource.

The kinds of changes that have occurred have typically been of an evolutionary institutionalizing type and have resulted from a desire on the part of government to control or regulate the withdrawal of water. This has resulted in the development of laws which have attempted to codify traditional water rights and have removed the authority over water from the arena of public litigation and placed it in the hands of a government bureaucracy. This bureaucracy, in the form of the Ministry of Environment, has in turn developed an administrative tool - the Permit to Take Water Program - which has defined priorities in the use of water and formalized water rights in the province. This formalism, rather than "controlling the taking of water, has resulted in the generation of what Wescoat Jr. (1984) has termed "paper rights". That these paper rights do not reflect actual amounts of water diverted or used has been clarified in this section by contrasting the actual use of water with "formal" rights. Thus, it can be concluded that control of water-taking through allocation does not exist in any practical form, except on paper. In fact, the permit program fulfills only one of the functions of irrigation water management as defined by Chambers (1977), that being the arbitration and resolution of conflict within communities.

That some Ministry staff appreciate and admit that this is the case is indeed commendable, however, the impression persists, among others that the program is an effective method of control. For example, in a description of water management policy in Ontario, Salbach and Dennis (1980) state that "the taking of water...is regulated by the availability of supply, the efficiency of the taking, and established uses in an area." The regulatory nature of the "availability of supply" however, is determined by the farmers perception of it, not by any definitions on the part of the Ministry and the permit program has no set criteria for establishing "the efficiency of the taking." Relying on impressions fostered by such statements, external agencies erroneously presume that the permit program provides "a mechanism for allocating available flow among users", and that:

> "a means for taking account of non-agricultural values in making decisions about the future allocation of water to agriculture clearly exists in Ontario"(Bowden and Anderson 1985).

Similarly, water agencies tend to rely on data generated by the program (eg. Fortin and Veale 1985, Pirie 1975 and Yakutchik and Lammers 1970). This data, however, only reflects the formalism of water rights and not actual patterns of use, yet it presents a path of least resistance and effort for researchers. The end result is that water management studies are being based on information that has been generated by "water professionals" for "water professionals" in ignorance of the actual practices of the real "water managers", the farmers.

In short, it would appear that the primary goal in maintaining the permit program is not that the taking of water should be controlled or allocated fairly and efficiently, but that water professionals should believe that this is the case and feel that they have an accurate figure of the amount of water being used for various purposes in the province.

That irrigating farmers tend to perceive this lack of commitment while the "water professional" does not, tends to demonstrate the closed system of investigation within which most water studies operate, and points to the importance of understanding the nature of water control as it exists in the hands of local irrigators. This control will be examined in the following section through a discussion of on-farm water-use practices.

CHAPTER 5

ON-FARM MANAGEMENT OF IRRIGATION WATER

In the realm of reality, farmers in Ontario effectively control the flow and use of irrigation water. In an effort to describe this control, this chapter examines the management of water at the farm level. Discussion is based on the responses of 35 surveyed farmers and includes an examination of: the farmers' knowledge and perception of the water supply; the range of alternatives considered by irrigators in the case of water shortage; sources of water supply; techniques used in watering fields; factors which influence the scheduling of water applications; and the amount of water utilized on irrigating farms.

5.1 WATER SUPPLY

Unlike the majority of irrigation systems operating in the world today, the practice of irrigation in Ontario has typically not relied upon government agencies or community organizations to develop structures of water supply and delivery. The reasons for this anomaly relate directly to the historical development of irrigation and the availability of supply in the province. The establishment of irrigation in Ontario has not evolved from any desire to reclaim unproductive land or promote the settlement of agriculturally marginal regions, as has been the case in most arid or semi-arid regions of the world. The axiom, as Cantor (1970) put forth, is that irrigation in humid areas is essentially "a means of improving the existing kind of agriculture rather than creating an altogether new type of agriculture." In terms of supply, that "new type of agriculture", by virtue of its containment in arid regions, requires large volumes of water, commonly described in units of acre-feet, the source of which is usually a great distance from the point of application. In most societies the constraints imposed by these conditions have generally been dealt with through community organization. Initially, co-operatives of users emerge in order to legally and physically secure a source of supply and facilitate the construction of a delivery network. The nature of these organizations varies a great deal in different parts of the world. However, Thornton (1974) has proposed an evolutionary framework within which the degree of government or state involvement increases with acreage irrigated, quantity of water deployed and the complexity of technology employed in supply and delivery. Eventually, the cost of supplying water to an ever-increasing number of users becomes so prohibitive to local groups, that national treasuries must be tapped. This is generally accomplished through the pretext that supplying water for irrigation is, for several reasons, in the national interest. These reasons are usually given, in various forms, as the stabilization of both agriculture and food supply (eg. Wood 1981, Fukuda 1976). That this may not be the case has become the subject of much debate in recent years.

Conversely, in Ontario relatively small quantities of water are used in irrigating crops. Rather than "acre-feet", the common term in describing the seasonal application of water has been "acre-inches" (hectare-centimetres). This water requirement, in turn, can usually be satisfied by natural sources, either on, or a short distance from the farm property. This close proximity of most farms to a source of water tends to discount the need for the pooled financial resources or political power of community organizations. Indeed, only one such organization, calling itself an Irrigation Water Supply Association, was found in the Permit to Take Water files of the Ministry of the Environment. Although, it would have been of interest to examine the function of this organization, it did not fall within the sample areas selected for this study and as no personal name was listed on the permit, initiating contact with these irrigators would have been quite difficult.

The supply of irrigation water in Ontario then, has historically been an individual responsibility with minimal government support, and in terms of Thornton's (1974) organizational classifications can be described as private, "self-contained irrigation units serving single farms." Farmers have borne the greatest part of the cost in developing a supply of water and the result is a vast array of small-scale supply structures which dot the landscape. These supply techniques include direct stream withdrawal, pumping from bored wells and storage of water in a variety of farm ponds. The initial point in a farmer's control of water, therefore, is in developing and maintaining a secure source of supply.

5.1.1 Source of Water

Primarily, a source of supply can be seen as either surface-water or ground-water. Figures 5.1, 5.2 and 5.3 display the pattern of water supply for all of the known irrigating farms in each of the surveyed counties. This pattern is defined both by the dominance of riparian rights and by the availability of supply in each area. The riparian influence is exhibited most clearly in all three counties, where the majority of irrigators owning properties adjacent to surface streams are exploiting those sources. Conversely,

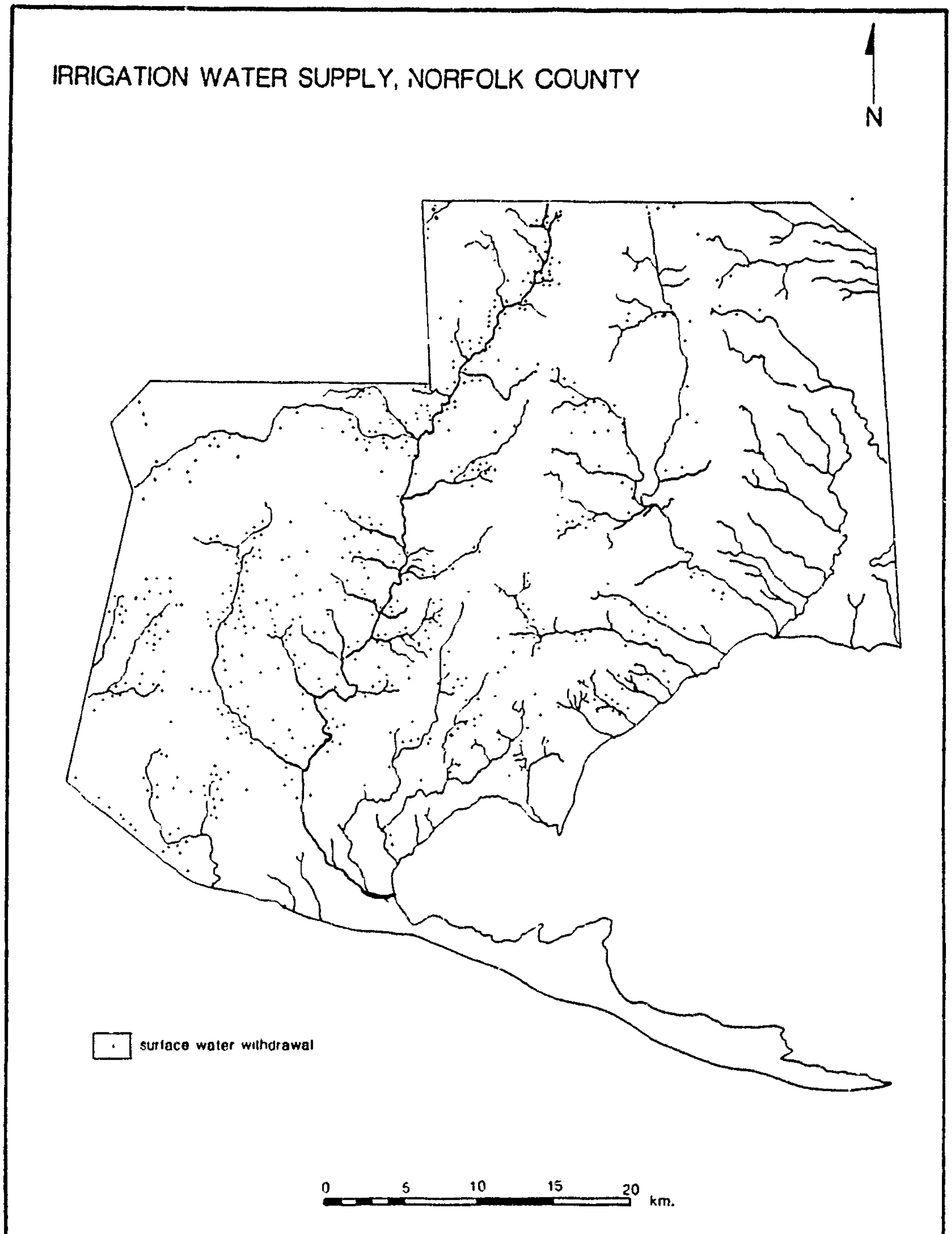
IRRIGATION WATER SUPPLY, NORFOLK COUNTY
N
surface water withdrawal
0
5
10
15
20
km.

FIGURE 5.1a

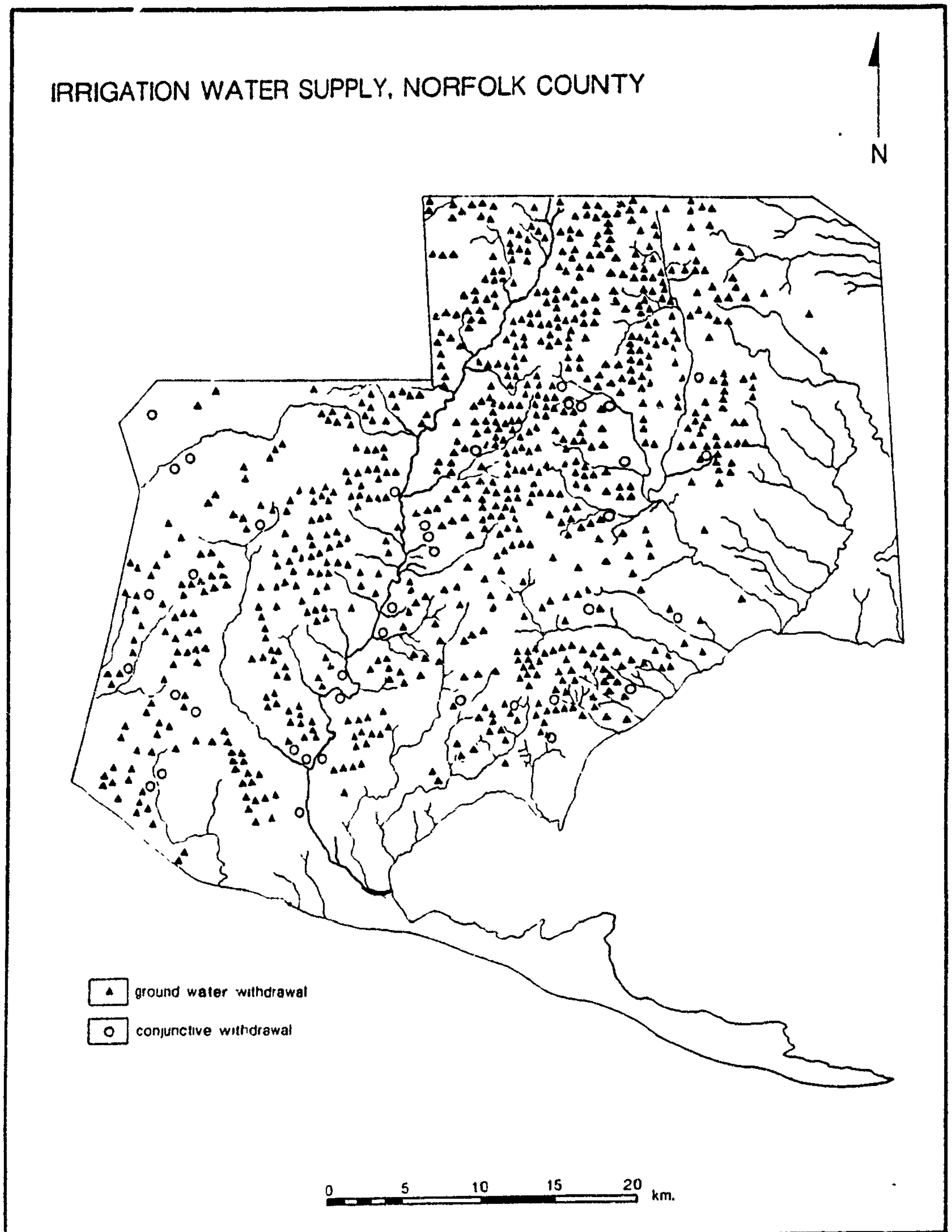
IRRIGATION WATER SUPPLY, NORFOLK COUNTY
N
ground water withdrawal
conjunctive withdrawal
0 5 10 15 20 km.

FIGURE 5.1b

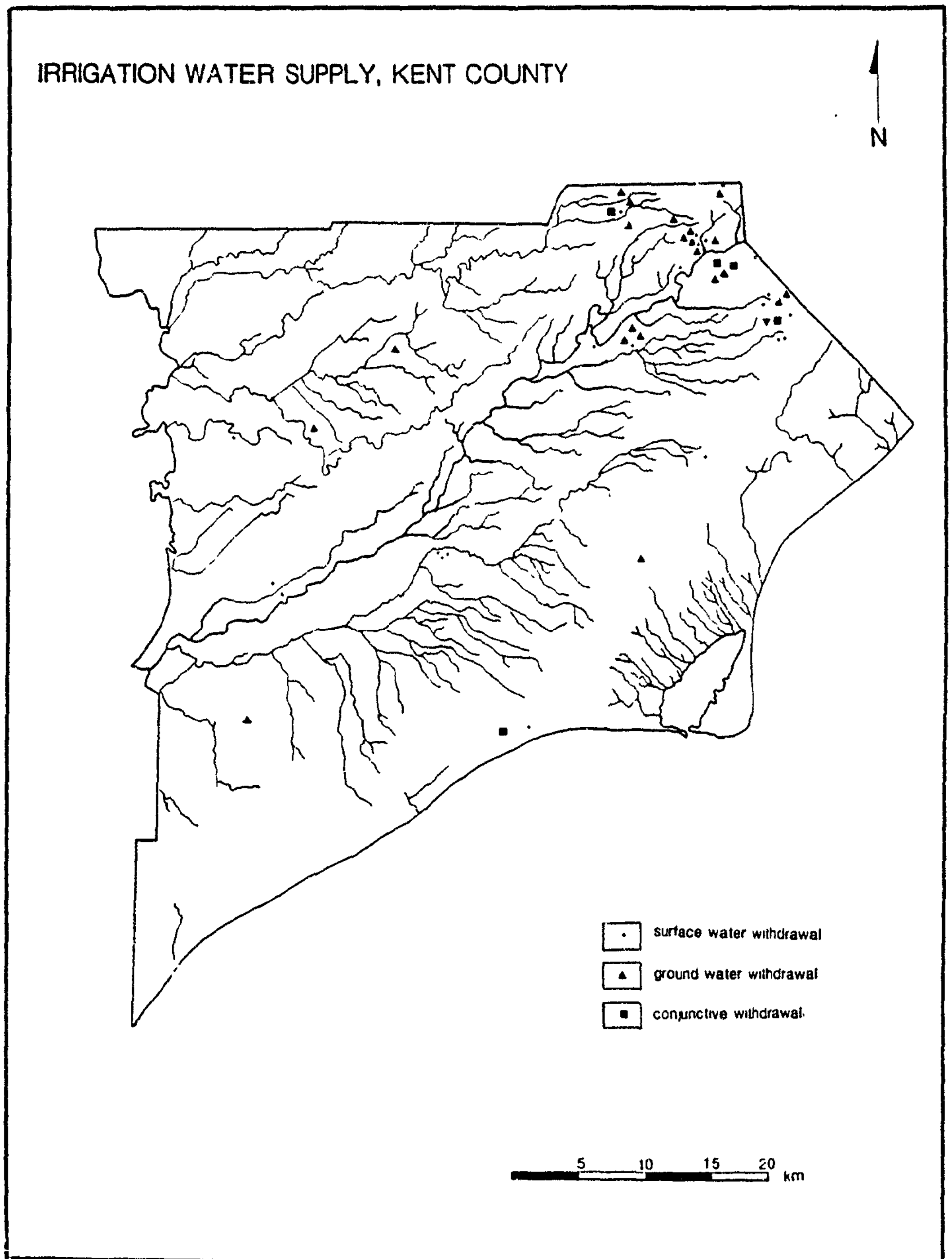
IRRIGATION WATER SUPPLY, KENT COUNTY
N
surface water withdrawal
ground water withdrawal
conjunctive withdrawal
5
10
15
20
km

FIGURE 5.2

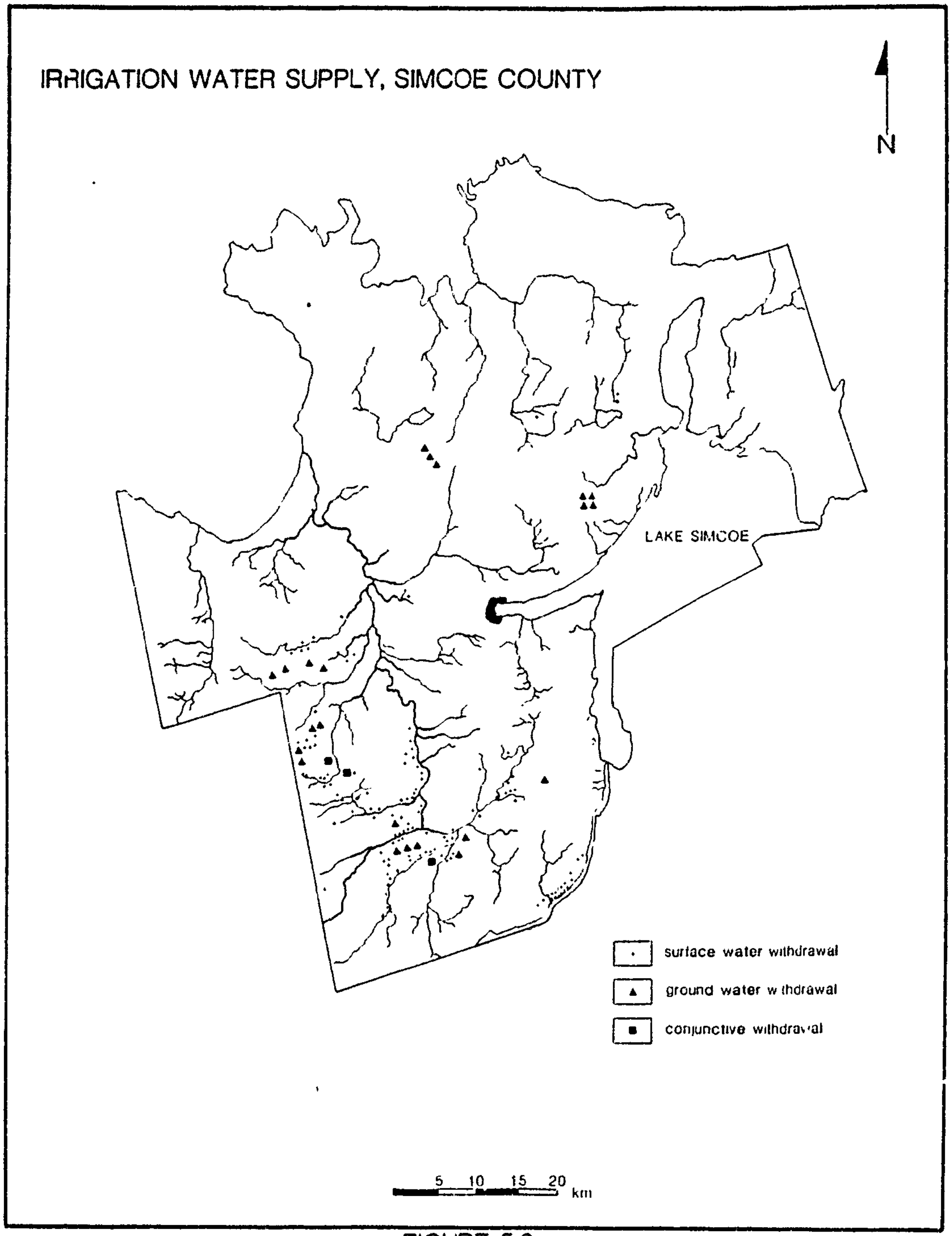
IRRIGATION WATER SUPPLY, SIMCOE COUNTY
N
LAKE SIMCOE
surface water withdrawal
ground water withdrawal
conjunctive withdrawal
5 10 15 20
km

FIGURE 5.3

those with properties not adjacent to streams commonly rely on groundwater.

To quantify the figures presented above; in Kent County, 54% of the sources exploit ground water while 46% are from surface water. Similar ratios are found in Norfolk County with 56% as ground water and 44% as surface water. Opposite conditions are found in Simcoe County where 81% of the sources are derived from some form of surface water while only 19% put ground water to use.

As irrigation was generally adopted after the farms in question had been established and was used to improve existing agricultural conditions, the exploitation of any source was limited to some degree by the location of the property. If the farm had a stream running through it, the opportunity existed to put the water in that stream to use. However, if a property did not contain a stream this did not mean that the opportunity to use surface water was precluded. Informal arrangements seem to exist in each of the three counties under study which allow the exploitation of streams by non-riparians to occur. A number of the farmers surveyed for this study confirmed observations made by the author while travelling in the irrigated areas of these counties.

Apparently, riparian owners will often grant permission to non-riparian neighbours to take water from streams on their property and transport it across their land to be used on the non-riparian property. Obviously this situation is impeded where roadways act as obstacles, but in the absence of roads, the distance of transport is only limited by the willingness of the "borrower" to pay the costs incurred through pump operation. Where this distance is not great, these costs might be less expensive than those of developing a source of supply. One irrigator in Simcoe County reported a knowledge of situations where some non-riparians have attempted, but failed, to get permission to transport water across riparian property. Not to be hindered, several of these irrigators simply run their pipe lines around the obstructing property, on public roadside land, until the road crosses a stream, and withdraw water from that point.

In another instance, one irrigator in Norfolk County reported sharing the cost of constructing a surface-water farm pond with a non-riparian neighbour in return for allowing him to transport water to his property. Additionally, two irrigators in Norfolk County and one in Kent County reported that they had lent or borrowed water from ground water supplies some time in the past. Although these situations do point to a small-scale form of co-operation in developing water supplies, such arrangements are not widespread and do not provide a great deal of security in supply, as a change in ownership of the property containing the source of water could potentially exhaust the supply of those non-owners relying upon it.

Just as the absence of a stream on a property does not necessarily preclude the use of surface water, the mere presence of a stream on a property does not necessarily provide security of supply. In most cases, irrigators in a localized area, relying on the same source of supply, will require water at the same time or within a short time of one another. Similarly, irrigation water is most commonly required at a time when stream flows are at their natural low points. These conditions seriously reduce the availability of water where the density of irrigators relying on any one source is high or where streamflow in any channel is naturally low due to a small catchment area.

In these cases, some irrigators will rely on the conjunctive use of both surface water and ground water or may rely entirely on ground water supply, even though a surface stream runs through or adjacent to their property. Both of these situations are evident in Figures 5.1, 5.2 and 5.3.

Although the main distinction in the source of supply is between ground water and surface water, there are a number of further categorizations that can be made. In an attempt to deal with the natural and man-induced vagrancies of seasonal stream flow, irrigators have come to rely on various types of farm ponds as storage reservoirs which can supply water when needed. Similarly there are various methods of exploiting ground water. These techniques, as they are found in the sample counties, are described below.

5.1.2 Storage of Water

i) Surface Water Storage

a) On-Stream Ponds - are built in the channel of permanent streams by erecting concrete or earth dams, or a combination of both, across the stream, forming a reservoir or pond behind the dam. Storage is thus contained by the banks of the drainage channel and the artificial embankment. Downstream flow is maintained by means of an outlet pipe running through the dam.

b) By-Pass Ponds - are built close to but not on a permanent stream. Water is diverted from the stream, by means of a flow deflector, through a pipe into an excavated pond. The level of water in the pond and downstream flow is regulated through an outlet control structure. The supply can be kept clean by shutting-off the intake when the stream is turbid and there is little danger of washout as excess water goes down the stream channel and not through the pond.

c) Run-Off Pond - as its name implies, this pond obtains supply from natural percolation and surface run-off accumulating at lower elevations of the field. The pond may be excavated or an embankment built to contain run-off in these low-lying areas.

ii) Ground Water Supply

a) Dugout Ponds - are commonly built where ground water exists at a shallow depth in unconsolidated sediments. A large hole is excavated into saturated sand and gravel, below the level of the water table and storage is maintained by in-flow from water bearing overburden in the region surrounding the pond. When positioned accordingly, these ponds can also capture diffused surface water.

b) Spring-Fed Ponds - store water derived from a spring usually upslope from where the pond is situated. The pond is excavated into wet hillside seepage areas in order to expose and capture the springwater, and embanked to contain the flow.

c) Wells - can be drilled, bored or driven. Drilled wells are typically sunk into bedrock whereas bored or driven wells do not usually extend beyond the maximum depth of overburden. Drilled wells are generally of small diameter with little reservoir storage capacity and typically do not yield sufficient quantities of water for irrigation. (Turner, 1981). Bored wells generally do not extend to a depth of more than 15 metres but their large diameter of approximately 3 feet provides reservoir storage capacity to augment low yields from the water-bearing formation. Driven or jetted wells (sand points) can be used when the water table exists within 4.5-6 metres of the surface. Small diameter pipe, capped by hardened points can be driven or jetted to the depth of the water table. If more water is required than one point can supply, several points can be manifolded into a common suction line where the pumping unit is located.

The extent of reliance on these structures varies between regions and is seen in Table 5.1. Data for this table was prepared using Permit to Take Water records and the limitations of this data source, mentioned previously, should be borne in mind when interpreting this data. Nevertheless, certain trends seem to stand out in the table.

The distinction between the predominance of ground water supply in Kent and Norfolk Counties and surface supply in Simcoe County can be related to the aereal extent and location of irrigated soils in each of these counties. In Simcoe County, the coarse textured soils which farmers have chosen to irrigate are seen to form a narrow band bordering the Nottawasaga River and its tributaries. The occurrence of these soils in relation to the existence of surface water sources, increases the probability that if a farmer is located on a coarse-textured soil, there will be a surface source nearby with which to irrigate it. Similarly, irrigators on the organic soils of the Holland Marsh area of Simcoe County have ready access to two main drainage canals,

TABLE 5.1 SOURCE OF IRRIGATION WATER SUPPLY BY PERCENT OF ALL SOURCES IN KENT, NORFOLK, AND SIMCOE COUNTIES

	KENT		NORFOLK		SIMCOE	
SOURCE	ALL FARMS	SURVEY SAMPLE	ALL FARMS	SURVEY SAMPLE	ALL FARMS	SURVEY SAMPLE
Dugout Pond	54%	36.25%	50%	61%	12.5%	6.2%
Well	0%	0%	6%	8.7%	6.5%	0%
Direct Withdrawal	19.5%	12.5%	18.5%	17.3%	64.5%	75%
On-Stream Pond	25%	31.25%	19.2%	8.7%	15%	18.8%
By-Pass Pond	1.5%	0%	6.3%	4.3%	1.5%	0%

one major river and a number of small drainage ditches. Conversely, the spatially ubiquitous distribution of coarse-textured soils in Norfolk County and the slightly more limited, but widespread pattern in Kent County provide potentially irrigable soils which are displaced from riverine properties. This distribution can be seen to result in an increased reliance on ground water in these areas.

Dugout ponds are the most popular method of containing ground water in Kent and Norfolk Counties. (It should be noted here that run-off and spring-fed ponds are not distinguished from dugout ponds on the Permit to Take Water, so that the incidence of these ponds is unknown. It can be presumed however, that run-off ponds are not widely used for irrigation due to the lack of recharge at a time when water is needed most). Wells are used to a minor extent in Simcoe and Norfolk Counties. The majority of wells in Norfolk, however, are in the form of sandpoints and are used to exploit the shallow water table. The wells in Simcoe County, conversely, are deep wells that have been drilled into regional aquifers by large agri-business operations. (Lottimer, 1987). Unlike most irrigating farmers, these organizations have the financial resources to construct and operate a high-capacity well. The absence of wells in Kent County would appear to be the result not only of financial limitations but also of a history of "dry holes" in the region (Fraser, personal communication 1986). This corresponds with Bowden's general observation that a farmer is unlikely to attempt to sink a well when his neighbours have not been successful in doing so.

In terms of supplying surface water, approximately 19% of the irrigators in each of Kent and Norfolk Counties rely on direct surface withdrawal while this figure rises to 65% in Simcoe County. These figures would appear to be related both to the density of irrigators and availability of supply. Although there is not an abundance of irrigators relying on any one stream in Kent County, the streams themselves are primarily short-run drainage ditches which, by their nature, supply minimal amounts of water during periods of greatest need. Conversely, in Simcoe County, the streams that are relied upon for irrigation water typically maintain an adequate flow throughout the growing season and the number of irrigators on any one stream has apparently not jeopardized this supply. In Norfolk County meanwhile, the majority of surface water withdrawers do not pump directly from streams, presumably due to a lack of security in supply, resulting from the high density of irrigators on those streams. Consequently, about 25% of the irrigators in Norfolk and Kent Counties have turned to on-stream or by-pass ponds as a means of storage while this figure is only 16% in Simcoe County. Of these two types of ponds, the majority of users have favoured the on-stream variety, presumably as they are cheaper to construct and easier to maintain.

It is of note that the development of farm ponds has not, historically, been undertaken solely by the irrigating farmer. As early as 1950, some river basin conservation authorities were promoting the construction of farm ponds as "one of the most effective ways in which the farmer...can assist in our conservation program" (Don Valley Conservation Authority 1950). These ponds were meant to serve a variety of purposes including water supply for stock-watering, fire-fighting, recreation, wildlife habitat and irrigation. In an attempt to promote their development, various conservation authorities established programs of financial support and technical advice for farmers wishing to construct ponds. In 1964, this program was transferred to the provincial Department of Agriculture who standardized a program of support for water supply providing 40% of the approved costs up to a maximum amount, which has varied over the years. For example, over the 10-year period from 1964 to 1974, this maximum amount increased from $500.00 to $1500.00 (Ontario Ministry of Agriculture and Food, 1974). In 1971, the program was expanded, under the Agricultural Rehabilitation and Development Act (ARDA), to include the construction of farm wells. Today, however, proposed water supply programs are eligible only for technical assistance in the design and preparation of plans (Fraser, personal communication 1986). Thus, although the government has supported the development of water supply on Ontario farms, this support has never been for irrigation alone, and the financial commitment has been minimal.

To summarize, the development of a supply of water for irrigation in Ontario has primarily been under the control of individual farmers with minimal community organization or public financial support. Consequently, the geographic pattern of water supply that has emerged in the province would appear to be a function of:

i) the system of water rights which defines the entitlement of an individual to exploit either surface water or ground water; and

ii) the adequacy of the entitled source of supply as determined by natural flow or yield characteristics and the number of users relying on that source.

Although informal arrangements or "illegalities" occasionally act to alter the limitations imposed by the riparian system of water rights, the general spatial pattern of water supply sources primarily reflects the geographic nature of this doctrine, with property owners on streams exploiting surface water while those displaced from streams rely on ground water. However, in areas where the adequacy of supply has been perceived to be a potential problem, farmers in the three study areas, have historically exercised a number of options. Some have foregone the right to use surface water and relied on ground water supplies. Where rights have permitted, others have practiced conjunctive use of both surface and ground water. By far the most common remedy to the problem, however, has been the construction of storage reservoirs. The type of reservoir selected is controlled by two factors. First is its suitability for the purpose of irrigation. For example, runoff ponds are not well suited to the temporal demands for irrigation water and are not widely used. The second factor relates to the personal circumstance of the irrigator and will reflect the expense and effort that an individual is willing to exert in developing and maintaining a suitable source of supply.

The influences described above have created different strategies of storage and withdrawal in each of the three counties studied. The dominance of direct withdrawal from surface water in Simcoe County is partly a function of the proximity of large streams to potentially irrigable soils and the absence of a perceived threat of flow depletion through temporarily concentrated competition for use of that source. In Kent County, there is not a great reliance on direct withdrawal from surface water simply because the majority of these sources are naturally inadequate to meet the demands of irrigation. The resulting pattern, displays a greater reliance on ground water sources and the storage of surface water. In Norfolk County, the majority of irrigators rely on ground water and surface water storage. The incidence of ground water supply, for the most part, follows the geographic rules inherent to riparian rights, while surface water storage reflects an attempt to avert the potential flow reductions caused by a high density of irrigators relying on the same source.

5.1.3 Water Supply on Surveyed Farms

As previously indicated (Table 5.1), the sources of water supply on the 35 surveyed farms follow the general patterns exhibited within each county. The absolute distribution of the sources on surveyed farms is found in Table 5.2. The majority of irrigators in Kent County depend on dugout ponds to supply ground water, four irrigators use on-stream ponds for surface water while two irrigators withdraw water directly from surface sources. In Simcoe County, most of the irrigators surveyed rely on surface water, eleven withdrawing directly from the source and three using on-stream ponds. Only one farmer used a dugout pond to supply ground water. In Norfolk County, the opposite is true with six farms relying on ground water from dugout ponds, two from spring-fed ponds and two from wells. For surface water supply, four take water directly from the source, two store water in on-stream ponds, and one relies on a by-pass pond.

Two conditions evident in Table 5.2 point to the fact that some of the surveyed farms rely on more than one source of water. That the total number

TABLE 5.2

SOURCE OF WATER BY TYPE AND LOCATION

	DIRECT WITHDRAWAL FROM LAKE OR STREAM(1)	ONSTREAM POND(2)	BYPASS POND	DUGOUT POND	SPRING-FED POND	RUN-OFF POND	BORED OR DRILLED WELL	SAND POINTS
KENT COUNTY								
a) number of farms reporting	2	4	---	7	---	1	---	---
b) total number of sources	2	5	---	8	---	1	---	---
SIMCOE COUNTY								
a) number of farms reporting	11	3	---	1	---	---	---	---
b) total number	12	3	---	1	---	---	---	---
NORFOLK COUNTY								
a) number of farms reporting	4	2	1	6	2	---	1	1
b) total number	4	2	1	12	2	---	1	6

(1) Includes direct withdrawal from local drainage ditches.

(2) Includes ponds on local drainage ditches.

of farms reporting by individual source type does not equal the total number of farms surveyed, and that the total number of sources reported is greater than the number of farms reporting by source, is evidence of this fact. Of the 35 farms reporting, 54% relied solely on one source of water, while the remainder (46%) relied on two or more sources. A breakdown by sampled county (Table 5.3) reveals that the majority (78%) of those surveyed in Kent County rely on two sources of water. Conversely, as would be expected from the previous discussion, only 25% of the irrigators in Simcoe County relied on two sources of supply. The greatest variation occurs in Norfolk County, where 57% of the irrigators receive water from one source, 21.5% rely on two sources and a total of 21.5% or 3 farmers rely on more than two sources. It should be noted that the respondent shown to be using six sources is actually using six sand points, or driven wells. Although these drive points are manifolded together to form one supply line, they are each individual wells that have their own intake line and create separate drawdown ranges. As such, each is spaced and sunk into the water table as if it were a separate well.

This multiplicity of sources of water is not, as Hudson (1962) suggested in the case of Utah irrigators, a function of farmers irrigating more than one "piece" of land. With the exception of one farmer, all of the respondents reported that they irrigated on only one parcel of land or on contiguous properties. Although some of the respondents stated that they leased additional farmland that was geographically separated from their property, this land, in all cases, was used to produce non-irrigated crops such as wheat or corn. Rather, the existance of more than one source can be seen as a reflection of

TABLE 5.3

NUMBER OF SOURCES OF WATER FOR SURVEYED FARMS

	Number of Farms		
	Kent County	Simcoe County	Norfolk County
Number of Sources			
One	2	9	8
Two	7	3	3
Three	---	---	1
Four	---	---	1
Five	---	---	---
Six	---	---	1

TABLE 5.4

AVERAGE NUMBER OF WATER SOURCES ON SURVEYED FARMS BY LOCATION AND EXPERIENCE OF SHORTAGE

	Average Number of Sources Per Farm	
	Farms Reporting Shortage	Farms Reporting No Shortage
Kent County	2	1
Simcoe County	1.3	1.2
Norfolk County	2.4	1.1

the attitude of the respondents toward the adequacy of the original supply, as discussed below.

5.1.4 Adequacy of Water Supply

The question of adequacy of water supply on the surveyed farms was dealt with by asking farmers if they had ever experienced a shortage of water from their source of supply. Respondents who replied affirmatively to this question generally reported that they could not completely "cover" their fields with their original supply of water, without waiting for that supply to recharge. This "shortage" was further qualified in terms of the time required for the supply to recharge. For example, if the farmer exhausted his supply before completing one irrigation, but the source was restored within a matter of a few hours, there was generally not considered to be a shortage, whereas if the recharge period was greater than one day, a shortage was reported.

The suggestion that the presence of multiple sources reflects the inadequacy of the original supply is supported through an examination of the number of sources used on farms that have experienced a shortage of water (Table 5.4). On average, those farms that have experienced inadequate supplies in the past rely on a greater number of sources than those that have not experienced a shortage. This is clearly true for Kent and Norfolk Counties but only marginally true for Simcoe County. These figures tend to exhibit the response to shortage and are a function of the number of farms experiencing a shortage of water, the perceived cause of that shortage, and the range of alternatives adopted by farmers in responding to inadequate supplies of water.

Among the farmers interviewed, 57% felt that their water supplies had always been adequate for their needs. These farmers felt that this was so for a number of reasons. The two farmers relying on wells, both in Norfolk County, stated that the water table had not dropped for as long as they had used the source; fifteen and eighteen years respectively. Three farmers cited the benefits of underground springs in securing their supply. Two of these respondents had ponded the spring and one who relied on direct withdrawal from a stream noted that the stream was spring-fed on his property. In Simcoe County, ten of the respondents who felt that they had an adequate supply generally received their water from large streams. Two of the farmers interviewed in Kent County stated that they had a problem of too much water. Both of these respondents had originally relied on Lake Erie to supply their water needs but had developed alternate sources of supply. Apparently, a great deal of equipment had been lost to the lake during summer storms. In addition, the cost of pumping water up a 27-metre embankment at the lake edge proved prohibitive to these users.

About 43% of the farmers interviewed stated that they had experienced a shortage of water in the past (Table 5.5), and felt that their supplies had been inadequate. The majority of these farmers were in Kent County where they accounted for about 78% of the farmers interviewed. This figure dropped to a minority of 25% and 36% of the farmers interviewed in Simcoe and Norfolk Counties respectively. The incidence of inadequate supply stands out most clearly where ground water is supplied through dugout ponds in both Kent and Norfolk Counties. In addition, three Kent County farmers reported shortages from on-stream ponds and, predictably, one from a run-off pond. The

TABLE 5.5 EXPERIENCE OF WATER SHORTAGE ON SURVEYED FARMS BY SOURCE AND LOCATION

	DIRECT WITH-DRAWAL FROM STREAM OR LAKE	ON-STREAM POND	BY-PASS POND	DUGOUT POND	SPRING-FED POND	RUN-OFF POND	BORED OR DRILLED WELL	SAND POINTS	TOTAL	
									NUMBER	%
KENT COUNTY										
a) number reporting shortage by source	---	3	---	5	---	1	---	---		
b) number reporting no shortage by source	2	1	---	2	---	---	---	---		
c) farms reporting shortage from at least one source	---	---	---	---	---	---	---	---	7	77.7
SIMCOE COUNTY										
a) number reporting shortage by source	1	1	---	1	---	---	---	---		
b) number reporting no shortage by source	10	2	---		---	---	---	---		
c) farms reporting shortage from at least one source	---	---	---	---	---	---	---	---	3	25.0
NORFOLK COUNTY										
a) number reporting shortage by source	1	---	---	4	---	---	---	---		
b) number reporting no shortage by source	3	2	1	2	2	---	1	1		
c) farms reporting shortage from at least one source	---	---	---	---	---	---	---	---	5	35.7

incidence of shortage in Simcoe County was not peculiar to any source and inadequate supply was reported from dugout ponds, on-stream ponds, and direct withdrawal by one farmer each.

As Andrews and Geertson (1970) have noted, the perception of the cause and frequency of the water shortage will influence the pattern of response that is adopted by farmers. When asked to supply reasons for a reported inadequacy of supply, the response of farmers generally fell within four categories. These are displayed in Table 5.6. Typically, those farmers who reported a shortage from dugout ponds saw the problem as recurrent, usually arising every year and blamed the problem on either a limited size of the pond or a lack of maintenance of the pond. Specifically three farmers in Kent County felt that their ponds were too small to satisfy their needs as did one farmer in Simcoe County and one in Norfolk County. Three additional respondents in Norfolk suggested that inflow into their ponds was hindered by the recurrent formation of a hardpan on the bottom of the ponds. All of these irrigators reported that they were forced to rake the bottom of their ponds once every five years to re-establish inflow. This problem can be related to the dominant practice of irrigators of pumping ponds dry and waiting for them to recharge. This practice permits the process of cementation to occur and the hardpan to form. Similarly, Richardson (1958) has put down the poor construction of farm ponds to the presence of a number of unscrupulous pond diggers in Ontario during the early 1950's when the demand for ponds exceeded the number of excavators. An additional problem, as previously suggested, is the irrigators lack of knowledge, in quantitative terms, of water supply requirements. When this requirement is not known, it is

TABLE 5.6 PERCEIVED CAUSE OF SHORTAGE BY LOCATION AND SOURCE OF WATER

Location and Perceived Cause of Shortage	Specific Source of Water	Number of Farms Reporting	
		Recurrent Shortage	Sporadic Shortage
1) KENT COUNTY			
a) natural lack of precipitation	- ponds on drainage ditches	-----	2
b) limited size of supply structure	- dugout ponds	3	-----
	- runoff pond	1	-----
c) lack of maintenance of supply source	- onstream ponds	1	-----
d) over-pumping of source by others	-----	-----	-----
2) SIMCOE COUNTY			
a) natural lack of precipitation	- ponds on drainage ditch	1	-----
	- direct stream withdrawal	-----	1
b) limited size of supply structure	- dugout pond	1	-----
c) lack of maintenance of supply source	-----	-----	-----
d) over-pumping of source by others	-----	-----	-----
3) NORFOLK COUNTY			
a) natural lack of precipitation	-----	-----	-----
b) limited size of supply structure	- dugout pond	2	-----
c) lack of maintenance of supply source	- dugout ponds	3	-----
d) over-pumping of source by others	- direct stream withdrawal	1	-----

difficult to specify the size of storage reservoir that will satisfy the demand.

Those farmers who reported a shortage from on-stream ponds generally received their supply from small drainage ditches. Two of these respondents in Kent County perceived the problem to be sporadic and the result of a natural lack of precipitation, occurring only "in dry years". An additional respondent in Kent County felt that his storage problem was caused by debris clogging the stream above his property and that, although he was being deprived of water on an annual basis, farmers upstream from the jam were experiencing problems of excess water as the stream level had risen above, and blocked, their drainage outlets. One respondent in Simcoe County reported that his supply, ponded in a drainage ditch, was hindered annually by a lack of precipitation.

One farmer in Simcoe County reported that his supply from direct withdrawal had been inadequate because of a lack of precipitation in "dry years". This farmer noted that he was located near the headwaters of this small stream and that a lack of run-off in the spring had a drastic affect on the capacity of the stream to meet his needs. Only one respondent in this study cited over-exploitation of the source by other irrigators as the cause of his shortage. This irrigator, in Norfolk County, had received his supply through direct withdrawal from a stream which was consistently blocked by other irrigators, depriving him of adequate water to meet his needs.

In summary, data presented in the previous pages has focused on the farm operators experience with inadequate supplies of water and perceived causes of water shortage. Thus, the term "water shortage" as used in this study, does not necessarily imply that the physical supplies are less than the demand. Rather, this study uses the definition of a "shortage" as perceived by the irrigator. In the farmers estimation, a shortage is simply "not enough water to cover my crops" within a certain period of time and does not mean that there is a deficiency in a potential supply. More often, the general consensus is that the structural supply system lacks the capacity to provide sufficient water for the spatially and temporally concentrated demands of irrigation. This perception is important in influencing the range of alternatives that irrigators have historically chosen to remedy the problem of inadequate supply.

Lees (1974) has suggested that a local response appropriate to conditions of inadequate supply would be to cut back water use until the resource had replenished itself. This argument however, ignores the users estimation of the problem. Although the cause may be purely hydrological in nature, if the user does not perceive this to be the case, the "appropriate" response might not be included in his range of alternatives. Conversely, Hudson (1962) noted that farmers who have inadequate supplies of water may or may not be resigned to what they have and that the nature of each individual response will depend on personal circumstances. Andrews and Geertson (1970) have noted that the majority of farmers, operating under a structurally controlled system of allocation and distribution, generally perceive that there is "no way to get more water" in the event of a shortage. Where adjustments to deficiencies in the availability of water are made on an individual basis, however, the range of responses adopted is quite broad and reflects both the farmers estimation of the problem and ability to rectify it. This range of responses adopted by surveyed farmers is shown in Table 5.7. The categories listed are not meant to include the entire possible range of alternatives available to mitigate the effects of an inadequate water supply but reflect the actual choices that individual irrigators have made in response to the conditions of inadequate water supplies discussed above.

These solutions can be divided into two broad categories; demand-oriented and supply-oriented. Briefly stated, demand-oriented responses imply an intentional reduction in the need or demand for water to meet the available supply. Supply-oriented responses, on the other hand, include intentional attempts to supplement the original source by developing new supplies of water to satisfy established demand requirements.

Within the demand-oriented responses, respondents generally chose one of three courses of action: reduce the rate of withdrawal; suffer shortage; or eliminate the need for water. Two irrigators in Norfolk County reported that they had reduced their rate of withdrawal from dugout ponds to make up for an inadequate supply. This response involved reducing the number of hours of taking per day rather than reducing the amount of water actually used. In essence, this necessitates a longer irrigation period in terms of the operating days required to cover the full acreage of a crop, but it allows the source time to recharge and provides an adequate supply of water on each of the irrigating days. In both cases, this adaption to shortage was combined with a pond maintenance plan to reduce the problems caused by the formation of a hardpan.

An additional two respondents, one in Kent and one in Simcoe chose to

TABLE 5.7 RESPONSES TO SHORTAGE ADOPTED BY SURVEYED FARMS

			DEMAND - ORIENTED			SUPPLY - ORIENTED		
LOCATION	RESPONDENT	CAUSE OF SHORTAGE[1]	REDUCE RATE OF WITHDRAWAL	SUFFER SHORTAGE	ELIMINATE DEMAND FOR WATER	IMPROVE EXISTING SOURCE	SECURE ADDITIONAL WATER FROM EXISTING SOURCE	CONSTRUCT NEW SOURCE
KENT	1	a						x
	2	b						x
	3	c				x		
	4	a				x		
	5	b					x	
	6	b		x				
	7	b				x		
SIMCOE	1	a			x			
	2	b					x	
	3	a		x				
NORFOLK	1	c	x					
	2	c	x					
	3	b						x
	4	d						x
	5	b				x		

[1]Assigned letter refers to cause listed on Table 4.9

suffer the shortage. This is essentially, a passive action where no attempt is made to reduce demand or increase supply. One of these farmers has experienced sporadic shortages from a surface stream and does not see a need to develop an additional source of supply where it would not be required on a regular basis. The other has experienced recurrent shortages from a dugout pond but does not feel that they are severe enough to take any action.

The third option, that of eliminating the demand for water, was reported by only one farmer. This response basically implies the adoption of practices which can act as a surrogate for irrigation and thus reduce or eliminate the demand for irrigation water. The Simcoe County farmer who responded to inadequate supplies in this manner had been dependent on ponded drainage ditches to supply water and relied on irrigation to reduce crop losses from wind erosion induced "shear-off", and spring "burn-off". The perceived cause of the shortage was inadequate precipitation at times when the water was required. This respondent's initial reliance on drainage ditches would seem paradoxical. Presumably, if there existed sufficient rainfall to provide a drainage flow, the need for irrigation in this case would be negated. However, he felt that he could not afford to sink a well and, in order to reduce his reliance on irrigation water, planted a cover crop over his main crop of carrots in an attempt to reduce wind erosion and heat stress. This cover crop was chemically destroyed after the young carrot plants were established.

Two-thirds of the farmers reporting a response to inadequate supplies had enacted supply-oriented solutions. These responses fall into three sub-categories: improve the existing source; secure additional water from an existing source; and construct a new source. Four of the farmers interviewed had attempted to provide an adequate supply of water by improving their original source. Obviously, this response is only perceived as a viable option where the supply structure is seen to be the cause of the shortage. Responses in this category included clearing or dragging the stream or drainage ditch and expanding the source of supply through enlarging the pond or deepening and widening drainage ditches in an attempt to capture more water.

Two of the farmers interviewed had secured additional water from an existing source of supply as an alternative to the construction of a new source. One respondent in Simcoe County has turned to direct withdrawal from a small stream on his property in response to a recurrent shortage from his dugout pond. An additional irrigator in Kent County who experienced an annual shortage from a run-off pond reported that he had purchased water from a property adjacent to the farm. In this case, the original supply is used to the point of exhaustion before the respondent purchases water. This rental supply exists in the form of an exposed water table in an abandoned gravel pit. The farmer suggested that under the original owner of the pit he had only paid for water as he required it. When a change in ownership occurred, the new owner demanded an annual fee of $300.00 for the privilege of access to the pit, whether the water was used or not. This respondent felt that he had no choice but to agree to this arrangement. He had investigated the possibility of sinking a well to supply irrigation water, but felt that this proposal was too expensive and unlikely to succeed. Although only reported by one farmer, several of the surveyed irrigators stated that they had heard of similar purchase or leasing arrangements. Also, as previously mentioned, informal arrangements exist whereby irrigators can borrow or "steal" water as needed.

The final, and most structural, response to shortage mentioned by the surveyed farmers was the construction of an additional source of supply. This response involves developing a new source of water rather than modifying existing opportunities. In all four reported cases, this response took the form of the construction of a dugout pond to either supplement extant sources, or replace those no longer reliable, such as an over-drawn stream. One respondent reported that he had turned to a dugout pond after the blockage of a stream by upstream irrigators prohibited his use of that source. Although he financed the construction of this pond himself, he found that he had sufficient supply to allow four neighbours to take water from this new source.

In summary then, a slight minority of the farmers interviewed (43%), felt that they had an inadequate supply of irrigation water. The bulk of these respondents did not relate this "shortage" to natural conditions but rather, to a deficiency of their original supply structures. In response to recurrent shortages, most farmers have not attempted to reduce their demand for water but have attempted to secure a greater supply, primarily through structural means. It could be concluded that the general response is structural because the problem is not perceived to be a lack of physical supply, but an ineffective means of supplying and storing sufficient water on-farm. However, several observations complicate this conclusion. For example, of those two respondents who chose to reduce withdrawal in response to a structural supply problem, one had the opportunity to exploit a stream running through his property. This irrigator, however, stated that he "didn't like the idea of taking water out of the stream" and felt that this practice had a detrimental effect on aquatic stream-life and stream quality. The other expressed a concern that if he developed another supply source, he might deprive his neighbour of water who "needs it as much as I do."

Based on observations such as these, the broad conclusion stated above requires refinement. A more suitable suggestion is that the form of response to water shortage, and indeed the existing pattern of water supply, is not only governed by physical limitations and technological possibilities, but equally, and perhaps to a greater degree, by the goals and values of the resource user. Again, the previous sections, through an examination of prevalent water supply patterns and practices, have emphasized the influence and consequence of the individual water manager, in the form of the irrigating farmer, in exercising control over the use of water for irrigation in the areas under study. The remainder of this discussion will focus on the actual practices employed in delivering water to the fields, methods used to apply water to crops and techniques utilized in scheduling waterings.

5.2 IRRIGATION METHODS

In describing on-farm irrigation techniques, a distinction is commonly made between surface and sprinkler methods of irrigation. Within both of these classifications, various methods of applying water to cultivated fields exist. Irrigators employing surface techniques, commonly described as wild flooding, border strip and furrow or corrugation (Holmes 1986, Hudson 1962, Quackenbush et al. 1957), rely on gravity flow to transport water to, and distribute it within, their fields. In these systems, "water is designed to be led from its source in an orderly fashion through a network of bifurcating channels of increasingly fine size", until the irrigation is complete (Carlstein 1982). In Ontario, where sprinkler irrigation is the dominant practice, the pattern is similar. Water is forced, under pressure, through a series of increasingly fine-sized enclosed pipes until the irrigation is complete. The initial difference between the two systems then is the means of diverting or delivering water to, the fields.

5.2.1 Diversion of Water to Fields

Unlike those areas where methods of surface irrigation are practiced, delivery and distribution of water by gravity flow is not practical in Ontario for reasons having to do with topography and the considerable amount of land preparation necessitated by gravity flow systems. Contrary to the claims of Rubey (1954), farm ponds do not "usually occupy high ground" but are typically found in low-lying areas where they can capture a supply from shallow water tables, run-off and underground springs. Similarly open water in river channels or natural lakes is commonly found below field level and must be lifted prior to use. Consequently, the diversion of water by gravity flow has never been popular in Ontario. Irwin and Armitage (1981) cite a reference from a 1911 farm periodical which described a gravity flow furrow irrigation method but suggest that this system never developed beyond a rudimentary stage. Indeed only one of the farmers interviewed for this study mentioned a knowledge of surface techniques having been practiced on his farm. Although he did not know the actual details of the diversion methods used, this irrigator stated that his grandfather flood irrigated his Kent County orchards during the early 1900's.

Given the constraints to the diversion of water by gravity flow, irrigators in Ontario have historically relied on pumps to withdraw water from the source and conveyance pipes to deliver it to the field. All 35 respondents to this survey stated that they used some form of pump to provide irrigation water.

The most common pumps for irrigation are centrifugal and turbine pumps. The centrifugal pump is best suited to pumping from surface water or shallow ground water supplies and operates most efficiently when the suction lift is less than 4.5 metres (Ayers and Spencer 1974). Turbine pumps are required when pumping from wells where the water surface is too deep for a centrifugal pump. Power units for these pumps usually take three forms. Historically, the most popular method of powering irrigation pumps was a gasoline fuelled internal combustion engine. More recently, in an effort to reduce fuel costs, many irrigators have replaced gasoline engines in irrigation pumps with diesel engines. Similarly, in areas where suitable hydro service is available, some irrigators now use electric motors on irrigation pumps in an attempt to reduce operating and maintenance costs. Other farmers utilize the power-take-off (P.T.O.) shaft of a tractor to run their irrigation pumps. As Irwin and Armitage (1981) have noted, this strategy allows the farmer to reduce fixed costs by using a tractor, which would otherwise have been idle, in place of a stationary engine. Of course this is only true if a farmer has no other use to which the tractor could be put while he is irrigating. In many cases, farmers have other fields or non-irrigated crops with which they could be working, while a nearby field is being irrigated. Still more recently, propane has become an attractive alternative fuel in powering irrigation pumps. A 38% savings in fuel costs can be realized by using propane instead of gasoline (MacLaren 1982) and as propane is a cleaner burning fuel than gasoline, engine life is extended and maintenance problems reduced.

Although farmers interviewed for this study were not directly asked for details concerning pumping units, three respondents in Simcoe County reported that they had switched from diesel to electric powered pumps and two irrigators in Norfolk County noted that they had converted gasoline engines to propane fuel. By far the majority who volunteered information on irrigation pumps were using the shaft of their tractors to drive their pumps. This observation would seem contrary to the results of a 1950 survey in which 17% of all irrigation pumps were driven by electric motors, 76% by stationary engines and only 7% by tractors (Cooper and Armstrong 1953 cited in Irwin and Armitage 1981), but seems to represent an effort on the part of farmers to reduce the cost of irrigating as fuel and equipment costs have increased over the years. These observations are reinforced by the findings of another recent survey of Ontario irrigators, which discovered that 60% of respondents relied on P.T.O. driven pumps, while 31% used stationary engines and 7% employed electric motors (Ontario Ministry of Agriculture and Food 1986). It should be noted that the cost of supplying water to the farm, other than developing a source of supply, is synonymous with the cost of pumping water from the source to the field. Farmers taking part in this study generally found it difficult to separate labour and fuel costs for irrigation from those resulting from other production activities. The labour involved in irrigating was commonly performed by the farm operator or his family and respondents did not place a dollar value on this work. Most associated the cost of irrigating with that of pumping water to their fields. These values ranged from a minimum of $24.00 to a maximum of $10,000.00. Although this cost could be expected to have a direct relationship to land area irrigated, this does not appear to be the case. For example, the respondent reporting an average operating cost of $24.00 irrigated 162 hectares while the irrigator reporting $10,000.00 irrigated 101 hectares of land. A detailed analysis of these costs was not carried out due to the non- specificity of responses and it is felt that any such analysis would present misleading results. Generally though, the cost of water as viewed by most irrigators is synonymous with that of fuel, and any increase in the cost of pumping represents an increase in the "price" of water. In response to this increased price, most irrigators have not attempted to reduce their pumping requirements through lowering demands for water, but have opted for the more concrete alternative of switching to more efficient power units and lower cost fuels.

5.2.2 The Distribution and Application of Water to Fields.

As previously stated, sprinkler irrigation systems are the predominant means of applying water to crops in Ontario. These systems can be broadly classified in a number of ways according to both mobility of equipment and the type of device used to project the water (Wiesner 1970). In general, these systems are composed of a number of units including a pump and drive unit to divert water, main lines and smaller lateral pipes to distribute water to the point of application, and a spray head to apply water. Main distribution lines are commonly 12 to 20 cm. in diameter and run the length or width of the irrigated field, depending upon the location of the source. Lateral pipes of smaller diameters, usually 7 to 12 cm. in diameter, are attached to the mainline by means of a coupler and run perpendicular from the mainline to the edge of the irrigated field. "Riser" pipes, of a smaller diameter, are attached to the laterals and deliver water upward to the sprinkler head. It is unlikely that any two farms will have identical irrigation systems as the arrangement of mains and laterals is commonly governed by the location of the water source and is dependant upon the size, shape and lay of the field (Ayers and Spencer 1974). Similarly, the infiltration characteristics of the soil and water requirements of the irrigated crop are used by irrigation engineers to determine the amount and rate of application of water. This information is then used to determine the diameter of the lateral pipe and the spacing of sprinklers on the lateral in order to provide a uniform distribution of water (Ayers 1956). Irrigation pipe is commonly available in lengths of 6, 9 and 12 metres and a number of fittings such as elbows, ties, valves, reducers and end plugs are available so that any configuration of pipes in the field is possible. Irrigation publications tend to stress the importance of consulting an agricultural engineer or irrigation design specialist when planning an irrigation system (ie. Ayers 1953, Ayers 1956, Ayers and Irwin 1974, Campbell and Ayers 1960, Korven and Randall 1975), but a number of the surveyed farmers stated that they had designed their irrigation layout themselves after purchasing used equipment, or had experimented with their initial design until they found a layout most suitable to their operating practices.

Most sprinkler systems are commonly classified as portable, semi-portable, permanent or travelling. The farmers interviewed for this survey made further distinctions according to the commonly applied names of their techniques. These can be found in Table 5.8. A similar distinction was made by farmers in terms of the spray head used to apply water. This was between sprinklers and volume guns. Essentially, both of these spray heads are rotary type sprinklers. However, conventional sprinklers are typically double nozzled mechanisms, which are classified according to pressure, and which break up water drops through a combination of operating pressure and nozzle size. Revolutions of these sprinklers are relatively rapid and operate on the principle of an impact arm which is deflected by a jet of water and returned by spring tension. Volume guns, however, are large single-nozzle sprinklers which operate under high pressure, and revolve slowly in a circle emitting a large, high-velocity stream of water into the air in a pulsating manner. Air resistance breaks up the stream into fine drops. The diameter of coverage from these guns can exceed 140 metres compared to from 6 to 30 metres for conventional sprinklers (Wiesner 1970). The advantages of these guns is that less equipment and less labour are required for their operation than with conventional sprinklers (Irwin and Armitage 1981). Some farmers however feel that they do not provide an adequate coverage of crops and have preferred to remain with sprinklers (Surgeoner 1983).

In watering their fields, farmers in the three study areas use a wide variety of techniques based on the pressure flow of water. The most widely employed methods are hand-move sprinklers and guns, followed by solid-set sprinklers, travelling systems, and drip or trickle irrigation. Table 5.8 displays the land area of particular crops irrigated by each of these systems as reported by surveyed farmers in each of the sample counties. The total number of farms reporting by technique is greater than the total surveyed, as

TABLE 5.8 IRRIGATION TECHNIQUES USED ON SURVEYED FARMS

Crop Location	Number of Fields and Hectares Irrigated by Technique											
	Hand-Move Sprinkler		Solid-Set Sprinkler		Hand-Move Guns		Travelling Guns		Centre Pivot		Drip	
	No.	Ha.	No.	Ha.	No.	Ha.	No.	Ha.	No.	Ha.	No.	Ha.
Tobacco												
Kent	1	4.6	--	--	6	65.9	--	--	--	--	--	--
Simcoe	--	--	1	18.2	--	--	--	--	--	--	--	--
Norfolk	2	23.5	--	--	5	102.7	2	34	--	--	--	--
Potatoes												
Kent	1	6.5	--	--	--	--	--	--	--	--	--	--
Simcoe	--	--	--	--	--	--	3	238.7	4	621.1	--	--
Norfolk	--	--	--	--	1	8.1	1	70.8	--	--	--	--
Peppers												
Kent	--	--	1	12.1	3	3.4	--	--	--	--	--	--
Norfolk	--	--	--	--	2	8.1	--	--	--	--	--	--
Onions												
Kent	--	--	--	--	1	1.6	--	--	--	--	--	--
Simcoe	1	16.2	1	28.3	--	--	--	--	--	--	--	--
Carrots												
Simcoe	3	56.7	--	--	--	--	--	--	--	--	--	--
Other Vegetables												
Kent	--	--	--	--	1	10.5	--	--	--	--	--	--
Simcoe	1	36.4	1	24.3	1	36.4	--	--	--	--	1	6.1
Norfolk	1	2.8	--	--	3	18.2	1	20.2	--	--	--	--
Tree Fruits												
Kent	2	12.4	--	--	--	--	--	--	--	--	--	--
Strawberries												
Kent	2	5.4	1	5.7	1	0.8	--	--	--	--	--	--
Simcoe	--	--	1	6.1	--	--	--	--	--	--	--	--
Norfolk	1	0.4	1	10.1	--	--	--	--	--	--	--	--
Other Small Fruits												
Kent	--	--	1	5.2	--	--	--	--	--	--	--	--
Total	15	164.9	8	110.0	24	255.7	7	363.7	4	621.1	1	6.1

some farmers are using more than one method in irrigating their crops. A general description of each of these methods is provided below.

a) Hand-move Sprinklers. These systems can be either completely portable or semi-portable. In the latter, the main lines are buried in the field with vertical hydrants remaining above ground level to which laterals can be connected. In a fully portable system, all pipes, including the mains, are moveable. Irrigators lay out the pipe at the beginning of an irrigation period and remove it at the end. With hand-move systems, farmers generally employ one or two laterals to which sprinklers are attached. These laterals can provide a certain depth of water to a specific area of land within a certain period of time. To irrigate an entire field, farmers sequentially move these laterals through each of these "settings". The number of settings, and the time required to cover a field will depend on the width of a strip of land covered at each setting. For example, if the sprinklers on one lateral provide a wetted diameter of 30 metres and the length of the lateral is 183 metres, an area of approximately 0.4047 hectares (1 acre) can be covered at one setting. Once this area is covered to a certain depth of water, the irrigator moves the lateral pipe to the next valve on the mainline and begins a new setting. The time of each setting is dependant upon the discharge rate of the sprinkler which can be controlled through the size of the sprinkler nozzle. The number of laterals employed is controlled by the ability of the pump to supply sufficient pressure to meet the demands of sprinkler application rates. The obvious disadvantage of these hand-move systems is the high labour requirement involved in moving the pipe which, of course, will increase with the amount of land to be irrigated.

b) Solid-set Sprinklers. These systems are permanent in the sense that they are laid out at the beginning of the growing season and removed after harvest. The main purpose of this system is to irrigate an entire crop without moving pipes. As such, sufficient laterals are required to cover an entire field and low volume sprinklers are used resulting in a closer spacing of the laterals. Solid-set systems generally entail high fixed costs due to the amount of equipment required but very little operating labour is required aside from the initial set-up in the spring and removal in the fall.

c) Hand-move Guns. Two types of hand-move guns were apparent on the surveyed farms. One resembles conventional hand-move sprinkler systems, with guns mounted on risers attached to laterals. This system involves changing settings similar to that described above with the exception that fewer settings would be required to irrigate a complete field due to the greater aerial projection of water from volume guns. This system is generally used on low-level vegetable and fruit crops. On taller crops such as tobacco, a single gun is mounted on a small portable trailer which can be pulled along the laterals and connected to hydrants rising vertically out of the lateral pipe. These trailers can be transported either by hand or hauled by a tractor to each subsequent setting.

d) Travelling Systems. Two types of travelling systems were observed on the surveyed farms. Travelling guns resemble the portable trailer described above where a single large sprinkler is mounted on a trailer. In a travelling system, the trailer is moved, toward a specific point, by a winch which is powered either by a water turbine, using the flow of water to the sprinkler, or by a small stationary engine. Water for most travelling sprinklers is fed from a main line through a flexible plastic hose which is reeled in around a large diameter spool as the trailer travels toward the main. A new type of travelling gun, employing a self-contained steering device which guides the system along lateral pipes and automatically connects to hydrants, has been described by MacLaren (1982) but was not reported by any of the surveyed farmers.

The second form of travelling system mentioned by the respondents was the centre-pivot system. This system has been describea by a number of authors (Korven and Randall 1975, McKnight 1978, and Weatherford et al. 1982), and consists of an elevated lateral pipe, commonly 15 cm. in diameter, which is mounted on towers spaced about 27 metres apart. These towers ride on wheels and are individually powered by hydraulic water, electricity, hydraulic oil or air drive units. The system is anchored, at the centre of the area to be irrigated, to a vertical pipe that supplies water to the lateral line and around which the sprinkler pipe rotates as it irrigates a circular piece of land. The towers along the lateral are kept in position by an allignment mechanism and the sprinklers along the lateral are graduated in size so that a constant depth of water is applied along its length. Water is supplied to the vertical pivot point by a permanent mainline which is buried to avoid obstructing the path of the towers. These systems have historically been designed to irrigate the traditional "quarter section" (65 hectares) and as such, laterals are commonly 400 metres in length (McKnight 1978).

e) Drip Irrigation. Drip irrigation, the last technique mentioned by surveyed farmers, is not a form of sprinkler irrigation but is more commonly used as a sub-surface method of applying water to crops. This system is based on a different concept than sprinkler irrigation. "Rather than applying large amounts of water at one time, after a portion of the available water has been used, water that is utilized in transpiration or evaporation is replaced on a daily basis" with drip irrigation (Cline 1982). The layout of the system is similar to that of a sprinkler system with a network of plastic pipes of graduated sizes, either lying on or buried beneath the ground surface, delivering water to a series of emitters which control the flow and allow the water to emerge as drops, usually at a rate of 2 to 4 litres per hour (Wittwer 1979). The network consists of main lines of 7.5 to 20 cm. in diameter and equipped with pressure regulators, submains of 5.0 to 10 cm. diameter, and laterals of 1.2 cm. diameter, along which the emitters are spaced according to the distance between plants (Amir and Zur 1980). In addition, the pump motor is commonly equipped with a time clock to control the duration of flow. Thus, water is applied to the vicinity of the plant rooting zones at very low discharges so that the soil in a portion of the rooting area is kept at or near field capacity (Atkinson 1979). In terms of water use, the advantages of this system are found in a reduction of water losses. Since water is generally applied to individual plants, the inter-crop area is not wetted and surface evaporation is reduced. Similarly as water is not distributed through air, evaporative losses and poor coverage due to wind drag are eliminated.

5.2.3 Water Application Techniques on Surveyed Farms

On those farms surveyed, 15 fields were irrigated by hand-move sprinklers which applied water to a total land area of 165 hectares or an average of 11 hectares per field. By crop, the smallest irrigated area was a 0.4 hectare strawberry patch in Norfolk County, which could actually be irrigated without moving the lateral; and the largest was a 36.4 hectare field of Chinese greens in Simcoe County. This system appears to be used most commonly with vegetable and fruit crops as well as tobacco crops of relatively small acreage. Within the survey sample hand-move sprinkler systems are unique to only three carrot fields in Simcoe County, where irrigation is of primary import in the spring to reduce heat stress and wind erosion; and on two orchards in Kent County where low angle, low volume sprinklers are used to apply water beneath the level of foliage.

Eight fields on surveyed farms were irrigated using solid-set sprinkler systems. The total area watered by this method was 110 hectares with an average field size of 13.75 hectares. The largest area was a 28.3 hectare onion field in Simcoe County and the smallest a 5.2 hectare area of mixed small fruits in Kent County. It is important to remember here that the number of fields is not synonymous with the number of farms. For example, although three fields of different crops are irrigated by solid-set in Kent County, all of these fields belonged to one farmer who also uses a hand-move sprinkler system to irrigate an orchard plot. Most commonly, solid-set systems are found on relatively large small fruit and vegetable fields where the prevention of frost is a prime consideration in the use of irrigation. Frost prevention, through the use of irrigation, is most effective when the entire crop can be covered with a consistent, low volume, application of water. This coverage is best obtained with the use of a solid-set system which does not require constant moving and can be layed-out in anticipation of frost occurrence. This practice was found to be most dominant on strawberry and other small fruit fields in all areas as well as a pepper plot in Kent County which the operator felt was particularly prone to frost damage. Solid-set systems were also found on a tobacco farm, a celery field, and an onion plot in Simcoe County. In all of these cases, the main advantage of this method of irrigation was a reduction in labour requirements. For example, the tobacco farmer was an older man who had switched from a hand-move to a solid-set system when his offspring had left the farm. In a different vein, the celery grower practiced relatively frequent water applications on this crop and felt that the expense of a solid-set system was more than off-set by the reduction of labour involved in the frequent moving of pipes.

Hand-Move guns were reported to irrigate 24 fields comprising a total land area of 255.7 hectares or an average of 10.7 hectares per field. By far, these systems are most popular on the tobacco farms of Kent and Norfolk Counties. Although these systems are also reported to irrigate small fields of fruits and vegetables, in all cases but two, these fields belong to tobacco farmers who have recently begun to grow these crops as an income supplement. Consequently, they are utilizing their gun-system, designed to irrigate their main tobacco crop, on these other fields. Similarly one farmer had discontinued tobacco production and switched to market garden vegetables while retaining his original irrigation system.

Travelling gun irrigation systems were reported to irrigate fewer but larger fields primarily of tobacco and potatoes on the sandy soils of Norfolk and Simcoe Counties. A total of seven fields and 363.7 hectares were irrigated under this system giving an average of 52 hectares per field. One respondent in Norfolk County watered both potatoes and sweet corn with this system, while the remainder irrigated only one crop. The largest land area under these systems were reported by three potato growers in Simcoe County, two of whom combined travelling guns with centre-pivot systems, due to field configuration restrictions of the centre-pivot technology. Centre-pivots are essentially designed to irrigate a circular area of land within a perfect square and cannot provide full coverage of a field, without overlapping, when the length of a rectangular field is not twice the width of that field. For example, if a given field were 400 metres wide by 600 metres long, the rotational circle of the lateral arm is confined by the 400 metre width and irrigates within a block of land with an area of 160,000 square metres. This leaves an area of 80,000 square metres that must remain unirrigated, or be irrigated twice, if the system is moved to a new pivot point. The two irrigators mentioned above have solved this problem by irrigating their remaining land with travelling gun systems.

A total of four irrigators reported an area of 621.1 hectares under centre-pivot systems, averaging 155.3 hectares each. All of these operators were potato farmers in Simcoe County. The land area under centre-pivot systems ranged from 80.9 hectares to 263 hectares. The large acreages of potato farms in and around the Alliston area of Simcoe County would seem particularly amenable to both types of travelling irrigation systems but it is of note that all of the respondents cited first-hand knowledge of the operation of several centre-pivot systems on a large agri-business farm at least three years prior to adopting this practice. Similarly, all respondents stated that they did not intentionally seek out information on this new technique but were first approached by an irrigation equipment representative who recommended the practice to them prior to adoption. Although McKnight (1978) predicted rapid adoption of this practice on "many farms in southern Ontario", this does not appear to have occurred and seems to be strictly confined to potato farms in Simcoe County. Several reasons for this can be postulated. First is the high initial cost of centre-pivot systems. This ranged from $250,000.00 to $450,000.00 for those irrigators reporting. All of these systems were adopted between 1983 and 1985 and it is unlikely that many farmers could contemplate such an outlay of capital given the current economic climate of agriculture. Second is the relatively small size of the majority of irrigated fields in Ontario. Centre-pivot systems were originally designed for the large-scale irrigated agriculture of the western United States and Canadian provinces and in most cases are not suitable for the much smaller irrigated fields of southern Ontario.

Only one surveyed farm reported the use of drip irrigation on a small 6.1 hectare field of celery. This particularly large, incorporated farm on the Holland marsh had been irrigating their celery crop on a weekly basis using a solid-set system but had decided to experiment with drip irrigation beginning this year (1987). Similar to those farmers using centre-pivot systems, this irrigator had been approached by a representative of an irrigation equipment dealer and had consulted with drip irrigation specialists from Israel before proceeding with the project. This respondent suggested that if drip irrigation proves to be successful, he would expand the system to cover his entire 24.3 hectares of celery, a high water content, shallow rooted crop, but would not include his acreage of carrots and onions as their lower water requirements did not justify the expense of installation, which he estimated at $1500.00 per hectare. Although drip irrigation has also been recommended for small fruits, particularly strawberries (Cline 1982), it was not used by any of the farmers interviewed for this survey. The apparent reason would seem to be that the drip method does not provide the frost prevention that most of these growers are seeking from their irrigation systems.

5.2.4 Summary of Irrigation Methods

Contrary to statements made by some authors (Lees 1974, Holmes 1986, Hudson 1962) that irrigators are resistant to changing traditional methods of applying water when more efficient and economic methods exist, the survey data from this study suggests that Ontario farmers are quite amenable to changing systems. On the surface, the conclusion of Bajwa (1983), that the ability of larger farms to attract capital will result in the use of more advanced techniques on those farms, would appear to hold true, but other factors come into play. Generally, the appearance of any technique on a farm will depend on its applicability to the physical, economic and personal constraints of the operator. Some of the variables accounting for differences in irrigation techniques on the surveyed farms include the size and shape of a field, the nature of the soil, economic standing, reasons for irrigating and the personal preferences of farmers.

For example, the appearance of more technologically advanced systems such as centre-pivot on larger farms not only reflects the availability of capital on these farms but also reflects the nature of the technology. These systems are specifically designed to automatically irrigate large fields where the labour required by traditional irrigation methods such as hand-move systems is prohibitive to the timely application of water. On the other hand, it is of note that tobacco farmers have not, to a large extent, adopted more advanced irrigation systems such as travelling guns. Most farmers however reported that these systems were "too expensive". The advent of these automated systems during the early 1980's has coincided with a general economic decline in the tobacco industry. A number of the interviewed farmers reported having invested large sums of money in bulk kilns during the mid-1970's and were quite wary of committing additional borrowed capital to "luxury" items given the bleak economic outlook of the tobacco market.

Conversely, market gardeners on the muck soils in Simcoe County enjoy a relatively stable market for their produce, but, as with tobacco farmers, have not adopted travelling irrigation systems. The prime reason here would seem to be due to the low load-bearing capacity of these soils and a lack of traction on the ground. Indeed, most of the machinery used on these organic soils does not rely on wheels but is of a light weight, track-drive type. Alternately, these soils are not usually irrigated for the conventional reason of reducing physiological moisture stress on plants but to reduce wind erosion and heat stress. Consequently, farmers irrigating crops on these soils do not perceive the benefits of automated systems to be large enough to outweigh the costs of these systems. In the one case where drip irrigation was practiced, the irrigator specifically noted that he would only use it on one crop which required frequent applications of water.

Although a number of operators have progressively adopted increasingly technological methods of irrigation, undoubtedly, many farmers are satisfied with their original irrigation systems and have developed a set of irrigation methods over the years that are in accordance with their routine operating practices and rationale in irrigating. Decisions to use any particular method are, to some degree, influenced by conditions of physical and economic commitment, but at the same time are influenced by the personal preferences of farmers. For example, one surveyed farmer reported that he had switched from sprinklers to volume guns but felt that they did not provide a sufficiently uniform coverage of his crops and required too much operating time to irrigate his fields. Consequently, this farmer reverted back to his familiar traditional method of irrigating with hand-move sprinklers. Apparently, other farmers are willing to overlook these perceived disadvantages in an effort to realize reduced labour requirements provided by these more recent techniques.

In general then, the pattern of irrigation methods that exist on the surveyed farms is one of adaption, which reflects the applicability of specific techniques to a wide range of operating conditions. These conditions, as displayed, differ between individual farmers but are found to be broadly similar for those farms of common crop and soil types. In short, the pattern that emerges is one of labour intensive techniques being employed on smaller multiple-crop farms, while automated, labour-extensive systems, although fewer in number, predominate on larger single-crop farms.

The preceding section has discussed the physical techniques of water application on the surveyed farms, examining both the operating practices and distribution of these techniques among irrigators. The final element of on-farm water management examined in this study is the scheduling of water application. This will be discussed in the following pages.

5.3 SCHEDULING OF WATERINGS

The final element of the hierarchy of water control described earlier is the scheduling of water applications. The general topic of scheduling of irrigation water includes the timing of a watering, the frequency of applications, the amount of water used in irrigating, and factors which affect these decisions on the part of the farmer (Holmes 1986, Hudson 1962).

5.3.1 Factors Affecting Scheduling

Although the actual irrigation practices of farmers were not observed in this study, surveyed farmers were asked how they determined when it was time to apply water. Several specific factors that affect the scheduling of water were mentioned by respondents (Table 5.9) and the range of alternatives considered by farmers were found to be out of accordance with those of the general scientific community. Interestingly, the availability of water was not mentioned by any of the respondents. This contradicts the findings of both Holmes (1986) and Hudson (1962). Both of these studies, however, were concerned with a rotational system of water delivery where the sample population did not have direct control over the timing of delivery. In contrast, the respondents to this study have direct control over the provision of water and although an irrigation may be interrupted because of an inadequate source, the initiation of an application is not hindered by the decision of any external agent. The specific guides mentioned by respondents are listed below.

TABLE 5.9 IRRIGATION SCHEDULING TECHNIQUES USED BY IRRIGATING FARMERS

	NUMBER OF FARMS REPORTING							
	CROP APPEARANCE	STAGE IN CROP GROWTH	PREDETERMINED MOISTURE REQUIREMENT	SPECIFIED TIME PERIOD WITH NO PRECIPITATION	SOIL FEEL	SOIL MOISTURE BUDGET	SOIL MOISTURE MEASUREMENT INSTRUMENTS	PERIODS OF STRONG WIND
KENT COUNTY								
Tobacco	7	2	---	---	1	---	---	---
Tree fruits	---	1	---	2	---	---	---	---
Small fruits	---	2	---	1	---	---	---	---
Vegetables	3	4	---	1	---	---	---	---
SIMCOE COUNTY								
Tobacco	1	1	---	---	---	---	---	---
Potatoes	3	---	1	---	2	---	1	---
Small fruits	---	---	1	---	---	---	---	---
Vegetables	2	4	1	---	1	---	1	4
NORFOLK COUNTY								
Tobacco	10	7	---	---	---	---	---	---
Potatoes	---	---	---	---	---	---	---	---
Small fruits	---	---	---	1	---	---	---	---
Vegetables	3	1	---	2	1	---	---	---

a) Crop Appearance

Similar to what Hudson (1962), Holmes (1986) and Lambert (1980) have observed in various regions, most farmers in Ontario judge the apparent need for water by the appearance of their crop. The most common indicator mentioned was a change in the colour of the leaves of certain crops. For example, the appearance of dark green leaves on tobacco plants is a signal to farmers that the crop is suffering from a lack of water. Other indicators of water need cited by tobacco farmers included the appearance of "sharp" leaves on the plant and stunted growth. One grower actually commented that he did not water his crop until the lower leaves were beginning to burn. Many farmers also suggested that the wilting of plant leaves act as a guide in the scheduling of water. This was most common with tobacco and potatoes. No doubt, these are practical guides in scheduling water applications, however, conventional scientific wisdom suggests that reliance on these techniques could have negative consequences for the crop. By the time that these indicators emerge, significant damage could have already occurred. Indeed, according to Hansen (1980) the practice of withholding water until the crop shows a definite need is likely to retard growth and "reduce both yield and quality" (Sheidow 1968).

b) Stages in Crop Growth

Depending on the growth stage of different crops, the past experience of farmers appears to have been translated into specific rules for scheduling irrigations. The majority of tobacco farmers surveyed stated that their crops always require irrigation water during "topping". In addition, two onion growers and one garlic producer stated that the formation of a "nut" on the leaf of the plant indicated that the bulb was about to "set" and that the crop required water. Similarly, carrots are irrigated for a short period after breaking the ground surface to prevent "burn-off". One peach grower in Kent County also reported that he regularly irrigated his crop one week before harvest to boost the size of the fruit.

Among some farmers, new practices have evolved which affect the scheduling of irrigations but are not directly related to crop water needs. Some irrigation occurs in conjunction with the planting of crops. A number of irrigators stated that they schedule applications of water immediately after transplanting to "help establish the crop". This practice replaces the traditional technique of attaching a water tank to the planting machine and watering plants as they are set into the field. In effect, irrigating after transplanting represents a significant waste of water through the wetting of the inter-crop area, whereas with a watering planter, a certain amount of water is applied directly on top of the plant. Similarly three farmers applied fertilizers, herbicides and fungicides with their irrigation systems and scheduled applications based on the need for these additives rather than crop water needs.

c) Pre-determined Moisture Requirement

A small number of respondents based their irrigation schedules on a pre-conceived notion of plant water requirements. In the three cases reported, this requirement was one inch (2.54 centimetres) per week. If this amount was not supplied by natural precipitation, presumably within any seven-day period, these farmers would irrigate. It is of note that this scheduling practice was not specific to any one crop or soil type.

d) Specific Time Period With No Precipitation

This practice is similar to that described above with the exception that no specific amount of water in the form of precipitation or crop requirements was mentioned and the time period varied between farms. The implication here is that if no rainfall has occurred within a certain number of consecutive days, these farmers will irrigate. This "no-rainfall" period included every 3 days for a blueberry patch and 14 days for an orchard in Kent county, and ranged from 5 days for a small fruit and vegetable grower to every 10 days for a market gardener in Norfolk County.

e) Soil Feel

Four farmers reported using soil-feel techniques to determine soil moisture requirements and decide when to irrigate. Generally, this involves using a spade in the field to collect a soil sample from root depth and squeezing the sample into a firm ball in the hand. If the soil does not hold together the moisture content has dropped to a stage where irrigation should be started (Ayers and Spencer 1974).

f) Soil Moisture Budget

This scheduling technique will be discussed in more detail later but is included here because some farmers mentioned it as a possible alternative in scheduling irrigations but none actually used it.

g) Soil Moisture Instruments

Two surveyed farmers reported that they used detailed measurements of soil-water tension or suction to schedule irrigations. Both of these respondents used tensiometers to determine soil water content and used this, in combination with other factors mentioned above, in scheduling water applications. One of these farmers, however, stated that he did not "trust" the tensiometer readings and usually began irrigating before a critical level was indicated by the tensiometer. In addition, three irrigators stated that they had attempted to use instruments such as tensiometers and conductivity meters as a guide to applying water, but had found this practice to be ineffective. All of these respondents felt that the measurements provided by these instruments were not representative of actual field conditions and did not reflect variations within large fields. In the same vein, these farmers felt that the expense involved in setting up enough instruments to provide representative coverage and the labour involved in monitoring was prohibitive and would not provide significant benefits over the traditional practice of observing crop conditions. Consequently, these respondents reverted back to this practice.

It should be noted at this point that the irrigators who are or have attempted to use this "scientific" technique of scheduling are the same people that have adopted automated travelling or drip irrigation systems. The suggestion could be made that changes in irrigation technology bring about changes in other water use practices, but as the chronological order of the adoption of these practices is not known, this claim cannot be validated in this study.

h) Periods of Strong Winds

The presence of severe winds that could potentially result in serious soil erosion and "shear-off" problems was cited by four farmers as a factor which influences their scheduling of waterings. All of these respondents were located on organic soils in Simcoe County. This irrigation generally occurs in the spring before crops have matured to a sufficient degree to act as a barrier to the aeolian transport of sediments. Although media weather reports commonly contain wind warnings, the exact timing of these irrigations appears to depend on visible signs and the application of water is usually initiated at the most susceptible points of the field, such as high spots or the farthest distance from a windbreak.

A similar climatic influence, not directly related to crop water needs could be expected where irrigation is used as a form of frost prevention, but this was not mentioned by farmers. In this case it could be expected that irrigators, in anticipation of a frost, would monitor temperatures during the period of potential frost occurrence and begin irrigating when this temperature drops below a threshold level, most commonly considered to be just above the freezing point of water (0-1° C).

i) Other Observed Scheduling Factors

After many discussions with farmers in the study areas, several general factors, other than those mentioned above, which affect the timing of water applications can be postulated. The first of these is related to the exact timing of irrigation as opposed to apparent indicators of crop water needs. As already suggested, most farmers rely on the observation of crop conditions such as leaf wilt and colour change to determine the need for irrigation. The actual decision to irrigate however is in fact, a game of chance. The irrigator in playing this game must weigh a number of factors. For example: when is it likely to rain again? How long can I afford to wait for rain before irrigating? The answers to these questions could be expected to be related to personal circumstance, but one irrigator, a Norfolk County tobacco grower, suggested that this decision is also a function of the decisions of other farmers. In the illustrative words of this farmer, "if you want to know the honest truth, as soon as one pipe rattles around here, everybody is out there irrigating." Conversely, the pattern of irrigation timing observed by this respondent could simply be the result of a number of farmers, operating under relatively homogeneous soil, climatic and crop considerations, within a localized area, making similar choices within a time period that is constrained for all by the potential magnitude of crop damage. Unfortunately, this "micro-scale" level of irrigation scheduling was not considered in this study but would appear to be an important component of irrigation water management in areas where the timing of irrigation is not directly controlled by the exogenous delivery of water. As such, it is deserving of future study.

A less esoteric determinant of irrigation scheduling mentioned by another tobacco farmer related to the particular mix of crops grown on his farm. Whereas most tobacco farmers responding to this study grew only wheat or rye as a rotation crop, this particular irrigator grew a significant acreage of corn in addition to a rotation crop of wheat. As with most of the tobacco farmers surveyed, this respondent believed that his tobacco crop should be irrigated at "topping" time, during the last two weeks of July. He noted, however, that this period coincided with the "tasselling" season for corn and

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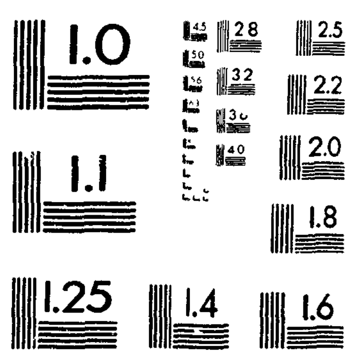


stated that he delayed irrigating the tobacco crop until this cultural demand of corn had been completed. Consequently, whereas most tobacco farmers stated that they most frequently irrigated their crop during the last two weeks of July, this respondent cited his most frequent period as the first two weeks of August.

This example provides a contrast to the observations of Holmes (1980) and Hudson (1962) that, under conditions of choice, high value crops are usually tended prior to those of low value. It is however, in accordance with a commonly held belief among tobacco farmers that tobacco should be made to "suffer" the effects of moisture deficiencies. As one irrigator has put it: "I don't think you can improve crop weight by irrigating too soon or too much. In my opinion, weight is being put in the leaf when tobacco suffers" (MacLaren 1973). Opinions similar to this were echoed by a number of tobacco farmers responding to this study, yet there does not appear to exist any physiological evidence to support this belief. Indeed, according to the conventional wisdom of agronomists and plant scientists, when a crop suffers from a moisture deficiency, the quality of the product will be impaired, yield will be reduced and maturity delayed (ie. Gilley and Jensen 1983, MacLaren 1970, Scheidow 1968). Lacking any physiological base, the explanation of this belief, which results in the deferment of irrigation beyond the point where crop water need indicators have become visible, is left open to interpretation. One such interpretation is offered here and is based on observations and general discussions with irrigators in the field.

The conception that tobacco should "suffer", rather than being founded on any scientific knowledge, can be seen in terms of an adaption of beliefs to correspond with cultural attitudes regarding irrigation. A number of tobacco farmers, especially those utilizing hand-move irrigation systems, viewed the task of irrigating as an added burden to the farm operation and particularly undesirable work. The reasons for this attitude are understandable. Aside from the labour involved in irrigating, complaints were voiced by numerous farmers about the working conditions associated with the irrigation of tobacco. With any type of hand-move system, this involves a considerable number of hours spent moving lateral pipes on wet soil among wet plants that can be upwards of 1.5 metres tall. The obvious drudgery of this work has created a condition where tobacco farmers do not like to irrigate; in the words of one farmer, "it's nobody's favourite job." As a result of this aversion to the physical chore of irrigating, it is common for some irrigators to delay the application of water in the hope that it will rain, and the accumulated precipitation will be sufficient to alleviate the need to irrigate. Consequently, a diurnal decision cycle is established. On any one day, after the visible signs of moisture deficiency have appeared, the irrigator realizes the need to irrigate but ponders the question "Maybe it'll rain tomorrow." If it does not "rain tomorrow", the choice reappears; irrigate or wait for rain. Hence, the cycle continues until the irrigator decides that he can wait no longer, or the anticipated rainfall occurs. Of course by delaying the application of water in the absence of precipitation, until he can wait no longer, the probability of a rainfall event occurring, within a short period of time following the initiation of irrigation, is increased. This suggestion is supported by the perception of more than one respondent that: "it never fails; a day or two after I start irrigating, it rains." It is difficult to speculate exactly when and under what conditions, the decision to irrigate occurs but it does not seem outside of the bounds of reason to suggest that it can, in part at least, be attributed to the "leader-follower" relationship previously discussed. As a player in this "waiting game", the tobacco crop is subject to an escalating deprivation of moisture and as a result, "suffers". The irrigator, presumably, realizes this but in an attempt, over the years, to rationalize this practice of postponement, the opinion has formed among some farmers, that tobacco benefits from, and should be made to "suffer" the effects of moisture deficiency.

Although based on aural observation, this argument is, for the most part, unsubstantiated and at best conjecture. Yet, it does not seem an unreasonable meshing of the comments made by interviewed farmers, and it certainly provides a starting point for further study into the understanding of irrigation scheduling within private systems that are not dependent upon a rotational method of water delivery.

5.3.2 Irrigation Scheduling on Surveyed Farms

A number of the factors which have been cited as influencing the scheduling of waterings are verified by data collected from surveyed farmers regarding their application of water. Unfortunately however, the actual scheduling and application practices of these farmers could not be observed within the limited time frame of this study. Consequently, although data is presented in a quantitative manner, this inquiry into irrigation scheduling is subject to qualitative reporting on the part of the respondents. Based on the comments of these respondents, two broad irrigation "situations" became apparent. Generally, it was found that farmers who irrigate multiple crops (primarily fruits and vegetables), on individual farms, tend to treat each crop as unique and differentiated between these crops in their applications of water. Conversely, those farmers irrigating a small acreage, "supplemental", crop in addition to a larger acreage primary crop typically treated all crops as the same and did not make a distinction between crops when irrigating. With this in mind, the information gathered for each surveyed farm was categorized by crop type and each crop type on a farm is treated as an individual field. In turn, data for each crop type is tabulated independently for each sample county.

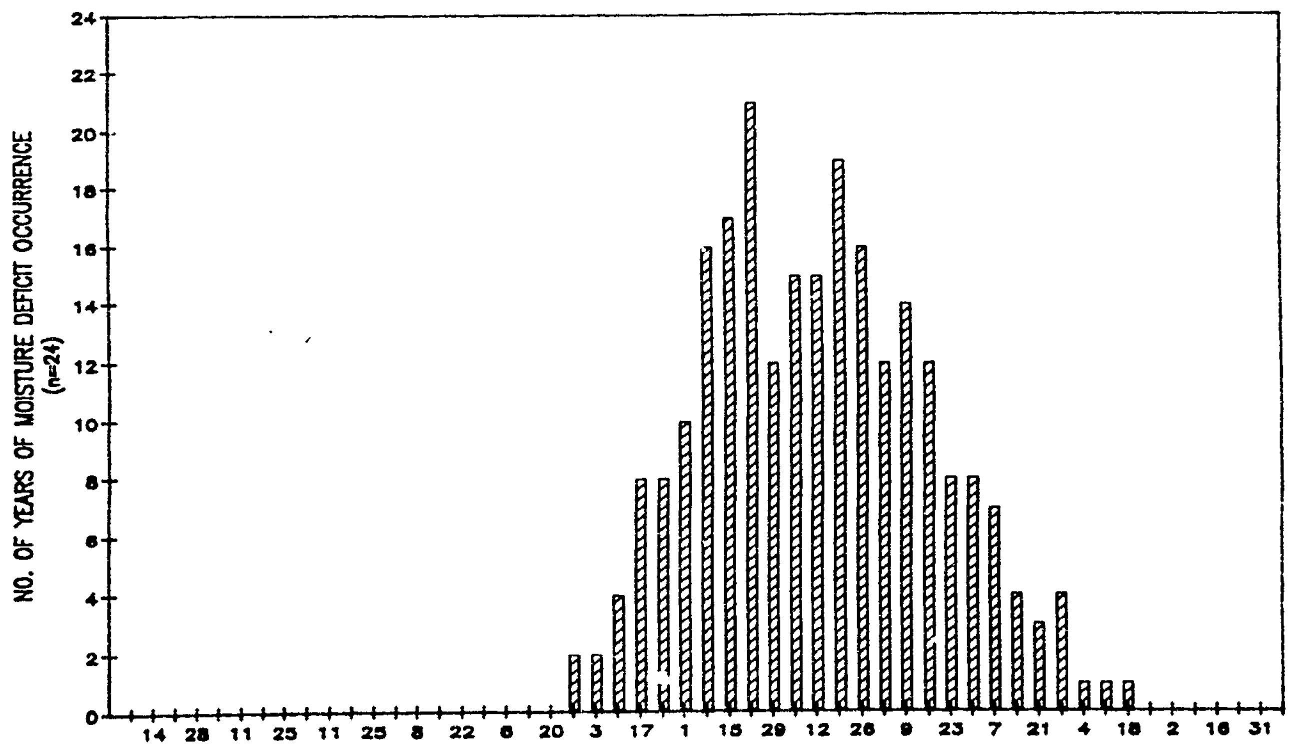
5.3.2.1 Irrigation Season

The irrigation season in Ontario, or the period of time within which the application of water is scheduled, is naturally confined by the growing season of irrigated crops, but can be defined both in terms of the frequency of occurrence of moisture deficits and recurrent periods of need as reported by irrigators. Figures 5.4, 5.5 and 5.6 provide an indication of the dates when moisture deficits have most frequently occurred in each of the sample counties. Although the data used in these figures is taken from particular stations within each area and cannot be expected to reflect conditions on individual farms, it does provide an approximation of the situation in each county.

Over a 24-year period of record for Norfolk County (Figure 5.4), moisture deficits have occurred in at least one year in each week between May 27 and November 25. Between July 8 and September 16, deficits have occurred in at least half of the years considered. Weeks in which moisture deficits have occurred in over 75% of the years examined are limited to two

FIGURE 5.4

FREQUENCY OF MOISTURE DEFICIT BY WEEK
FOR THE PERIOD 1962 TO 1985
NORFOLK COUNTY
(Delhi station)



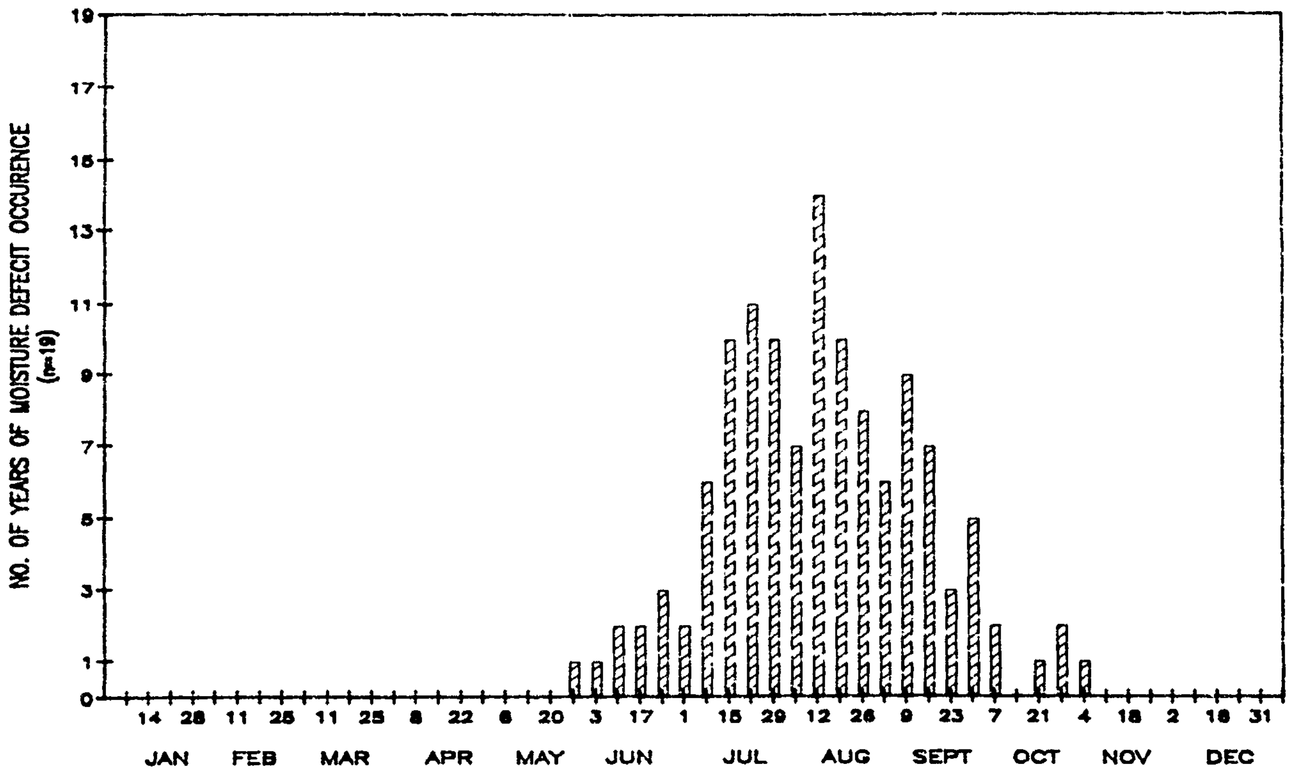
Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

seven-day periods between July 22-29 and August 19-26 respectively. In Simcoe County (Figure 5.5), moisture deficits have occurred as early as May 27 but have not extended beyond October 11. Deficits have most commonly occurred between July 15 and September 18, although there are only five weeks in which deficits have recurred in over half of the period of record. the seven-day period of August 12-19 stands out, with deficits occurring in 14 out of 19 years or over 73% of the years considered. Unlike Simcoe and Norfolk counties, moisture deficits in Kent County (Figure 5.6) do not exhibit a strong pattern of recurrence in any particular week or set of weeks. Moisture deficits have occurred in each week between July 22 and November 4 over 25% of the period of record, while deficits have occurred in 12 of the 26 years (46%) in each of the seven-day periods between August 6-12, September 9-16, and October 14-21. In general, deficits have not been noted before June 10 but have occurred in at least one year until December 16.

Other than examining the occurrence of moisture deficits, the irrigation season can also be examined in terms of the actual scheduling of water applications. Farmers interviewed in this study were asked to specify dates when they would commonly expect to irrigate in any given year. Although replies to this question could be expected to vary from year to year, respondents were able to provide remarkably specific answers, usually within the range of a two-week period. Based on the statements of surveyed farmers, some irrigation can be expected to occur in each of the five months from May through September (Table 5.10). In May, the application of water is typically unrelated to the physiological water requirements of crops but is coupled with the use of irrigation equipment for other cultural practices. The

FIGURE 5.5

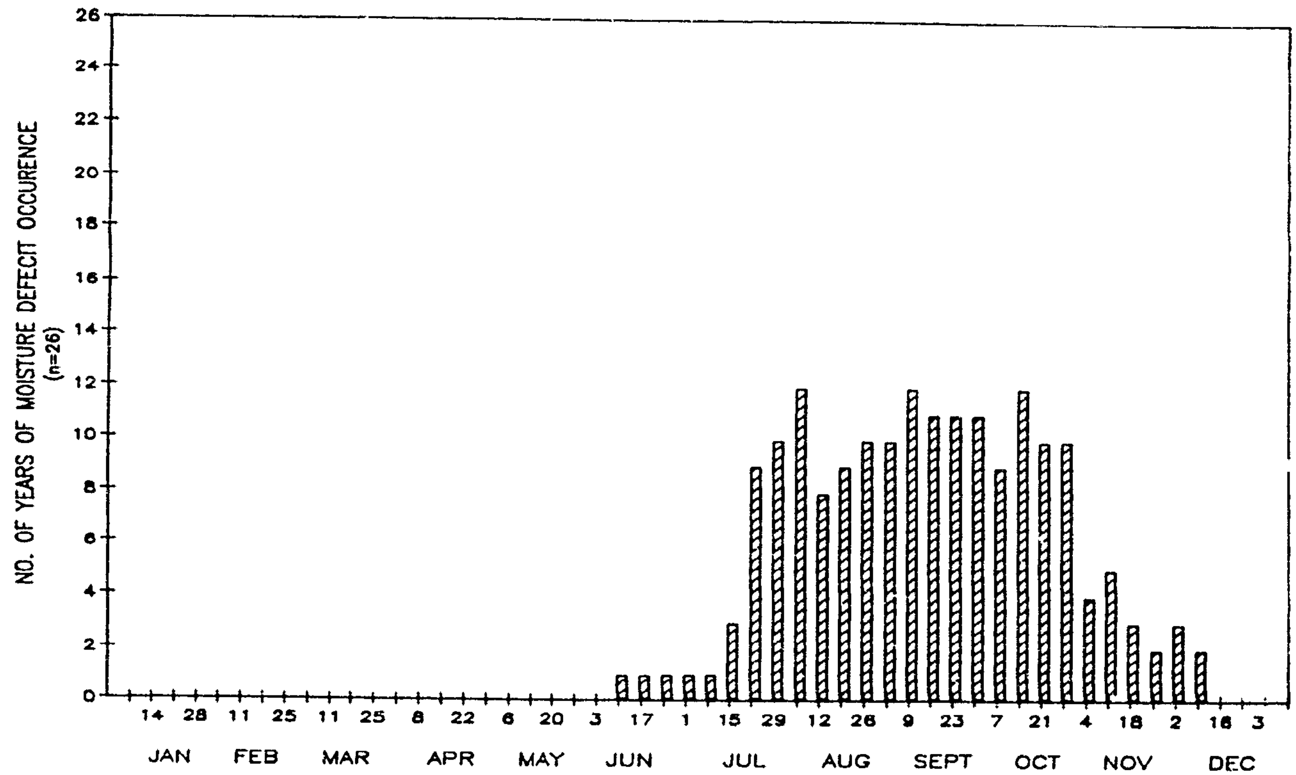
FREQUENCY OF MOISTURE DEFICIT BY WEEK
FOR THE PERIOD 1967 TO 1985
SIMCOE COUNTY
(Midhurst station)



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

FIGURE 5.6

FREQUENCY OF MOISTURE DEFICIT BY WEEK
FOR THE PERIOD 1960–1985
KENT COUNTY
(Ridgetown station)



Source: Environment Canada; Atmospheric Environment Service, Water Budget Records.

TABLE 5.10 SCHEDULING OF IRRIGATION ON SURVEYED FARMS BY MONTH, CROP AND LOCATION

CROP TYPE AND LOCATION	NUMBER OF FIELDS AND PERCENT OF AREA (1)				
	MONTHS				
	MAY (% Ha)	JUNE (% Ha)	JULY (% Ha)	AUG. (% Ha)	SEPT. (% Ha)
TOBACCO					
Kent	3 33.3	1 17.5	7 100	-- --	-- --
Simcoe	1 100	-- --	1 100	-- --	-- --
Norfolk	-- --	-- --	9 76.5	3 43.3	-- --
POTATOES					
Kent	1 100	-- --	1 100	-- --	-- --
Simcoe	-- --	2 47.1	5 100	3 57.6	-- --
Norfolk	-- --	1 10.3	2 100	-- --	-- --
TREE FRUITS					
Kent	-- --	-- --	2 100	1 32.3	-- --
Simcoe	-- --	-- --	-- --	-- --	-- --
Norfolk	-- --	-- --	-- --	-- --	-- --
STRAWBERRIES					
Kent	4 100	-- --	4 100	-- --	1 47.9
Simcoe	1 100	1 100	1 100	-- --	-- --
Norfolk	1 96.2	2 100	1 3.8	-- --	-- --
OTHER SMALL FRUITS					
Kent	1 100	1 100	1 100	-- --	1 100
Simcoe	-- --	-- --	-- --	-- --	-- --
Norfolk	-- --	-- --	-- --	-- --	-- --
ONIONS					
Kent	-- --	-- --	1 100	-- --	-- --
Simcoe	3 100	1 43.7	2 56.4	-- --	-- --
Norfolk	-- --	-- --	-- --	-- --	-- --
CARROTS					
Kent	-- --	-- --	-- --	-- --	-- --
Simcoe	4 100	3 77.8	1 22.2	-- --	-- --
Norfolk	-- --	-- --	-- --	-- --	-- --
PEPPERS					
Kent	3 89.6	-- --	5 100	-- --	1 78
Simcoe	-- --	-- --	-- --	-- --	-- --
Norfolk	1 49.4	-- --	1 49.4	1 50.6	-- --
OTHER VEGETABLES					
Kent	-- --	1 100	1 100	-- --	1 100
Simcoe	2 96.8	2 96.8	3 100	-- --	-- --
Norfolk	1 19.4	2 26.2	4 90.0	3 31.6	2 16.7

(1) Refers to the area of a crop in the named county as a percent of the total hectares of that crop reported by surveyed farms in that county.

early irrigation of tobacco, potatoes and peppers in Kent County, for instance, primarily is associated with the substitution of irrigation for watering planters, on some farms. Similarly, irrigation is used on most of the strawberry and small fruit acreage in May and June as a frost-prevention technique or to help establish the crop. All of the surveyed carrot and onion acreage in Simcoe County was irrigated during the spring to reduce the problems of wind erosion and heat stress.

With few exceptions, the irrigation of all crops in each of the sample counties can be expected to approach 100% of total acreage in the month of July. The exceptions include carrots and onions grown on muck soils in Simcoe County, and tobacco, peppers and other vegetables produced in Norfolk County. The acreage of these latter crops, not irrigated in July, is accounted for by one farmer who, as previously mentioned, was committed to the needs of another crop during this period. Consequently, these crops were irrigated in early August.

Fewer respondents mentioned a frequent need to irrigate during the months of August and September. Among those who cited irrigating during August, two tobacco farmers suggested that within the last six or seven years, there has been an increasing need to apply water during the first two weeks of the month. Irrigation in the month of September is mostly attributable to one irrigator in Kent county who uses his system for the application of chemicals. Two additional respondents reported a common need to irrigate cauliflower and sweet corn respectively, in September.

In general then, the occurrence of irrigation early in the growing season is largely unrelated to physiological moisture deficiencies. For most crops, irrigation increases to a maximum amount of land area in July. The only exceptions are crops grown on muck soils in Simcoe County. These soils have good moisture retention characteristics and irrigation is not commonly used to combat actual moisture deficiencies in the soil per se, but to protect plants from potential damages which are indirectly related to a lack of precipitation.

Although the data in Table 5.10 is presented by month, a number of respondents were more specific in providing dates when they would normally expect to irrigate. Tobacco farmers in all three counties, typically confined their responses to the last two weeks in July, which is coincident with the period of "topping", while potato growers generally cited a wider ranging period of time. Two potato growers stated that in any given year, they would expect to irrigate anywhere from mid-June until the end of July, whereas three producers suggested that they would typically expect to apply water between the start of July and mid-August.

The timing of irrigations as reported by surveyed farmers can be compared with the frequency of occurrence of moisture deficits during the growing season, discussed above. Generally, most irrigation occurs during the latter part of July in all three counties. This corresponds well with the tendency for moisture deficits to occur at this time in the three study areas. Although deficits have also occurred just as frequently in the months of August and September, most irrigated crops are in the preliminary stages of harvest or have been taken off the field by this time. The potential to delay harvest and increased susceptibility to damaging early fall frosts also makes farmers wary of irrigating late in the season. For example, an unanticipated rain shortly after a late irrigation could saturate a field and make it impossible to operate essential harvest machinery, effectively lengthening the harvest operation.

5.3.2.2 Number of Irrigations

In addition to the timing of irrigations, surveyed farmers were asked how many times they would irrigate, on average, per year. The range in the number of waterings reported by irrigators was quite large, ranging from 1 to over 30(Table 5.11). When the total number of irrigations are considered, on average, a majority, (53%) of the fields receive between two and four applications of water per year. A lesser number (30%) would usually be irrigated once, while 12% would receive between five and ten irrigations. Only 8% of the surveyed fields would commonly be watered more than 11 times during the growing season. In terms of crop types, small fruits and vegetables tend to be irrigated more often than field crops such as tobacco and potatoes or tree fruits. Although there is some variation in the number of waterings within and between crop types, this variation does not appear to be distinct between the study areas. Similarly there does not appear to be any relation between the irrigation technique used and the number of waterings per year on the surveyed fields. There is, however, a noticeable absence of the use of hand-move sprinkler systems on those fields that would usually be irrigated more than five times per year. Generally, these fields are irrigated by solid-set, travelling or volume gun systems, although these techniques are also used to irrigate fields receiving less than five irrigations. The methods used by

TABLE 5.11 AVERAGE NUMBER OF IRRIGATIONS PER YEAR ON SURVEYED FARMS, BY CROP AND LOCATION

CROP TYPE AND LOCATION	NUMBER OF FIELDS			
	1 IRRIGATION	2 - 4 IRRIGATIONS	5 - 10 IRRIGATIONS	11 OR MORE IRRIGATIONS
TOBACCO				
Kent	3	4	--	--
Simcoe	--	1	--	--
Norfolk	4	6	--	--
POTATOES				
Kent	--	1	--	--
Simcoe	--	4	1	--
Norfolk	1	--	1	--
GREEN PEPPERS				
Kent	1	3	--	--
Norfolk	1	--	--	--
CAULIFLOWER				
Kent	--	1	--	--
Norfolk	--	--	--	1
CUCUMBERS				
Kent	--	1	--	--
Norfolk	--	--	1	--
ONIONS				
Kent	1	--	--	--
Simcoe	1	2	--	--
TOMATOES				
Norfolk	--	--	1	--
CARROTS				
Simcoe	1	3	--	--
CELERY				
Simcoe	--	--	1	--
LETTUCE				
Simcoe	1	--	--	--
SWEET CORN				
Norfolk	1	1	--	--

TABLE 5.11 (continued)

	1 IRRIGATION	2 - 4 IRRIGATIONS	5 - 10 IRRIGATIONS	11 OR MORE IRRIGATIONS
GARLIC				
Norfolk	--	1	--	--
CHINESE GREENS				
Simcoe	--	--	--	1
STRAWBERRIES				
Kent	--	3	1	--
Simcoe	--	--	1	--
Norfolk	--	1	--	1
RASPBERRIES				
Kent	--	2	--	--
BLUEBERRIES				
Kent	--	--	1	--
MELONS				
Kent	1	--	--	--
PEACHES				
Kent	1	1	--	--
APPLES				
Kent	1	--	--	--
CHERRIES				
Kent	1	--	--	--
PLUMS				
Kent	1	--	--	--

farmers to schedule irrigations do appear to have an influence on the annual number of waterings. In all cases where fields received greater than five irrigations per year, the scheduling of water applications was based on either a predetermined water requirement, or a specified period of time with no precipitation. In other words, farmers who felt that their crops required "one inch of water per week", or irrigated "every five days without rain", tended to irrigate more frequently than those who scheduled irrigations by crop appearance or "scientific" methods.

5.3.2.3 Depth of Water Applied

Just as important to water use as the number of waterings per year, is the amount of water applied during an irrigation. As previously noted, farmers, in irrigating their crops, define the amount of water applied in terms of depth rather than any volumetric measurement. Generally, based on experience, irrigators know how long it takes their system to apply a certain depth of water, although quite a number of respondents stated that they set a rain guage in the field being irrigated and periodically checked it to determine when a desired depth of water had been applied.

The range in the depth of water applied per irrigation is great for crop types both within and between the sampled counties and varies from a minimum of 0.8 cm for three crops in Simcoe County to almost 5.1 cm for tree fruits in Kent County. When the depths of water per application are averaged crops in Kent County generally receive the greatest amount of water per irrigation, followed by those in Norfolk County and crops in Simcoe County receive the least amount of water per irrigation(Table 5.12).

TABLE 5.12 AVERAGE DEPTH OF IRRIGATION WATER APPLICATIONS ON SURVEYED FARMS, BY CROP AND LOCATION

CROP LOCATION	NUMBER OF FIELDS	AVERAGE DEPTH PER APPLICATION (cm)	RANGE	AVERAGE TOTAL DEPTH PER YEAR (cm)	RANGE
TOBACCO					
Kent	7	3.18	(2.54-3.81)	6.4	(2.54-11.4)
Simcoe	1	2.54	(---)	7.6	(---)
Norfolk	10	2.73	(2.54-3.8)	4.8	(2.54- 7.6)
POTATOES					
Kent	1	3.81	(---)	7.62	(---)
Simcoe	5	2.1	(0.8 -2.54)	8.42	(3.81-16.9)
Norfolk	2	3.2	(2.54-3.8)	10.8	(2.54-19.1)
PEPPERS					
Kent	4	3.0	(1.9 -3.8)	8.7	(2.54-11.43)
Norfolk	2	3.2	(2.54-3.8)	10.8	(2.54-19.05)
ONIONS					
Kent	1	2.54	(---)	2.54	(---)
Simcoe	3	2.3	(0.8 -2.54)	4.8	(2.54- 6.8)
CARROTS					
Simcoe	4	2.3	(0.8 -2.54)	6.1	(2.54-10.16)
OTHER VEGETABLES					
Kent	2	3.81	(---)	11.4	(---)
Simcoe	3	2.96	(2.54-3.81)	26.2	(2.54-50.8)
Norfolk	6	3.1	(2.54-3.8)	14.6	(2.54-27.9)
STRAWBERRIES					
Kent	4	3.0	(1.9 -3.8)	9.4	(5.7 -19.1)
Simcoe	1	2.54	(---)	20.3	(---)
Norfolk	2	2.54	(---)	40.64	(5.1 -76.2)
OTHER SMALL FRUIT					
Kent	3	3.8	(---)	17.8	(3.8 -38.1)
TREE FRUITS					
Kent	5	3.8	(2.54-5.08)	4.6	(2.54- 7.62)

Similarly, a great range occurs in the total depth of water applied per season for different crop types as well as for the same crop type within an area. For example the total depth of water applied to tobacco in Kent County ranges from 2.54 cm to 11.4 cm, whereas in Norfolk County this amount varies from 2.54 cm to 7.6 cm. For different crop types in Kent County, the range in the total depth of water applied is from 2.54 cm to over 38 cm. Similar patterns of variation in the total depth of water applied to crops exist in all three sample counties.

No spatial pattern between areas emerges when the average total depth of application per year is considered. For example, tobacco grown in Norfolk County receives less water per year, on average, than tobacco crops in Simcoe or Kent Counties. Conversely, potatoes grown in Norfolk, on the average, receive a greater amount of water than those produced in Simcoe or Kent Counties. In general however, there is a distinction between crop types in the total depth of water applied per year. In all counties, small fruits and vegetables are receiving more water than other crops. The only exception to this rule are carrots and onions, most of which are produced on the high moisture retaining muck soils of Simcoe County. Potatoes in turn generally receive more water than tobacco in each of the counties surveyed. In part, this variation between crop types can be related to the total number of waterings scheduled. As noted above, in some instances, there is a greater number of waterings on vegetables and fruit crops. As a consequence, on average, a greater total depth of water is applied to these crops than others. Commonly, this generalization holds true for all crops; the greater the total number of waterings per year, the greater the total depth of water applied. In other words, those farmers who schedule few waterings during the growing season are not necessarily applying more water per irrigation than those who irrigate more frequently; and obversely, those who apply water frequently during the growing season are not putting on significantly less water per application than other irrigators.

In a temporal sense, there is little variation in the depth of water applied at different points during the growing season. Although the moisture requirements of most crops increase as the plant approaches maturity, only five farmers reported that they altered the depth of water application during the growing season. In all five cases, there was a distinction of time, and depth applied. For example, two Norfolk County tobacco growers reported that they would apply 2.54 cm (1") prior to mid-July and 3.8 cm (1 1/2") after this period. Similarly, two potato farmers in Simcoe County stated that they would water to a depth of 0.8 cm (1/3") prior to July and increase this amount to 2.54 cm (1") during July. In addition, one farmer raising garlic in Norfolk County, reported that he would reduce the depth of application after the end of July to avoid putrification of the bulb.

Just as most farmers do not adjust the depth of application to meet differing crop water requirements, the data collected also suggests that the depth of water applied does not always relate to the depth of the root zone. In a number of cases, shallow-rooted crops receive as much, or more, water per application than deeper-rooted crops (Table 5.12). For example, strawberries and other small fruit in Kent County with an average root depth of about 30 cm., receive approximately the same depth of water, on the average, as tobacco; even though the average root depth of tobacco, at 60 cm., is double that of these fruit crops.

In short, for those cases studied, there do not appear to be any variables which significantly affect the depth of water applied to irrigated crops. If the techniques of application, and physical factors such as soil type, field size and water supply are compared between farms, no common trends in the depth of application stand out. For example, just as there is a great variation in the depth of water applied within and between crop types, there is a similar variation both within and between classifications of irrigation techniques, soil types, field size and water sources.

Regrettably, the question of how the depth of application is determined was not asked of farmers surveyed for this study. It has, however, been considered in another recent survey of Ontario irrigators which asked what factors were used to determine "how much water to apply at one time" (Ontario Ministry of Agriculture and Food 1986). Unfortunately, the reported classification of responses to this question yielded little useable information. It was ascertained that the most important factor cited by farmers was "crop appearance". This was closely followed by "soil condition" and other factors such as "a set amount" and "irrigating for a set length of time." Yet, it is not clear how these factors determine the amount of water to be applied to a crop. Observations that the amount of water applied depends upon crop appearance or soil condition would imply that farmers vary the depth of application with the apparent severity of these indicators. Data collected for the current study, however, would tend to suggest that this is not the case. Most farmers apply a set amount of water at each irrigation and, in the few cases where this amount varies, the determining factor is a stage of crop growth rather than crop appearance or soil condition. This apparent discrepancy can be partially accounted for by the fact that the question, as asked by the government survey offered pre-formulated response categories which were identical to those of another question, on the same survey, asking farmers how they determine the timing of irrigations. Consequently, a bias is evident in this study in the form of a pre-supposition that the factors which influence the scheduling of an irrigation, would also influence the amount of water applied. Similarly, the "closed" nature of this question poses the oft-mentioned problem of presenting the respondent with an easily identifiable response which need not be applicable to the question being asked. The question that remains unanswered then, is what determines the set amount of water applied to crops during an irrigation.

Rather than basing the application of water on any obvious factors, or set of factors, current irrigators are more likely applying an amount of water that is in accordance with their past experience of success and failure; or more accurately, the experience of their predecessors. In general, those farmers surveyed are "second-generation" irrigators and were first introduced to the practice on "the home farm". Their fathers, who initially adopted the practice were responsible for learning how to use this new technology. According to a number of farmers, over-irrigation was a common problem during the early years of its use in Ontario and resulted in high crop losses. Similarly, Richardson (1958) noted that quite a number of farmers tried "to get as much water on their land as soon as possible" and felt that more irrigation "know-how" was needed on the part of farmers.

This lack of "know-how," however, is not unusual during the initial adoption period of any new technology. As noted by Feder et al. (1985), "the introduction of new technologies results in a period of disequilibrium behaviour where resources are not utilized efficiently by the individual farm and learning and experimenting lead the farmer toward new equilibrium levels." In other words, there is a change over time in the farmers effectiveness with new technologies, and these changes are usually the result of learning by doing whereby the farmer becomes more adept with the technology as he accumulates information by using it. Hence, as the visible damages of over-irrigation, became readily apparent to early irrigators, these farmers "learned" to apply less water. The attainment of this "new equilibrium level" according to Feder et al. (1985) may also be aided by the research efforts of extension agencies. Thus, it is of note that during the mid-1950's, a number of agricultural bulletins and articles in farm periodicals were published which contained recommendations pertinent to the application of water. Most of this advice was based on the water storage capacity of specific soils and an estimated daily moisture requirement of certain crops. For example, Hore (1953) stated that it was "important to apply an amount of water to wet the soil down to the depth of the majority of plant roots", and recommended an application of 1.25 inches (3.18 cm.) of water to potatoes grown on sandy loam soils. Similarly, Fulton (1956) suggested an application of 1 inch (2.54 cm.), after seven consecutive days without rain, to potatoes grown on coarse sandy soils; and 1.5 inches (3.81 cm.), every ten days without rain, on finer sandy loam soils. Meanwhile, Walker (1956) recommended a range of applications to "average tobacco soils" with a minimum of 0.5 inches (1.27 cm.) in June, 0.75 inches (1.9 cm.) to 1 inch (2.54 cm.) during July, and a maximum of 1.25 inches (3.18 cm.) in August.

Through such an accumulation of experiential and exogenous knowledge, early irrigators reached an "equilibrium behaviour" in applying water to their crops that has become accepted practice by their offspring. As Bennett (1986) put forth, "as knowledge accumulates...there is a tendency for it to become part of culturally standardized routines"; and in the case of later generations, "there is bound to be much routine agricultural activity where farmers need not 'make decisions', they simply do what they have always done." Or, in this case what they have learned to do. In the illustrative words of one tobacco farmer, "I learned a lot about irrigating on my father's farm,...we always put plenty of water on the crop when we irrigate...there is never less than 1 1/2 inches of water put on." (Crandon 1962).

To conclude, although visible, local field conditions have a determining effect on the timing of irrigations, they exert little influence on the amount of water that current irrigators apply to their crops. Rather, the depth of application appears to be a static irrigation practice, rarely varying between waterings, whereby individual farmers rely on "traditional" routines which have proven to be reasonably effective in avoiding any visible signs of crop impairment.

5.4 CONCLUSION

In this chapter, the actual irrigation techniques and practices used on 35 surveyed farms in southern Ontario have been examined. Based on this investigation, some generalizations relating to the management of water on the surveyed farms can be stated. On a broad scale, a distinction can be made between "technical" and "cultural" water management practices. By "technical", is meant the structural methods of storing, delivering and applying irrigation water. Since the initiation of irrigation on the surveyed farms, the sources of water and techniques utilized in watering fields have been subject to a great deal of modification and change. For example, under conditions of inadequate supply due to natural shortages, competition, or operational failure of storage structures, farmers have attempted to secure a sufficient supply of water for irrigation through structural alternatives rather than attempting to modify their demand for water. The alternatives selected in turn, have been influenced to varying degrees by the physical availability of supply, and the economic standing and personal preference of the farmer. Similarly, the technical methods of irrigation have been subject to continual change. Farmers have not been averse to adopting new techniques of irrigating when the innovations have been particularly applicable to the crop and soil parameters of their operation, where the farmer could afford the new system, and especially where the innovation offered a recognizable solution to an obvious problem, such as excessive labour requirements under the old system.

Cultural practices, however, can be seen as distinct from technical practices as they determine the actual timing of water applications and the amount of water applied to crops. In deciding when to apply water, farmers have developed a set of rational guides which rely not only on crop appearance, but physical factors such as the occurrence of frost and wind and stages in crop growth. Similarly in determining how much water to apply, farmers rely on historical decisions that have been made under conditions of evaluation and empirical observation. That the application of water to a crop may not occur exactly when it is required and the amount applied may not be the precise amount necessary for optimum production, is not of great import to the farmer. What is important is that these guides have proven to be effective in satisfying the farmers rationale for irrigating. As Bennett (1986) has noted, "satisfaction is the key that binds current uses to past practices." Thus, in the absence of any salient detrimental effects arising from the use of these indicators and guides, they can be expected to continue.

In recent years, however, the technical-scientific community has expressed a great deal of concern that irrigation water is not being used as efficiently as possible and that farmers have no rational basis for determining when to apply water and how much water to apply (see O'Riordan 1969). In general, the attitude of these "resource managers" is summed up as follows:

> "the wastage of irrigation water is common wherever distribution is casually monitored, on-the-farm distribution systems are poorly designed and poorly managed...Wastage may be in the form of over-application, undue losses in delivery or uneconomical choices of crops. Occasionally the wastage of water is the result of uncertainty over the state of water supply so that needed on-the-farm investments are not made. Often however, the wastage is either the result of carelessness or uninformed agricultural methods" (United Nations 1976; my emphasis).

Based on this perception, most irrigation management research has focused on means of reducing irrigation requirements and enhancing irrigation efficiency; primarily through improved technologies and "refined" irrigation scheduling techniques. Yet, as several studies have noted (Irwin and Armitage 1981, O'Riordan 1969...), these "improvements" have not been readily adopted by irrigating farmers. The following chapter will deal with the nature of these improvements and, in light of the actual irrigation practices discussed in this chapter, suggest that the variance between optimal and actual water management practices is not so much a result of "carelessness" or uninformed agricultural methods, but reflects differing degrees of focus and concern on the part of both the farmer and the research scientist.

CHAPTER 6

THE "EXPERT"-PRACTITIONER DICHOTOMY IN IRRIGATION MANAGEMENT

6.1 INTRODUCTION

Within the last 25 to 30 years, irrigation scientists (predominantly agronomists, agricultural economists and agricultural engineers) have concentrated their research efforts on questions of irrigation efficiency. The problem, as most of these researchers view it, is that traditional irrigation practices and methods, as developed by farmers, have resulted in an injudicious use of water (ie. Bos and Nugturen 1983, Jensen et al. 1980, Replogle and Merriam 1980). This attitude however, as noted by Chambers (1980), is commonly based on broad generalizations which have been extrapolated from one or few case studies and are not necessarily universally applicable. Yet the predominant view of the technical-scientific community remains that wherever "water is plentiful, farmers tend to overirrigate in both frequency and depth of application" (Blaney 1955). This condition, in turn, represents an inefficient use of irrigation water. Several authors have noted that although the technology for reducing water requirements and achieving efficient use of water has existed for decades, the application of this technology on irrigating farms has been minimal (ie. Jensen et al. 1980, Replogle and Merriam 1980). There is an implicit assumption among "agro-scientists", however, that merely because the information and knowledge required to increase efficiency and maximize production exists, it should and will be used by farmers. Take for example the comments of Gilley and Jensen (1983) that "because of better water control...farmers <u>will</u> continue to <u>improve</u> their irrigation systems" (my emphasis); or the belief of King and Tuertell (1984) that "undoubtedly, as our understanding of soil-plant-atmosphere interactions grow, new and improved models and estimates of evapotranspiration will become available for the benefit of agriculture." In their desire to develop "new and improved" models and irrigation systems, researchers commonly display several objectives. Based on a perception that indigenous (farmer) knowledge results in an overuse or a misuse of water, one objective is to reduce the amount of water used in irrigation. Predominantly however, the commonly stated objective of the irrigation research community is to, properly manage water in order to "achieve yields close to the maximum." (Gilley and Jensen 1983). Indeed, as Bennett (1986) suggests, this attempt to "increase output in the shortest possible span of time", has been the primary objective of agricultural research and national agricultural policy in most countries since the emergence of modern commercialized agriculture.

When these desires or objectives are not reflected in the practices of farmers, and when available information is not utilized and incorporated into agricultural operations, "unsatisfactory" performance is commonly explained in terms of the "backwardness" of the farmer, or the "catch-all" notion proposed by White (1962) and echoed by O'Riordan (1969) that a particularly strong social resistance to change in rural areas is to blame. Rarely, however, is attention given to the purposive action or objectives of the farmer in relation to individual irrigation practices. Even rarer still is it imagined that these objectives may differ from those of the irrigation "expert." Based on the insightful observations of Levine (1980) that

"there are some important management constraints on irrigation

> efficiency that are not under the control of the irrigation engineer, but which greatly influence the efficiency of water use in practice."

the remainder of this chapter suggests that the degree to which the measures suggested for reducing water requirements or increasing efficiencies are within the ability of the farmer to change, and the extent to which these changes reflect his objectives in irrigating will determine the degree to which improved irrigation efficiencies or reductions in water use are practically attainable. This examination of the variation between optimal and actual water management practices hinges on several key issues:

i) the awareness of a problem as determined by irrigator estimations of existing efficiency and possibilities of enhanced efficiencies;

ii) the availability of irrigation management information through agricultural extension agencies and government programs;

iii) sources of information used by farmers;

iv) desire for extension support on the part of irrigators; and

v) incentives that have led farmers to adopt "improved" practices in the past.

Before examining these issues however, a definition of efficiency must be provided and existing alternatives for reducing water requirements and increasing efficiencies should be examined.

6.2 THE EFFICIENCY EQUATION

As noted by Bos and Nugteren (1983) the term "efficiency" is a relative one which has been interpreted in a variety of ways dependant on the intentions of the user. Generally, "irrigation efficiency can be considered in both an economic and a physical sense" (Weatherford et al. 1982). An economic definition of irrigation efficiency is usually considered in allocative terms and is measured by comparing the productivity of water used in irrigation to its productive value in alternate uses (ie. Timmons 1983, United Nations 1976). In physical terms, however, water application efficiency is typically defined in one of two ways: (a) as a ratio of the quantity of water stored in the root zone following an irrigation (available water) to the amount of water delivered to the field; and (b) a ratio of the amount of water needed by a crop to the amount of water applied (ie. Cannell 1962, Hudson 1962). According to Hudson (1962), the sole difference between the two is that irrigation water retained in the root zone but not needed by the crop during the growing season is considered efficient under (a) and inefficient under (b). "In practice, such amounts are usually so small as to be insignificant" (Hudson 1962). In fact the standard definition accepted by the International Commission on Irrigation and Drainage (ICID) combines these two formulae and expresses field application efficiency as: a ratio of "the volume of irrigation water needed, and made available, for evapotranspiration by the crop to avoid undesirable water stress in the plants throughout the growing season <u>to</u> the volume of irrigation water furnished to the field. (Bos and Nugteren 1983). It should be noted that this discussion has omitted consideration of conveyance and distribution efficiencies. However, these components of the efficiency equation are primarily applicable to irrigation systems which utilize open channel conveyance and distribution methods, where seepage losses pose a severe problem, rather than closed conduit transport channels such as those found on the surveyed farms.

Under the definition supplied above then, maximum efficiency is achieved when all losses of water other than that evaporated from wet soil surfaces and transpired by plants, are eliminated. According to Keller et al. (1980), the major sources of on-farm water loss associated with sprinkler irrigation are: direct evaporation from droplets and transpiration from unwanted vegetation; wind drift; leaks and system drainage; and deep percolation and/or runoff losses due to over-watering.

6.2.1 Balancing the Efficiency Equation

Based on the general perception of irrigation specialists that irrigation water is being used inefficiently by farmers, research efforts have focused on means of reducing irrigation requirements and improving efficiencies. There is however, considerable uncertainty and, often, disagreements concerning the primary causes of inefficiency and the means of achieving compliance with various disciplinary norms (ie. Weatherford et al. 1982). Agricultural engineers, for example, tend to stress the importance of technology. The common parlance is that an "inefficient use of water results from the physical condition...of the on-farm irrigation system" (Gilley and Jensen 1983), but, "we know that sprinkler irrigation, drip irrigation and other engineering measures increase water application efficiency" (Gardner 1984). Consequently,

> "because automated sprinkler and centre-pivot systems provide the capability for improved water management, advanced water management concepts should be more easily applied where these techniques are used." (Gilley and Jensen 1983).

Agronomists and agro-meteorologists, on the other hand have concentrated on decreasing the demand for water through: modification of the field micro-climate to reduce evaporative and transpirative water demands; the development and selection of low-water-use plant varieties; and improved irrigation scheduling through theoretical, climatically derived estimates of potential evapotranspiration. Efforts to modify micro-climate generally concentrate on the beneficial effects of tree windbreaks in reducing wind speed over farm fields and thereby reducing air turbulence in the immediate soil-plant environment. As increased turbulence accelerates the transfer of water vapour to the environment, a consequent reduction should decrease water loss through evapotranspiration (ie. Robins 1967, Rosenburg 1982). An alternative means of reducing irrigation water demands, recommended by plant scientists, is the selection and use of varieties of related species that have inherently, or genetically manipulated, low transpiration rates.

Although both of these alternatives would tend to reduce the demand for water and hence the irrigation requirement, they are not necessarily related to the question of physical irrigation efficiency which under the definition supplied above, considers the in situ conditions of irrigation. In other words, how much water is required to satisfy the consumptive demands of a particular crop-soil combination vs. the amount of water applied. Consequently, most research on the subject of improved irrigation efficiencies has focused on the scheduling of irrigation applications, both in terms of timing and amount, to meet the needs of the crop for maximum production. The premise here is that farmers do not have sufficient information to judge the water requirements of crops and due to this uncertainty, "tend to overirrigate" (Biere and Worman 1983). This in turn leads to great variability "in the growth and yield of crops from year to year on the same farm and from farm to farm in the same year" (King and Tuertell 1984). The optimum goals in scheduling, according to Gilley and Jensen (1983) should be:

> i) to reduce the negative effects of applying excess water by delaying irrigations until soil water depletion is sufficient to permit the storage of the next application; and
>
> ii) to avoid plant water stress by irrigating before crop yields and/or crop quality are reduced because of inadequate soil water."

Although several "scientific" scheduling methods have been available for a number of years, most of the emphasis since the early 1950's has concentrated primarily on meteorologically-based soil moisture budget procedures. Robertson (1956) appears to have been the first to experiment with soil moisture budgets in Ontario, although several researchers have developed a number of variations on the theme (see Ayers 1965, Griffin and Hargreaves 1974, Krogman and Hobbs 1976, Lambert et al. 1981, Pitblado 1984, Sly 1977, Tan 1984, Wilcox and Sly 1974). The idea of the budget itself is quite simple and essentially entails balancing outgoing water in the form of evaporation from the soil surface and transpiration from plants (evapotranspiration) against incoming water in the form of precipitation. Based on this balance irrigation water is added when the water stored in the root zone of the soil has been depleted to a critical level (usually considered to be 50%) of field capacity (the maximum amount of water held in storage in a particular soil). The amount of water added should be sufficient to restore the soil to field capacity, or in humid regions slightly below field capacity in consideration of the possibility of a rain shortly after irrigation. Although the format is generally the same for all moisture budget procedures, the terminological definitions differ. Specifically, the reliability of any particular budget depends on the accurate measurement of several components:

a) crop evapotranspiration;
b) effective rainfall;
c) available water storage capacity of a soil; and
d) the allowable level of soil water depletion.

Yet few researchers agree on standards of measurement. Estimations of evapotranspiration have become increasingly complex since the landmark work of Thornthwaite (1948) and Penman (1948) but recent reviews suggest that there is still no consensus on the subject (Burman et al. 1980, King and Tuertell 1984). Indeed, in assessing several scheduling procedures for humid areas, Lambert et al. (1981) noted that although crop needs could normally be adequately met using water budget methods, researchers:

> "obviously don't know enough about how to estimate available water in a profile; how to account for dry conditions in the upper, more densely rooted portions of the root zone while the lower portions are still wet; how to calculate evapotranspiration, especially under limited soil water contents; or how to manage the allowable depletion parameter to optimize crop behaviour."

Although it is refreshing to find at least one author who suggests that the knowledge of science may be just as "imperfect" as that of the farmer, most researchers still express surprise that although the technical knowledge to improve water use efficiencies has existed for decades, it has not, to any great extent, been incorporated into the water management practices of irrigators. However, in devising methods to improve on-farm water management such as those outlined above, "agro-scientists" tend to neglect the one important component of the efficiency equation that they criticize the most - the farmer. A notable exception to this condition, however, is the work of

Weatherford et al. (1982) who question the deterministic assumption that merely because scientifically "rational" methods exist, they will be incorporated into the irrigation practices of farmers. Rather, Weatherford et al. (1982) argue that an understanding of the perceptions of irrigators are "as important as any 'objective' facts that purport to tell the truth to the fourth decimal point." In a similar vein, Korsching and Nowak (1983) suggested that "it would be a blessing if the solution to water problems were simply physical, biological or even economic", but that many social factors often negate the potential technological and economic benefits of the proposed solutions. Some of these factors have been outlined in Section 6.1.1 and will be discussed below.

6.3 THE CONTEXT OF IRRIGATION EFFICIENCY

6.3.1 Awareness of a Problem

For any change in the water-use practices of farmers to occur, there must first be an awareness of a problem. Obviously, farmers will only seek a remedy when they believe a problem exists. As Korsching and Nowak (1983) have noted, "this seems almost too self-evident and simplistic for elaboration but is something that...change-agency personnel often overlook." Typically, there exists an implicit assumption that farmers have the same impression of the problem and objectives in solving it, as the researchers who are advocating change. In this study, a measure of awareness was established by gaugeing irrigators' perceptions of efficiencies and inefficiencies in their use of water.

6.3.2 Perceptions of Efficiency

In conducting the survey, farmers were asked whether they thought that they were using irrigation water as efficiently as possible and to supply explanations for their beliefs. No definition of efficiency was presented to the respondents. The great majority of the 35 farmers interviewed (86%) felt that they were using water as efficiently as possible while only five of the respondents (14%) felt that their use of water was inefficient to some degree (Table 6.1). Although farmers were not asked to state specific measures of efficiency, several respondents provided qualitative answers stating that their efficiency was good or that there was minimal waste.

6.3.3 Reasons for Efficiency

Among those farmers interviewed, there did not appear to be uniform agreement as to a single reason for efficiency in the use of water. Over one-half (19) of the respondents felt that efficiency was the result of their cultural practices. Ten of these farmers felt that by irrigating at night, they eliminated any loss of water from evaporation and wind drift that would occur if water were applied during the day. Nine farmers suggested that they achieved efficient use in a temporal sense by irrigating "only when necessary". "Necessary" in all of these cases referred to obvious signs of water need as determined by the observation of crop condition. A few respondents (5) related efficiency to the economic cost of pumping water. Although these respondents could not provide specific estimates of their pumping costs, the general response was that "it costs money to pump so we don't water just for the fun of it." Presumably, the cost of supplying water, in the minds of these farmers, provides an incentive to minimize water use and eliminate any wasteful

TABLE 6.1 PERCEPTIONS AND REASONS FOR IRRIGATION EFFICIENCY ON SURVEYED FARMS

Number of Farms Reporting

	Reasons for Efficiency						Reasons for Inefficiency			
Location	Efficient Use of Water	Cost of Pumping	Irrigate at Night	Irrigate Only When Necessary	System Design Minimizes Overlap	Minimal Leakage	Inefficient Use of Water	Leakage From System	Evaporation and Wind Losses	Application Method
Kent	8 (89%)	2	2	1	1	2	1 (11%)	--	1	1
Simcoe	11 (92%)	1	5	4	--	--	1 (8%)	--	1	--
Norfolk	11 (79%)	2	3	4	1	1	3 (21%)	1	2	--
Total	30 (86%)	5	10	9	2	3	5 (14%)	1	4	1

practices, but little evidence is available to support this presumption. A final five irrigators attributed their efficient use to their technical irrigation systems. Two of these respondents suggested that the design of their system minimized any wetted diameter overlap so that a uniform depth of water was being applied to the field. Three irrigators stated that their use of water was relatively efficient as there was minimal leakage from their irrigation systems.

6.3.4 Reasons for Inefficiency

Of the five farmers who felt that their use of water was inefficient, the majority felt that a great loss of water occurred due to evaporation and wind drift. In one farmer's estimate, this could be up to as much as one-third of the amount applied. One farmer felt that his application system resulted in an inefficient use of water because it did not provide a uniform coverage of the field. An additional respondent suggested that a leakage of water from conveyance pipes reduced his efficiency in applying water.

6.3.5 Opportunities to Improve Efficiency

Given the generally strong impression among the surveyed farmers that they are using water as efficiently as possible, a surprisingly high number of respondents were able to identify specific measures when asked how they might make more efficient use of irrigation water (Table 6.2). Overall, slightly less than half of the farmers (49%) responded that there were opportunities to improve efficiencies. The remainder responded "no" or "don't know". Again, there was no unanimity as to one factor leading to increased efficiency and farmers typically qualified their responses by supplying reasons for why these

TABLE 6.2 OPPORTUNITIES TO IMPROVE IRRIGATION EFFICIENCY ON SURVEYED FARMS

Location	Number of Farmers Citing Opportunities	Number of Farmers Reporting Specific Opportunities					
		Irrigate at Night	Improved Scheduling Techniques	Adopt. Travelling Irrigation System	Adopt. Trickle Irrigation System	Plant More Windbreaks	Combine Fertilization with Irrigation
Kent	3 (33%)	2	--	--	1	--	--
Simcoe	7 (58%)	1	1	2	2	1	1
Norfolk	7 (50%)	5	1	1	--	--	--
Total	17 (49%)	8	2	3	3	1	1

opportunities had not been realized. The most frequently-mentioned responses related to an alteration of cultural irrigation practices. For example, eight respondents suggested that by irrigating at night, losses due to evaporation and wind drift could be significantly reduced. These respondents however were generally willing to accept these losses in order to maintain an acceptable daily labour routine. The general impression among these farmers is summed up by the comments of one irrigator: "I could irrigate at night, but who wants to stay up all night." In a similar vein, two respondents felt that efficiencies might be improved by adopting "improved" scheduling techniques that had been recommended by local extension agents, but that they did not irrigate frequently enough to justify the time involved in maintaining the records required to use these techniques. It is of note that two of the respondents who related their existing efficiency to the cost of pumping water were among those who cited these opportunities to increase efficiency, but were averse to change for the reasons outlined above. These attitudes would tend to suggest that even where the cost of supplying water is borne by the farmer, social desires (ie. maintaining a routine daily schedule) can take precedence over the economic benefits of improved efficiencies. This example would seem to contradict the positivist argument of some scholars that where water users bear the full cost of supplying their demand, they will strive to realize and adopt measures to reduce that demand (see Millerd 1984, Mitchell 1984). As Hart (1975) has suggested, although this argument might hold true at the regional aggregate level, "perhaps it does not operate quite so neatly at the level of the individual farmer."

Fewer respondents mentioned improved irrigation technologies as a factor leading to improved efficiency. Of the six farmers who perceived opportunities, half cited automated travelling systems while three others mentioned drip irrigation. Again however, most of these respondents felt that the expense of these systems precluded their adoption or that they did not irrigate frequently enough to justify the expense. One additional respondent cited the re-establishment of windbreaks as an opportunity to improve efficiency. This particular respondent, a Holland-marsh farmer, noted that an extensive windbreak had been destroyed by government road crews in order to widen a highway that runs through this intensively farmed area. Since that time, this irrigator felt that his water applications had become more frequent.

A final respondent suggested that efficiency could be increased by combining the application of fertilizer with the application of irrigation water. This alternative however, would appear to be related more to production efficiency than the physical efficiency of water use.

In general t n, the majority of the irrigators surveyed believe that they are using water as efficiently as possible. Most of these farmers apparently defined efficiency based on their impression of the causes of water loss and efforts that they undertake to reduce these losses. These efforts generally relate to cultural irrigation practices rather than the technical attributes of their irrigation systems. As such, the recognition of opportunities to improve efficiencies are identified based on perceptions of the major cause of water loss. Where this is seen to be due to evaporation and wind loss, there is a belief that irrigating at night would reduce these losses. Where problems are due to poor uniformity of water application, there is a perception that improved technologies might provide a remedy. Again the perceived opportunities to improve efficiency are dependant upon the unique operating conditions of each individual farm and farmer. The realization of these opportunities, in turn are constrained to some degree by a number of factors, the most apparent of which seem to be social and economic acceptability. For example, whereas some farmers are willing to, and do, irrigate at night to reduce losses, and hence increase efficiency, others who may recognize the inherent efficiency of this practice find it socially unacceptable, yet still believe that they are using water as efficiently as possible. Similarly the cost and perceived benefits of realizing the opportunity are constraining factors. Whereas some farmers simply cannot afford the cost of improved technologies, others do not believe that the relevant benefits arising from them justify the investment of time (in the case of scheduling) or money (in the case of equipment).

In addition the ability of farmers to adopt water-reducing measures, such as specific crop varieties may be constrained by external factors such as marketing arrangements. One example of such a situation was discovered in general discussions with three individual producers of processing potatoes in Simcoe County. Each of these farmers held a contract, through a broker, with three major potato chip manufacturers in the province. In return for an assured market outlet for their produce, these producers were bound, by contract, to grow a specific variety of potato. In recent years, according to these farmers, the manufacturer had been demanding a specific variety which, in the eyes of these farmers was more susceptible to moisture stress than varieties which they had previously grown and consequently required more frequent irrigation to obtain a marketable crop. The manufacturer, however, felt that this variety produced a whiter potatoe chip, which according to their market surveys, reflected consumer desires. In these cases at least, it would seem that the concerns of the processor determine the crop variety grown rather than the concerns of the farmer. Thus, the manufacturers' role as the provider of a stable market creates a situation where, through contractual obligations, the farmer is not permitted to adopt low-water using varieties.

6.4 FOCUS AND CONCERNS OF IRRIGATORS

In recognizing opportunities to improve water management practices on the farm, irrigators are also constrained, to some degree, by the availability of information and the sources of information that they most frequently come into contact with. As Irwin and Armitage (1981) have noted, several methods have been used to disseminate knowledge to irrigators in Ontario. These methods have included descriptive articles in farm periodicals, publications released by the government, experimental results published in professional disciplinary journals, conferences and extension personnel at government agricultural offices, research stations and universities. In each of the three study areas, for example, there is at least one government extension agent or research scientist willing to provide information on advanced irrigation technologies and scheduling techniques. However, when asked what sources of irrigation information they used, few farmers mentioned a significant number of these sources (table 6.3). Rather, most farmers rely upon commercial equipment

TABLE 6.3 SOURCES OF IRRIGATION INFORMATION USED BY SURVEYED FARMERS

LOCATION	ORDER OF IMPORTANCE	Number of Respondents Reporting Source by Order of Importance						
		IRRIGATION EQUIPMENT SUPPLIER	FARM PERIODICALS OR BOOKS	COUNTY AGRICULTURAL REPRESENTATIVE OR EXTENSION AGENT	GOVERNMENT PUBLICATIONS	CROP RESEARCH STATIONS	OTHER IRRIGATORS	OWN KNOWLEDGE
KENT	FIRST	7	--	2	--	--	--	--
	SECOND	--	1	--	--	1	5	--
	THIRD	--	1	--	--	1	--	--
	FOURTH	--	--	--	--	--	--	--
SIMCOE	FIRST	4	3	--	--	--	2	3
	SECOND	1	--	2	--	2	5	--
	THIRD	1	1	--	--	--	2	--
	FOURTH	--	1	--	--	--	--	--
NORFOLK	FIRST	7	2	--	--	3	2	--
	SECOND	4	1	--	--	2	5	--
	THIRD	--	--	--	--	1	--	--
	FOURTH	--	--	--	--	--	--	--
TOTAL		24	10	4	0	10	21	3

dealers, general farming publications or conversations with other irrigators as their most important primary and secondary sources of information. Ease of access is likely the most important factor in determining the use of these sources. For example, equipment dealers strenuously attempt to contact irrigators and promote their products, tailoring their advice to the immediate needs and concerns of the farmer. Agricultural specialists (ie. research scientists and extension agents), on the other hand, have a tendency to take communication for granted and assume that farmers actively engage in search and learning activities in an effort to improve their management practices (see Chambers 1974, Feder et al. 1985). No doubt this is true when farmers believe a problem exists with their current practices, however, as suggested above, most of the surveyed farmers believe that their irrigation scheduling practices are satisfactory and not in need of change. In fact, most of the respondents to this study stated that they did not actively seek out irrigation advice and had to be prompted to provide an answer to this question (ie. If you did desire irrigation information, where would you be most likely to look?)

The fact that most respondents cited equipment dealers or manufacturers as their primary sources of information points to their concern with the technical aspects of irrigation management. This concern is reflected in the types of government programs which irrigators have used in the past, and the form of government support that they would like to see in the future. Given the relatively low level of contact with government agricultural representatives, it is not surprising that the majority of irrigators surveyed had no knowledge of government programs which provide support for irrigation (Table 6.4). Those who had taken advantage of programs in the past, however, were generally concerned with acquiring assistance in the development of a water supply or the purchase of irrigation equipment. Similarly, when asked if there was a need for government involvement in irrigation management and what form this involvement should take (Table 6.5), most farmers who responded in the affirmative felt that this involvement should be in the form of economic incentives to update irrigation equipment or the development and maintenance of an adequate water supply. Fewer suggested that there was a need for research or educational programs related to improved scheduling practices. The majority of farmers who responded negatively to this question were of the opinion that any form of government involvement was synonymous with unfavourable attempts to control their behaviour through legal regulations or economic penalties. Among these farmers, this oppositional attitude does not seem to be confined to issues of irrigation, but permeates through the entire sphere of agricultural operations. Nonetheless, this attitude in relation to irrigation is not surprising. Where government has been involved in farm water management activities in the past, this involvement has typically been of a regulatory nature. The example of the Permit To Take Water Program is obvious. Similarly, the farm pond program, discussed in chapter 5, requires conformity to specific design, location, and construction standards as a precondition for assistance. Farmers often view these standards as impractical or feel that the amount of assistance available does not warrant the effort required to satisfy bureaucratic demands.

TABLE 6.4 KNOWLEDGE AND USE OF GOVERNMENT PROGRAMS WHICH PROVIDE SUPPORT FOR IRRIGATION

Number of Farms				
Location	Knowledge of Programs	No Knowledge of Programs	Have Used Programs	Purpose of Support
Kent	3	6	3	- Construction of Farm Ponds
Simcoe	0	12	0	---------
Norfolk	6	8	5	- Purchase of Irrigation Equipment - Construction of Farm Ponds - Construction of Well

TABLE 6.5 NEED FOR GOVERNMENT SUPPORT OF IRRIGATION AS SPECIFIED BY SURVEYED FARMS

	Number of Farms					
	Need for Government Support		Form of Support			
Location	Yes	No	Financial Aid to Update Equipment	Develop or Maintain Water Supply	Education	Research
Kent	4	5	--	4	--	--
Simcoe	6	6	4	--	1	1
Norfolk	9	5	6	1	1	2

These findings are similar to those of Korsching and Nowak (1982; cited in Korsching and Nowak 1983), who in studying the acceptability of water management policies, concluded that farmers were more likely to favour policies of economic incentives and educational programs than regulatory policies of forced compliance.

6.4.1 Incentives For the Adoption of Improved Water Management Practices

As noted in the preceding chapter, those farmers interviewed have more readily altered their technical irrigation methods than their cultural practices. Similarly, as emphasized above, most respondents rely on equipment suppliers for irrigation information; and where farmers are desirous of government support, the most frequently cited need is for financial assistance to purchase improved equipment or develop a water supply. Where farmers have adopted "improved" irrigation systems, however, the goal has not been to acheive greater control over water or higher efficiencies in water use. In fact, when those surveyed farmers who had adopted improved systems were asked why they had changed, not one mentioned increased water use efficiency as a reason. Rather, the great majority stated that their primary goal was to reduce the amount of labour required in irrigating (Table 6.6). Although Table 6.6 lists reasons as articulated by the respondents, the stated responses of "ease of operation" and "wider coverage of crop" are synonymous with the reduction of labour requirements. For example, by providing a wider coverage of the area under crop at each setting, the number of settings and hence, the amount of

TABLE 6.6 REASONS FOR CHANGING IRRIGATION SYSTEMS ON SURVEYED FARMS

		Farms Reporting Specific Reason				
Location	Number Reporting Change	Ease of Operation	Reduce Labour Requirements	Provide Wider Coverage of Crop	Ease of Maintenance	Suitability for New Crop
Kent	5 (55%)	3	--	4	--	--
Simcoe	8 (67%)	5	4	2	--	1
Norfolk	10 (71%)	7	4	--	1	--
Total	23 (66%)	15	8	6	1	1

labour required to irrigate a complete field, are reduced. This concern with the labour-reducing benefits of improved irrigation systems has also been echoed by promotional articles in farm periodicals (Gardiner 1982). In a similar vein, Wong (1969) in a study of industrial water use found that, in adopting new technical developments, industrial managers recognized the impacts on production efficiency moreso than the effects on water use and placed greater emphasis on the benefits of reductions in labour and operational costs, than any increases in physical efficiency.

The important point here is that the rationale for adopting improved irrigation systems differs from the expectations of irrigation "specialists". Whereas these specialists feel that farmers tend to improve their irrigation systems because of better water control, and see reductions in labour as indirect benefits, farmers tend to improve their systems because of the direct benefits of lower labour requirements, regardless of the effects on water use. Additionally and unfortunately, some writers tend to consider efficiency as an inherent attribute of a specific technology. For example, McKnight (1979), in an almost fervent review of the benefits of centre-pivot technology concludes that,

> "... no other commonly used irrigation technique can provide such efficiency of water application. The frequency and rate of watering can be completely controlled, thereby meeting the varying moisture requirements of the crop at all stages of growth."

This attitude however, fails to realize that irrigation efficiency is not automatically increased by installing an improved system. Given that the frequency and rate of application are under the control of the operator, the attainment of any level of efficiency is as much, if not moreso, a function of the way that the system is operated and managed, than the potential efficiency of the technology. In fact, the benefits of increased efficiency and reduced labour requirements offered by automated irrigation systems may actually be contradictory. For example, while conducting surveys in Simcoe County one day, the author observed two centre-pivot systems, which had been operating since early morning, continue to apply water during a severe late afternoon thunderstorm. This is obviously an "inefficient" practice that can, in part, be attributed to the non-labour intensive nature of the technology. Under traditional hand-move sprinkler systems, the supervision of water application is virtually assured by the need to visit the field frequently in order to move lateral pipes. With automated travelling systems however, the irrigator is not confined to the farm and is free to turn the system on and leave it unattended for an extended period of time. During this time, the farmer may take care of other chores or even leave the farm while the system is operating. In the event of a malfunction, or as in this case, a sudden storm, he or she may not be available to shut the system down. Thus, physical efficiency is not determined solely by virtue of the technology but is mediated by the human management factor. Where the technology is not adopted for reasons of efficiency, it is unlikely that the potential efficiency will be attained.

In general then, the observation of Bottrall (1978) that "the operational aspects of farm irrigation do not usually reflect a high degree of water use efficiency as a primary objective", would appear to hold true for the farmers interviewed. However, the assumption that this lack of concern with efficiency results in an overuse of water and the expectation that "reductions in water application below quantities dictated by rules of thumb will improve the value of the product, if not its quantity" (Howe 1976), are not universally applicable.

6.5 IMPLICATIONS OF "IMPROVED" WATER MANAGEMENT PRACTICES

Among those farmers surveyed, it can be shown that under-irrigation ,in terms of crop requirements, is actually the norm. Although few experimental studies of localized irrigation requirements have been conducted in southern Ontario, the results of some of those that have are summarized in Table 6.7. Each of the studies listed utilized a soil moisture budget technique to determine the seasonal need for irrigation and used a variety of climatic parameters to estimate potential evapotranspiration. Details on the specific techniques can be found by consulting each study. Regardless of the method used, the implication of these research studies is clear. When the results in Table 6.7 are compared with the actual practices of the surveyed irrigators (Tables 5.11 and 5.12), it is found that rather than over-irrigating, most farmers are actually applying much less water than their crops theoretically require for maximum production. Although none of these studies considered data for Simcoe County, Ayers (1965) examined data for 11 locations across southern Ontario and concluded that the pattern of irrigation requirements does not differ greatly by geographic region within southern Ontario. Thus, it can be expected that this relationship of actual to ideal water applications holds true for

TABLE 6.7 IRRIGATION REQUIREMENTS AS DETERMINED BY EXPERIMENTAL SOIL MOISTURE BUDGETS FOR SELECTED SOUTHERN ONTARIO STATIONS

Study	Location	Period of Record	Soil Type	Average Seasonal Requirements (cm.)	Average Depth Applied (cm.)	Average Number of Applications During Growing Season
Robertson (1956)	Ottawa	35 years	---	14.2	---	---
Ayers (1965)	Delhi	30 years	Sandy loam	20.3	2.54	8
	Simcoe	"	"	20.3	"	8
	Ridgetown	"	"	25.4	"	10
	Chatham	"	"	25.4	"	10
Yakutchik and Lammers (1970)	Delhi	1 year	Sandy loam	7.62	---	---
Sly (1977)	Delhi	30 years	Sandy loam	22.1	---	9
Pitblado (1984)	Blenheim	1 year	Sandy loam	22.8	5.7	4

Simcoe. Unfortunately, only one of these studies was an actual field trial. In testing a computer-based scheduling procedure, Pitblado (1984) compared the irrigation need as predicted by the model with the actual applications of one farmer. Whereas the model predicted the need for four applications throughout the growing season, the farmer irrigated only once. Interestingly, this irrigation occurred after 10 consecutive days without rain. All of the other consecutive no-rainfall periods had been less than 10 days.

Under the definition of physical irrigation efficiency supplied above, it is not certain whether this practice of under-irrigation should be termed efficient or inefficient. Potentially, it is "supra-efficient"; for in relation to crop requirements, efficiencies of greater than 100% are being attained. Nonetheless, this finding establishes the point that reductions in the amount of water applied used in irrigation and the adoption of "improved" technologies or scheduling procedures are not invariably coincident. In addition, this dichotomy is not limited to humid regions such as southern Ontario. McKenzie and Chanasyk (1981) for example describe the operation of a government-run irrigation scheduling service for farmers in southern Alberta. Although the program was initiated to counter water shortages caused by peak demands for irrigation water, it was subsequently found that the scheduling service directed a number of farmers to apply more water, more frequently than they had under their traditional scheduling practices.

6.6 THE DISCORDANCE BETWEEN "EXPERTS" AND FARMERS

In light of the above discussion, it is apparent that most of the farmers interviewed for this study are, by virtue of their cultural irrigation procedures, practicing a form of "deficit" or survival irrigation. In doing so, they are diverging from what the technical-scientific community commonly considers optimal irrigation management. Thus, Pitblado (1984), in justifying the development of an "accurate" irrigation scheduling procedure, suggests that the traditional scheduling practices of irrigators "are not good enough in this day and age". Unfortunately, in making this statement, Pitblado, along with other researchers, misses the point. When the objectives of irrigators are considered, these practices are just that -- good enough. In irrigating, farmers are not striving to maximize their gains in yield or profit, but are attempting to achieve a satisfactory level of production with a minimal input of labour and energy. Just as there is a distinction in objectives between the "experts" and the practitioners, there is also a distinction in the perceived benefits of "improved" practices. In weighing the value of information from irrigation "specialists", farmers view their recommendations with the appropriate "grain of salt" and consider the relevance of new irrigation developments in terms of their own objectives. Hence, it is not surprising that irrigators have readily adopted progressive technologies not because of their potential impact on water use, but because of their diminutive effect on labour requirements. For similar reasons, it is not surprising that irrigators have not adopted "improved" irrigation scheduling procedures. For the majority of these farmers, the use of these techniques would involve a greater input of labour and energy in irrigating. Additionally, a maximization of yields would entail increased production costs and place greater stress on related farm operations. Additional time, labour and perhaps machinery would be required for harvest, and transport of the final product to market. Similarly, for some crops, additional effort would have to be exerted to secure new market outlets for the produce. Hence it is conceivable, and likely, that increased production costs and exposure to risk associated with maximum production could outweigh any potential benefits. In general discussions, several surveyed farmers noted the lack of available labour as a disincentive to achieving increased yields. One of these irrigators put it quite bluntly; "I can't get enough help to get my crop off as it is now, why should I try to increase my yield when it's just going to sit in the field and rot?" Thus, in the real world of contemporary irrigation agriculture, the attainment of maximum yields is a dubious proposition and not as simple a matter as applying "the right amount of water at the right time." In failing to adopt "improved" scheduling practices, it is not that farmers fail to realize that these procedures might significantly increase yields (indeed, most do according to the Ontario Ministry of Agriculture and Food Survey, 1986), but that the goal of utility maximization brings with it significant alterations to all other production activities.

Rather than being strictly concerned with the "proper" management of water to achieve maximum yield, the farmer is concerned with balancing all of these production inputs, of which water is only one, to achieve a manageable, satisfactory level of output. In doing so, most farmers have developed tested and tried guides for using water that are rational within their own particular operating circumstance and in relation to their objectives. The degree to which farmers comply with the water management recommendations of irrigation specialists then, is not a question of carelessness, uninformed methods, or irrationality as reflected in the "backwardness" of the farmer or some abstract notion of social resistance to change; but one of differing objectives between the researcher and practitioner. Bennett (1986) explains this gap in objectives between researchers and farmers in terms of their respective operational circumstance. Whereas the researcher "lacking a stake in remunerative outcome", is free to conceive, define and control all factors affecting outcome in an objective manner, the farmer "is not free to systematically vary or control many of these factors because he cannot, or because he is bound by a fear of risking a negative outcome."

Unfortunately, most irrigation "specialists" seem oblivious to this distinction in objectives and operating constraints. To some degree , this is understandable given the complex task of understanding soil-water- plant relationships. In the words of Chambers (1980), "the maddening nature of water itself, with its tendency to flow, seep, evaporate, condense and transpire, and the problems it presents in measurement ...tie down natural and physical scientists to research intensive tasks denying them the time, even if they had the inclination, to branch out and examine wider aspects such as the people who manage water and how they behave." It is not acceptable however, when these same experts offer simplistic explanations as to why farmers do not conform to their conceptions of optimal water management. By ignoring the essential rationality of farmers and their objectives in irrigating, and in assuming a one-way flow of information from the "expert" to the practitioner, agro-scientists run the risk of transferring mis-guided recommendations to professional water managers and policy-makers, and developing water management technologies that will remain unused by the final decision-maker -- the irrigator.

CHAPTER 7

CONCLUSION AND SUGGESTIONS FOR FUTURE RESEARCH

Undoubtedly, as increased pressure is placed on available water resources in the coming years, the attention of resource managers, be they engineers, economists, geographers or a combination thereof, will continue to focus on estimates of future demand and procedures to match demand with available supplies. Rightly so; for adequate planning measures require and will continue to require some knowledge of the processes that operate to effectively consume a resource that has come to be realized as finite in time and space. This thesis however, has not concerned itself with generating any quantitative estimates of demand or with devising any new techniques for managing or reducing demand. Rather, it has attempted to compliment these efforts by questioning the assumptions on which they are based. The premise of the thesis is that any projections of future water demand or efforts to modify existing demands must rely upon a basic understanding of the water use and management practices that give rise to that demand. With respect to irrigation water use in Ontario this means examining the on-farm water management practices of individual farmers. As such, this study has been of a descriptive nature. Examination and discussion have not revolved around any specific hypothesis nor have they attempted to statistically delineate any cause-effect relationships in an individuals use of water. What has been accomplished is a description of how water is used by 35 farmers in the climatically humid region of southern Ontario. At the same time, several postulations have been offered as to why water is used in the way that it is. The lack of a specific hypothesis rather than being detrimental was seen as a necessary pre-condition to this study. Given the paucity of data and the lack of understanding of actual irrigation practices in Ontario, it could be argued that the conception of this research in terms of the standard "scientific" mode of a testable hypothesis would have hindered the flexibility to understand and convey some of the more salient features of irrigation water use in southern Ontario. Indeed, this study has not isolated any dominant factor or set of factors that affect water use or account for variations in use between individuals or between the geographical regions studied. Farmers adapt their practices to their particular circumstances; yet circumstance is a vague word. It cannot be construed to pertain only to the physical characteristics of site such as soils and hydrology but must also entail situational variables: agricultural features and economic factors such as crop choice, farm size, market potential; production costs, revenues, and labour availability; institutional and technological features such as resource allocation mechanisms, legal regulations, methods of distribution and application; all of which simultaneously control and are controlled by individual personal traits often described by even more ambiguous terms as experience, perceptions, attitudes, values and goals. It is the impression of the author that these components of circumstance which influence the final use of the water resource are so closely inter-related that the isolation of any or all of them for purposes of statistical analysis would engender dubious results.

Nonetheless, this study has provided several worthwhile results relevant to water management policy and practice. Of primary importance is a basic operational description of small-scale, privately managed irrigation systems in a humid environment. It is doubtful that the operations described for southern Ontario are unique in the world; indeed it is expected that similar systems can be found in other regions with climates commonly described as "humid". However, such a description does seem to be unique to the dominant irrigation water management literature which evokes a tendency to focus on large-scale, communally oriented or regulated irrigation "systems" operating in arid environments. If nothing else, such a description serves to clarify some of the common myths which pertain to irrigation in humid environments such as southern Ontario (and most likely all of eastern Canada) and stresses the importance of the need to understand the conditions that create and maintain irrigation agriculture in any localized area, over the need to provide provincial or national estimates of present and projected water demands for national or international agencies (see United Nations 1976; other statements demanding international estimates of demand can be found in publications of the International Committee on Irrigation and Drainage, ie. Bos and Nugturen 1981). This need to elucidate the practical conditions of irrigation in southern Ontario are of particular consequence today. The atmosphere of a "water crisis" in certain areas of Canada including southern Ontario (Sewell 1969, Foster and Sewell 1981) prompted the federal government, in 1984, to establish an Inquiry on Federal Water Policy. This inquiry in turn designed a research program to "obtain authoritative accounts of the various subjects of investigation, drawing on existing expertise" (Inquiry on Federal Water Policy 1984). Two of the resulting "authoritative accounts" point to a lack of understanding of humid region irrigation agriculture in Canada. Indeed, in assessing the socio-economic value of water for agricultural uses in Canada, Muller (1985) makes no mention of irrigation in Ontario and relies explicitly on data from the western provinces for his analysis. Similarly, Bowden and Anderson (1985) in a study examining national agricultural water issues revert to rhetoric when discussing irrigation water use in Ontario and display an obvious lack of understanding of the context of irrigation in this region. An example of this mis-understanding is provided with the suggestion that,

> "In Ontario...any future increase in irrigation area for major crops (corn, soybeans, white beans) is expected to be constrained by the availability of water, as well as labour and capital costs and...irrigation is expected to continue to be relied upon only during very dry years." (Bowden and Anderson 1985).

In light of the description of irrigation practices presented in this thesis, it is obvious that these sweeping statements belie the true nature of irrigation water use in southern Ontario. "Major" crops such as corn, soybeans and white beans have rarely been irrigated in Ontario and it is unlikely that they ever will be. This is not because of any constraining influences of water availability, labour or capital costs but is related to the locations in which these crops are grown and the negligible benefits accruing to these crops through the use of irrigation (Stevenson 1987, personal communication). Similarly, irrigation, at least for those areas studied, is not practiced only "in very dry years", but has come to be accepted as an annual production practice. In fact, a more accurate statement would be that irrigation is not practiced only in the very wettest of growing seasons. In addition, although irrigated acreage appears to be declining at present (primarily due to the continuing economic down fall of the tobacco industry), Smit (1987) in a study of the implications of escalating atmospheric concentrations of CO2 for agriculture in Ontario, made several observations that may significantly increase the use of irrigation in the southern part of the province, namely:

> a)"advantages of warmer temperatures under a changed climate are likely to be offset by increased moisture stress on crops;"
>
> b)"crops like corn and soybeans may become very risky in southern Ontario because of drought conditions;" and
>
> c)"horticultural crops may be grown across much of southern Ontario..."

Under these conditions, Smit (1987) concludes that,

> "increased use of irrigation may be seen, with more demands on water supplies at a time when other sectors are also drawing upon a diminished water supply."

The erroneous statements and omissions in the two federal studies are somewhat forgiveable given the previously mentioned paucity of data, the broad terms of reference, and the national macro-scale overview demanded of them. However when it is recognized that these statements and results will be considered by government decision makers in formulating resource use and allocation policies, the need to prepare and present research which accurately reflects localized conditions and practices of resource use becomes readily apparent. Similarly in water resource planning for irrigation, whether it be geared at providing supply, projecting demand or attempting to "improve" the management of irrigation water, it is necessary to be cognizant of the underlying factors behind all features of the existing system and particularly important to understand how farmers perceive and manage their resources prior to making any conclusive recommendations or implementing any plans. The consequences of not doing so risk the result of inconsistent predictions, failed water development projects and a lack of widespread acceptance of improved management practices.

Although with a different purpose in mind, Day (1974; cited in Mitchell 1979) in conducting a hindsight review of the benefit-cost considerations of a reservoir construction project indirectly depicted the consequences of failing to consult and understand the water management practices of farmers. The project in question was a reservoir in southwestern Ontario which, although multi-purpose in object, was designed to serve one major purpose: to "increase agricultural productivity from improved irrigation water" (Mitchell 1979). In turn,

> "the principal justification of the project was based on expected increases in farm productivity due to irrigation" (Mitchell 1979).

The basis for this project seems to be the findings of Yakutchik and Lammers (1970), in a 1964 survey, that irrigators were using less water than was required for maximum production according to climatically based water schedules. Planners consequently assumed that by increasing the physical availability of supply, farmers would irrigate for maximum production and expand their range of irrigated crops. However, Day (1974; cited in Mitchell 1979) questioned the project planning assumptions and dismissed the agricultural benefits as negligible when, after interviewing farmers two years after the reservoir construction, he found that,

> "none of the farmers to be assisted previously experienced any detrimental water shortages, none presently irrigates crops other than tobacco, and none intends to adopt vegetables or strawberries as cash crops or to irrigate corn, hay or pasture" (Day 1974; quoted in Mitchell 1979).

After reviewing other aspects of the dam and reservoir operations, it was concluded that original benefit-cost estimates of 2.2:1 were unrealistic and a revised analysis placed the ratio at 0:1. The project was essentially a failure in economic terms. Although not the sole cause, a failure to consult the primary target audience or to understand the objective rationality of their water management practices contributed in large part to the failure of this development project.

The example of misdirected water management planning outlined above emphasizes the primary conclusion and recommendation of this study. In formulating water management plans and water policy directives, it is necessary for pro ..ssional decision-makers to base their judgements on contextual reality. For example, basing irrigation water demand projections on bureaucratic records is obviously only suitable and acceptable if those using water are relying on similar methods of determining demand or if the government agency has some practical control over the amount of water being used in irrigation. As discussed in Chapter 4, this is not the case in

Ontario. Similarly the assumption that significant amounts of water can be conserved or that "beneficial" increases in production can be attained in almost any irrigation system by promoting the concepts and mechanisms of "irrigation efficiency" must be questioned. As Weatherford et al. (1982) have noted,

> "estimates of potential savings by those not thoroughly acquainted with the current irrigation practices in any area can exaggerate the possibilities of improving water use efficiency and lead to recommendations of unworkable and politically infeasible measures for increasing irrigation efficiency."

Hence, comments which recognize the diversity and complexity of circumstance must take the place of broad, generalized and rhetorical statements which disregard the fact that every irrigation system is location specific and that different management constraints in every location will affect the quantities of water that can be saved or used more efficiently. Thus, the statement of Bower et al. (1984) that,

> "in agriculture it is well known that there are at least two ways of substituting away from water quantity in irrigation. One is by changing or improving the irrigation system...The second is by investing in the care and timing of water application - by taking advantage of careful analysis of plant needs and soil moisture conditions to estimate the optimal quantity to apply rather than to follow a traditional rule of thumb,"

is meaningless without reference to a specific location in time and space. The contextual reality of irrigation water use in Ontario, for example, is that both of these "well known" means of "substituting away from water quantity in irrigation" (which presumable refers to reducing the demand for water), would not reduce demand at all but would maintain the "status quo" or effectively increase the seasonal demand for irrigation water.

There is then, a need to redefine the terms that are generally associated with agricultural water conservation in light of the unique operating circumstance of any particular setting or irrigation system. It must be recognized that, in promoting the concepts of physical irrigation efficiency, the primary objectives of agronomists and "professional" water managers, although intertwined within some disciplinary boundaries, differ in terms of the desired end result. Agronomists tend to view "improved" irrigation techniques as a means of supplying water to provide for maximum crop requirements in order to achieve maximum potential production. Water managers meanwhile view these same techniques as a means toward reducing water demand. The equation of demand with requirement to achieve perfect physical efficiency, however does not necessarily result in water conservation in all situations. By attempting to alter demand to meet physical requirements, researchers display a tendency to operate on the unqualified assumption that "the true 'requirements' are only a small part of observed water use." (Bower et al. 1984). This is likely true for many irrigation systems, especially in arid areas but it is important to note the general management constraints that give rise to this situation. Economists tend to stress the effect of historically low-priced water (ie. consumers not realizing the marginal cost of supply), as the main reason for excessive use. Their "commonsense" notion being, that for any good (resource) purchased, the quantity demanded will increase as the cost per unit decreases. Numerous studies however, while acknowledging and confirming the importance of the price-demand relationship, have suggested that institutional controls such as rigid bureaucratic or communal allocations and structural water delivery systems are perhaps more important in creating and maintaining conditions under which demand exceeds physical requirements (Chambers 1980, Coward Jr. 1980, Holmes 1986, Hudson 1962, Levine 1980, Thornton 1980). Where water allocation is based on a system of absolute rights and water is delivered to farms based on a calendar rotation, farmers have no control over the scheduling of water; they must accept water when it is delivered to them and in the amount determined by right. In the words of Hudson (1962), under such situations, "a farmer must take water when it is available, not when it is needed." Holmes (1986) arrived at a similar conclusion that "crops are not necessarily irrigated when water is needed" and that " the frequency in the delivery of water to the farms largely determines the frequency of waterings within a region." Several authors also express concern over variation of the "use it or lose it" principle where there exists a legal threat that users may forfeit all or part of their water rights by failing to use the full apportionment of that right (Ashworth 1982, Hudson 1962, Weatherford et al. 1982). In such cases, over-irrigation may be stimulated by the farmers fear of losing his right to water. Thus, Hudson (1962) concludes, for the Utah Valley at least, that the implementation of improvements in irrigation water management is not as simple as transferring "expert" knowledge or providing economic incentives through modified water pricing schemes, but that the farmer must be free of the "rigid institutional controls that hinder change" (Hudson 1962) for change to occur. The flexibility of the farmer to alter irrigation water use practices then, would seem to be the primary precondition of reducing the demand for water. Where the farmer does not have control over the delivery and application of water, it is unlikely that this flexibility exists.

It is the practically autonomous control of irrigation water by farmers that is the most salient characteristic of irrigation water use in Ontario. Here it is not a case of an abundance of water creating a tendency to over-irrigate. More likely, it is an abundance of water that gives rise to conditions by which water is under-utilized in irrigating. Historically, the dominant agricultural water issue in Ontario, as in other humid environments, has been a problem of excess water. Consequently, government involvement has generally been oriented toward ameliorating the detrimental effects of excess water through the support of artificial drainage, flood protection and land reclamation projects. Providin a supply of water to combat periodic deficiencies of natural rainfall has typically been an individual responsibility. The close proximity of available water sources to the point of use for most farms has not necessitated government or communal involvement or support in the delivery of water to irrigating farms. Thus, irrigators are free of the communal or bureaucratic restraints common to arid region canal distribution schemes (where water must be transported long distances and service the needs of a large number of users), and have the flexibility to control the timing and amount of water applied to their crops. The absolute control of the farmer in developing, maintaining and delivering a supply of water to his fields cannot be ignored.

Under these conditions of freedom from regulations, farmers have the ability to adapt their irrigation practices to their individual operating circumstance. Hence, similarity among farmers in their irrigation practices is not as evident as in arid areas. Rather, diversity is common-place. The landscape of irrigation in southern Ontario is not one of contiguity. Farmers rely on a variety of different sources of water, and a variety of different techniques of applying water to their fields. Decisions as to the frequency and quantity of water applications vary markedly between farmers irrigating similar crops on soils of similar texture. Thus, the form of irrigation water management - both technical and cultural practices - on any particular farm is not merely a response or adjustment to the availability of water. Where structural water delivery does not control the availability of water, the nature of water use and the resulting demand for water in any geographical region is determined by the decisions of the irrigator. A wide range of physical, economic, technical and social factors are involved in determining the nature of water management on any one farm and in reaching a decision on resource use, individuals will be guided by their own unique experience as farmers. However beyond variations in these factors at the micro-scale level of the individual farmer, as Hart (1975) has noted, there are some factors which influence farmers' decisions that are essentially similar over fairly extensive areas. In Ontario, irrigators operate within the constraints of a humid environment, under which they realize the economic and labour costs of supplying and using water as a supplemental production input. This is not necessarily seen in the strict economic sense of "marginal costs and returns" but nonetheless can be expected to result in a fairly efficient use of both the capital investment in developing an irrigation system, and the subsequent flow of water. It can not be overlooked that rainfall is the primary moisture input to agriculture in Ontario. It is free, does not require pumping and requires little labour in distribution. There is not then, the dry land condition of irrigate or have no agriculture. In the case where natural precipitation can be expected to meet the moisture requirements of plant growth throughout most of the growing season farmers can be expected to, and do economize on the seasonal costs of energy and labour required to supply supplemental water. Presumably, irrigators see irrigation as a means of providing a floor below which productivity should not fall, rather than a ceiling which productivity should reach. In essence this can be seen as a risk-avoidance strategy. Farmers in southern Ontario are familiar with the damages of excess water - the increase in 'rot' diseases, infestation of pests, leaching of nutrients, soil erosion. It is not without reflection on experience when farmers comment that over-irrigation is worse than under-irrigating.

This is not to suggest that selective on-farm improvements in water management and reductions in water use cannot be made on irrigating farms in southern Ontario. Certainly improved technologies such as drip irrigation have an important role to play in enhancing the efficiency of water use, and indeed in making improvements, farmers will require the aid of the "agro-scientific" community in the areas of research, information and education. At the same time however, the "agro-scientific" community will require the aid of farmers in the areas of research, information and education. Before undertaking to alter existing water use practices, researchers and planners must first understand how and why irrigators operate as they do now, before the ramifications of change can be understood. It is not good enough to borrow concepts that appear to have achieved some success in other areas. There must at least be a basic understanding of the unique physical, social, economic and institutional opportunities and constraints inherent to any particular geographic location. Only then can existing practices be understood as rational and the one-way flow of information and change from the expert to the farmer be reversed to include the knowledge and expertise of the farmer. "The major hopes for improving rational water resource management" do not, as O'Riordan (1969) has implied, rest "in the development of water use efficiency models", but rather as Weatherford et al. (1982) have more recently noted it is in the translation of these broad principles "into workable knowledge in the light of existing local conditions" that offers the most promise. The challenge in improving irrigation water management then, lies in understanding the characteristics of irrigation agriculture and the circumstances of individual irrigators. This study can pretend to be nothing more than a first step in this direction.

7.2 SUGGESTIONS FOR FUTURE RESEARCH

Due to constraints of time and funding, this study has necessarily been limited to an examination of an extremely small sample of irrigators in Ontario. Additionally, in an effort to present a "non biased" sample and include a wide variety of operating conditions, the sample was defined by political rather than watershed or "agricultural region" boundaries. Data on water use practices was not drawn from actual field measurements or records, and represents only the opinions and estimates of those farmers interviewed. Any inferences or conclusions presented are based on this data and pertain only to those 35 farmers surveyed. Thus, they must be looked upon as provisional and not absolutely "representative" (if in reality, there is such a beast as a representative sample). Bunting and Guelke (1979) have also lucidly pointed out the danger of inferring absolute patterns of individual behaviour based solely on a simple interview or questionnaire. Based on these limitations then, this exploratory research must be refined. Several recommendations for future research can be suggested.

> i) Future efforts to document water use practices should concentrate on levels which are appropriate for existing planning institutions. Given the emphasis on the watershed as the baseline planning unit in Ontario, studies should focus their efforts on basins or micro-basins, realizing that any results are not necessarily applicable outside of these boundaries.
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> ii) Studies of water use practices which incorporate a large sample population such as the Ontario Ministry of Agriculture and Food Irrigation Survey Report (1986), are perhaps useful in presenting an aggregate picture of irrigation agriculture in the province, but in the absence of any contextual interpretation, their benefits for planning or management principles are limited. The focus on extremely large sample sizes to satisfy some statistical notion of representativeness tends to hinder the ability to offer practical interpretations of the resulting data. Future studies should focus on manageable sample sizes in localized areas so that results and interpretations can offer some meaningful input to the planning process.
>
> iii) There is a need to conduct studies of overt behaviour in order to determine the applicability and acceptability of survey results. Are the water use practices implied from the results of interviews actually replicated in reality? As Bunting and Guelke (1979) have suggested,

"this is not an easy task and will involve critical and imaginative investigation of all available data - data which look closely at individual behaviour and at the overall environmental and cultural context."

In this regard there is a need to examine and define components of the "environmental and cultural context". Although physical and economic relations have received much attention, intangibles such as social goals, values and attitudes require a clearer definition and some means of measuring and evaluating their importance and impact on water use practices.

iv) If we accept that physical, economic and social contexts in any particular location change over time, so it must be accepted that resource use practices are not static but also change through time. Results of studies conducted at one point in time which demonstrate a relationship between resource use practices and the "environmental and cultural context" cannot be accepted as fixed or invariable. Thus, there is a need to conduct longitudinal studies of irrigation practices. By concentrating on individual farms over a certain period of time, a greater understanding of the inter-relationship between the contextual variables and the demand for water should be gained. What affect will a climatic warming trend have on water use policy and practice? How do water use practices respond to a changing agricultural economy such as the prices of inputs and products? Do the objectives of farmers - their desires for income, for leisure etc. - change within and between generations? How do these varying objectives alter or maintain the way in which water is used? These questions, among numerous others, are central to an understanding of the origins of the demand for water placed on any natural or artificial supply system. They require an answer before any definitive means of "managing" demand can be found. These answers in turn will not lie in any single disciplinary realm but as Chamber (1980) has suggested, they lie outside of the "cramped visions within narrow disciplinary boundaries" and in the elimination of a "mutual ignorance between social scientists and technologists and a reluctance to explore a no-man's-land between disciplines".

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APPENDICES

Appendix I - Questionnaire

TWSP. _____ LOT _____ CONC. __

BACKGROUND

1) a) How long have you farmed on your current property? ____________

b) Do you grow i) Greenhouse _____ or ii) Field Crops _____?

2) If known, what year did irrigation begin on your property? ____________

3) Why did you begin irrigating? (Please indicate importance of each eg. 1,2,3.)

a) Reduce Risk of Drought ____________
b) Increase Crop Yield ____________
c) More Intensive Farming ____________
d) Availability of Reliable Water Supply ____________
e) Availability of Capital in the Form of Loan or Grant ____________
f) Recommendation of Fellow Farmer or Agricultural Representative ____________
g) Other ______________________ ____________

4) a) Total Acres Currently Farmed ____________
b) Total Acres Currently Irrigated ____________
c) Total Acres Currently Owned ____________

5) Do you have a wind row on your farm? ____________

6) On what type of soil is your farm located? ____________

TWSP. _____ LOT _____ CONC. __

IRRIGATION ORGANIZATION

1) When did irrigation commence in this county?
   a) Last 10 years ______________
   b) 11 - 30 years ______________
   c) 31 - 50 years ______________
   d) 51 - 100 years ______________
   e) More than 100 years ______________

2) Are you solely responsible for your irrigation system or do you belong to a collective group who share responsibilities for irrigation?
   a) Individual ______________
   b) Group ______________

3) If you belong to a group, how many other farmers belong to this group? ______________

4) Did this collective share the initial capital cost of your irrigation system? Yes ______ No ______

IRRIGATION RESPONSE

1) Have you realized a significant increase in crop yields since you began irrigating? (Please describe)

TWSP. ______ LOT ______ CONC. ___

2) Since you began irrigating, have you: a) Increased ______________Hectares
b) Decreased ______________Hectares
your planted acreage?

3) Have you changed crops or cropping patterns since you began irrigating? ________ If so why?

4) Do you use your irrigation system for application of fertilizer or other uses? Yes ______ No _____
Use ________________

WATER SUPPLY AND USE

1) Please list your sources of irrigation water.

	Number	Names
a) Natural stream or river	________	______________________________
b) Natural lake or pond	________	______________________________
c) Ponds – Dugout	________	
– Onstream	________	
– By-pass	________	
d) Well	________	
e) Other ______________	________	

TWSP. _____ LOT _____ CONC. __

2) Have you ever experienced a shortage or irrigation water? _____
If known, please explain the reason for this shortage.

3) How do you determine when to irrigate?

i) Crop Appearance ________________
ii) Soil Feel ________________
iii) Water Budget Records __________
iv) Scientific Instruments ________

4) Do you feel that you are using irrigation water as efficiently as possible? ____________ Please explain.

5) How might you make more efficient use of irrigation water? Please explain.

IRRIGATION SYSTEM

1) Please indicate the amount of acreage that you have under different methods or irrigation:

TWSP. _____ LOT _____ CONC. __

a) Portable pipe and sprinklers _____________Hectares
b) Centre pivot system _____________Hectares
c) Volume Guns on a self-propelled trailer _____________Hectares
d) Hose and trickle or drip applicators _____________Hectares
e) Other ______________________________ _____________Hectares

2) If known, what was the initial capital cost of your irrigation system? $_____________

3) What is the approximate annual operation and maintenance cost of your irrigation system? $_____________.

4) a) Have you changed irrigation systems since you began irrigating?
Yes _____ No _____. If so, when? _____________.

b) Please describe this change. (eg. Additions or change from sprinkler to drip).

IRRIGATION POLICY

1) What is your major source of irrigation advice? (In order of importance)
a) Irrigation equipment supplier _____________
b) Agricultural representative _____________
c) Government Publications _____________

TWSP. _____ LOT _____ CONC. __

d) Farm Pericdicals (Magazines) ____________
e) Discussion with other irrigators ____________
f) Other ____________

2) Do you know of any government program which provides financial support to irrigators? ____________

If so, a) What is the name of the program? ________________
b) Have you made use of this program? ________________

3) Do you feel that government (OMAF, AGR, CDA.) support of irrigation is:
a) Non-existant ____________
b) Minimal ____________
c) Adequate ____________
d) Substantial ____________

4) Do you feel that there should be greater government involvement in irrigation incentive programs? ____________

a) What form should this involvement take?

TWSP. _____ LOT _____ C' :C. __

5) a) Do you have a M.O.E. permit to take water? Yes _____ No _____.

b) If yes, how did you calculate this amount of water to apply for?

c) Do you feel that this is an effective method of managing and protecting the use of irrigation water for the province?

d) Could you suggest any beneficial changes to this program?

MARKETING OF CROPS

1) What percentage of your crops are sold in a fresh market? ____________
What percentage are processed? ____________

CROP	% FRESH	% PROCESSED
____________	________	____________
____________	________	____________
____________	________	____________
____________	________	____________
____________	________	____________

TWSP. _____ LOT _____ CONC. __

2) a) Distance to processing plant? ____________

b) Distance to fresh market? ____________

3) a) Do you have a contract with a processing plant? ____________

b) Accepted before or after irrigation? ____________

c) Year this contract began? ____________

4) Why do you follow the cropping pattern described above?

a) Contractual agreements ____________
b) Best use of labour and other resources ____________
c) Best return considerations ____________
d) Common cropping pattern in the area ____________
e) Other ____________

FUTURE PLANS

1) Please describe any plans you may be considering including expansion or reduction of physical facilities. (Including equipment and acreage).

TWSP. _____ LOT _____ CONC. __

2) Please describe any plans you may be considering regarding major cropping pattern changes.

Can you supply any additional information regarding any presently existing problems of water supply and demand, irrigation efficiencies or wastages?

TWSP. _____ LOT _____ CONC. __

Comments:

Thank you for your time etc. If you have any questions about the research or would like the results, please contact me at:

c/o Wilfrid L ier University
75 Universit e. West
Waterloo, Ontario, Canada
N2L 3C5
Telephone: (519) 884-1970 Ext. 2877

IRRIGATION PRODUCTION

TWSP. ____ LOT ____ CONC. ____

Crop	Irrigated Acres	Water Use Per Acre (Acre Inches)	Times Water Applied	Heaviest Dates of Watering	Plans for 1987 Acreage
ASPARAGUS					
BEANS (GREEN)					
BEANS (SOY)					
BEETS					
CABBAGE					
CAULIFLOWER					
CARROTS					
CELERY					
CORN					
CUCUMBERS					
LETTUCE					
ONIONS					
PEAS					
PEPPERS					
POTATOES					
RUTABAGAS					
SPINACH					
TOBACCO					
TAME HAY					
IMPROVED PASTURE					
OATS					
BARLEY					
WHEAT					
FLAXSEED					
RAPESEED					
PEACHES					
APPLES					
PEARS					
CHERRIES					
GRAPES					
STRAWBERRIES					
MELONS					
OTHER					

Appendix II - Permit to Take Water Application

Ministry of the Environment
Ontario

Application for Permit to Take Water

The Ontario Water Resources Act, Section 20

Ce formulaire est également disponible en français

Please Print in Block Letters

Name of Applicant ____________________

Mailing Address ____________________

City, Town, Etc. ____________________ Prov ______

Telephone: Area ______ Number ______

Postal Code ______

Application Particulars

Please read instructions (Permit to Take Water Program Information Sheet)

A Source of Water

1 Well How many? ______ Spring How many? ______

2 Lake, Stream or River/Name ____________________

3 Pond How many? ______ Type ☐ Dugout ☐ By-Pass ☐ On Stream ☐ Pit or Quarry

4 Other Type of Source ____________________

5 Date of construction of source? D M Y ______ 6 Date of installation of water taking equipment? D M Y ______

B Location of Taking ____________________
(Lot, Concession, Township and County or Region or District, or City, Town or Village with Street and Number)

C Location of Water Use. Same as B ☐ or ____________________
(Lot, Concession, Township and County or Region or District, or City, Town or Village with Street and Number)

D Purpose of Taking ☐ Irrigation ☐ Commercial ☐ Industrial ☐ Municipal ☐ Public Supply ☐ Recreation ☐ Other ______

E Period of Water Taking (Complete 1 or 2)

1 Taking to commence on D M Y ______ and to extend for a period of ______ (Days, Weeks, Months, Years)

2 Seasonal taking to extend from D M ______ to D M ______ each year for ______ Years

F Request Amount of Taking from Each Source

	SOURCE 1	SOURCE 2	SOURCE 3
1 Source Name or Description			
2 Maximum Amount Taken in one Minute			
3 Maximum Amount Taken in One Day			
4 Number of Hours of Taking in One Day — Maximum			
Average			
5 Maximum Number of Days of Taking in One Year			

State Units Used (check one)
☐ Imperial Gallons Per Minute or Day
☐ U.S. Gallons Per Minute or Day
☐ Litres Per Minute or Day

G Submit a diagram of the area of water use in the space provided on the reverse side of this form
(Diagram instructions and example are shown on the information sheet)

Applicant agrees to indemnify and save harmless the Crown in right of the Province of Ontario and its officers, employees, agents and contractors from and against all damages, loss, costs, claims, suits, injuries, demands, actions and proceedings resulting from or in any manner connected with any act or omission of the applicant or any of its officers, employees, agents or contractors and relating to this Application and any Permit, Renewal Permit, or terms and conditions of a Permit, issued in response to this Application.

I understand that it is the policy of the Director in issuing a Permit to Take Water to impose the General Terms and Conditions appearing on the reverse side of this Application. There are no special circumstances or reasons why the Director should not impose such terms and conditions in issuing the Permit I am applying for. (Note: Cross out the underlined sentence if it is not applicable to you and enclose with your Application a letter to the Director setting out such reasons and special circumstances.)

Date D M Y ______ Signature of Applicant or of Authorized Officer or Agent ____________________

(For Office Use Only)

Permit to Take Water

Permit Expires D M Y ______ Permit Number ______

Pursuant to Section 20 of The Ontario Water Resources Act, permission is hereby granted for the taking of water in accordance with the above Application subject to the General Terms and Conditions which appear overleaf and subject to the Special Conditions and amendments to the Application Particulars as follows:

____

____

____

Notice of Terms and Conditions

The Ontario Water Resources Act, Section 61

Take notice that in issuing this Permit to Take Water I have imposed terms and conditions pertaining to the taking of water and to the results of the taking. The terms and conditions have been designed to allow for the development of water resources for beneficial purposes while providing reasonable protection to existing water uses and to public interests in water.

You may appeal the terms and conditions by giving written notice to the Director of the Ministry at the appropriate Region Office (see information sheet) and to the Environmental Appeal Board, 1 St. Clair Avenue West, Toronto, Ontario M4V 1K6, within fifteen days after service of this Notice. In the event of an appeal, the terms and conditions of the Permit, as issued, would remain in effect until the appeal has been finalized.

Date D M Y ______ Signature of Director ____________________

0508 4/82 (over)

Ministry
of the
Environment
Ontario

Permit to Take Water Program Information Sheet

Legislation and Rationale

On March 29 1961 legislation was enacted to authorize th Ministry of the Environment to regulate water takings in order to promote efficient development and beneficial use of surface and ground waters . appropriate section of The Ontario Water Resources Act as amended is reproduced in this circular

With few exceptions, a Permit to Take Water is required for the taking of more than 50 000 litres (approx 10 000 Imperial Gallons) of water in a day from any ground or surface source of water supply or combination thereof

A Permit is not required for the taking of water for domestic or farm purposes as defined in section 20 (1) of The Ontario Water Resources Act or for fire fighting purposes

A Permit is required for the taking of water for irrigation, public, municipal commercial, industrial recreational and aesthetic uses, for de-watering of quarries and gravel pits and foundation and construction sites and for the taking of streamflow into storage by damming, diversion or by excavation

Water in reservoirs created by damming or by excavation is considered as surface water and the taking from such a reservoir by means of an intake installed or re installed after March 29 1961 is subject to regulation by it even though the reservoir was constructed at an earlier date

e taking of less than 50 000 litres (10 000 Imperial Gallons) in a day or a taking by means of permanent works installed prior to March 29 1961, may, upon notice require authorization by Permit if in the opinion of the Director based on scientific evidence, the taking interferes with any public or private interest in any water

The Permit locates major sources of water takings and places the responsibility on the permitted taker to ensure that established water uses in the area are not interfered with

Specifically for withdrawals or impoundments of surface water the Permit requires that downstream flow is maintained to ensure the satisfactory continuation of downstream water uses

Specifically for withdrawals of ground water the Permit requires that the taking of water by pumping from wells does not adversely affect nearby water levels and therefore interfere with established uses

In cases where interference occurs the Permit holder is required to cease interference and/or restore affected water supplies and provide temporary supplies of water until restoration is complete All complaints of water supply interference should be reported to the Director of the Ministry of the Environment at the address appearing overleaf

It should also be noted that the Permit protects the Permit holder by establishing the holder s interest in water in terms of date and quantity

es on Permits

- Authorization to take water is given through a Permit which is completed on the lower half of the Application sheet and returned to the applicant
- Any person who contravenes any of the terms and conditions of a Permit is guilty of an offence and on summary conviction is liable to a fine of not more than $200 for every day the contravention continues
- No fee is charged for a Permit
- Permits are not transferable without Ministerial authorization New owners should make a new application
- Changes of address and ownership and/or changes in source of water supply, or in amounts of taking should be reported promptly on the Changes in Permit Particulars card supplied with the Permit
- Complaints received by permittees from established water users or complaints of interference with a permitted water taking should be reported promptly to the Ministry
- The Permit must be kept available for inspection at all times
- Records of the actual amounts of water taken may be required (see General Terms and Conditions on back of Permit) Forms which are used for maintaining such records are supplied by the Ministry when required
- Most Permits are issued for a period of ten years Within 6 months of the date of expiry, each Permit holder will receive a renewal notice Following completion, signing and returning of this notice, a renewal Permit will be considered and in most cases issued
- Water takings from streams must not stop streamflow

  Water takings from ground water must not interfere with water levels in local wells which were in use prior to the date of the Permit
- A Permit does not confer upon the holder any riparian rights that the Permit holder would not have under common law Riparian rights are rights which belong to a landowner and allow him to use water from a stream which flows past his land for the benefit of that land

The Ontario Water Resources Act, Section 20, reads as follows:

Interpretation — 20 —(1) In this section reference to the taking of water for use for domestic or farm purposes means the taking of water by any person other than a municipality or a company public utility for ordinary household purposes or for the watering of livestock poultry, home gardens or lawns but does not include the watering or irrigation of crops grown for sale

Idem — (2) In subsection 4 the reference to the taking of water for the watering of livestock or poultry does not include the taking of surface water into storage for the watering of livestock or poultry

Taking of water regulated — (3) Notwithstanding any general or special Act or any regulation or order made thereunder and subject to subsection 5 no person shall take more than a total of 50 000 litres of water in a day,

(a) by means of a well or wells that are constructed or deepened after the 29th day of March 1961, or

(b) by means of an inlet or inlets from a surface source of supply where the inlet or inlets is or are installed in the source of supply or is or are enlarged after the 29th day of March, 1961, or

(c) by means of a structure or works constructed after the 29th day of March 1961 for the diversion or storage of water or

(d) by any combination of the means referred to in clauses a, b and c,

without a permit issued by a Director.

Where taking of water interferes with other person s interest in water — (4) Notwithstanding any general or special Act or any regulation or order made thereunder where the taking of water for any purpose other than the taking of water by any person except a municipality or company public utility for use for ordinary household purposes or for the watering of livestock or poultry and other than the taking of water by any person for fire fighting interferes, in the opinion of a Director with any public or private interest in any water the Director may, by notice served on or sent by registered mail to the person who is taking or is responsible for the taking of water that so interferes prohibit the person from so taking water without a permit issued by the Director

Application to domestic and farm use — (5) Subsection 3 does not apply to the taking of water by any person for use for domestic or farm purposes or for fire fighting

Permit — (6) A Director may in his discretion issue refuse to issue or cancel a permit may impose such terms and conditions in issuing a permit as he considers proper and may alter the terms and conditions of a permit after it is issued

Flowing or leaking of water from well etc., regulated — (7) Where the flowing or leaking of water from a well or the diversion flowing or release of water from or by means of a hole or excavation made in the ground for any purpose other than the taking of water, interferes in the opinion of a Director with any public or private interest in any water the Director may, by notice served on or sent to the person who constructed or made such well hole or excavation or to the registered owner of the land in which such well hole or excavation is located, require the person or owner to stop or regulate such flowing leaking diversion or release of water in such manner and within such time as the Director may direct or require such person or owner to take such measures in relation to such flowing, leaking, diversion or release of water as the notice may require

Offences — (8) Every person who contravenes,

(a) subsection 3 or 4 or

(b) a notice served on him or received by him or on his behalf under subsection 4 or 7 or

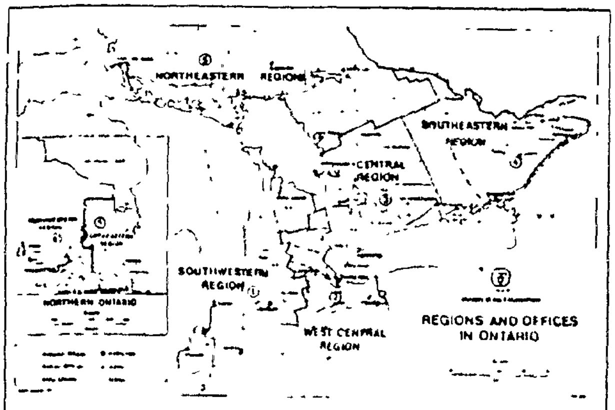
(c) any of the terms and conditions of a permit issued by a Director,

is guilty of an offence and on summary conviction is liable to a fine of not more than $200 for every day the contravention continues

Section 59 reads as follows:

False information — 59 Every person who knowingly gives false information in any application return or statement made to the Minister or an employee of the Ministry in respect of any matter under this Act or the regulations made under this Act is guilty of an offence and on summary conviction is liable to a fine of not more than $500

Permit to Take Water Program Information



Address all correspondence or enquiries to the attention of the Ontario Ministry of the Environment, Director, Permit to Take Water Program at the Region Office corresponding to the location of your water taking.

Northwestern Region (6)
Box 5000
435 James Street South
Thunder Bay, Ontario
P7C 5G8
Tel. (807) 475-1205

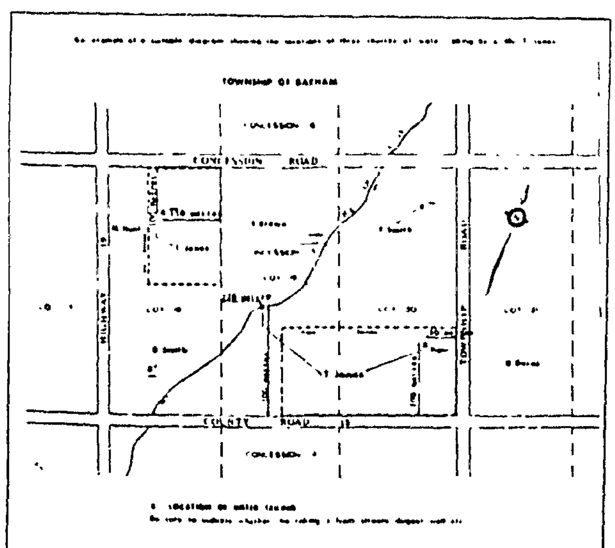
Northeastern Region (5)
199 Larch Street
Sudbury, Ontario
P3E 5P9
Tel. (705) 675-4501

Southeastern Region (4)
Box 820
133 Dalton Street
Kingston, Ontario
K7L 4X6
Tel. (613) 549-4000

Central Region (3)
150 Ferrand Drive
Don Mills, Ontario
M3C 3C3
Tel. (416) 424-3000

West-Central Region (2)
119 King Street North
Hamilton, Ontario
L8P 4T9
Tel. (416) 521-7640

Southwestern Region (1)
985 Adelaide Street South
London, Ontario
N6E 1V3
Tel. [illegible] 681-3600



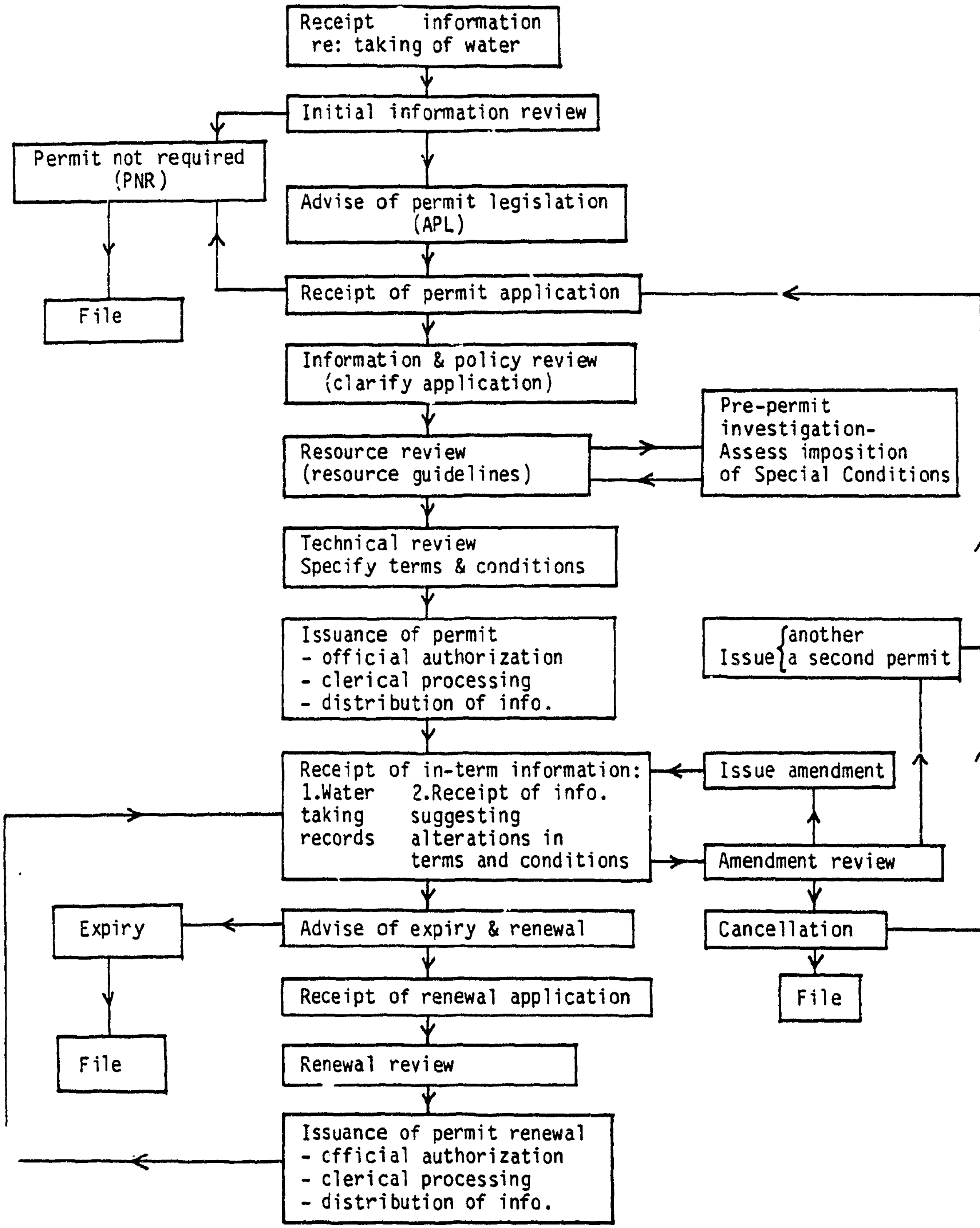
General Instructions on Completing an Application for Permit to Take Water

1. Please complete and submit one copy of the Application for Permit to Take Water to the Ontario Ministry of the Environment Region Office appropriate to the location of your water taking (see map). Addresses at the left are listed. If you are uncertain as to your need for a Permit, please enquire or complete an Application and you will be advised whether or not a Permit is required.
2. All sections of the Application form must be completed. The designation N.A. should be used where a section is not applicable. The omission of information or the required diagram will delay approval of a Permit.
3. Before constructing a well it is desirable to submit an Application for Permit. Any known limitations that may affect the granting of a Permit will be drawn to the applicant's attention at that time. It may not be possible for the applicant to provide all the required details concerning the taking before the well is constructed. Any revised or missing information should be submitted after the well has been completed.
4. A diagram must be submitted styled after the example below on a separate sheet and include:
   1) Lot and concession number and township name(s)
   2) Boundaries of applicant's property
   3) Locations and names of owners of adjacent properties
   4) Locations of proposed taking(s) or diversion(s)
   5) Locations of all wells, intakes, dams and diversion works within 300 metres (1000 ft) of proposed taking(s)
5. If water is to be used for the purpose of supplying a subdivision [illegible] five residences, a Certificate of Approval is required from the Ministry of the Environment, Municipal and Private Approvals Section, 135 St. Clair Avenue West, Toronto, Ontario M4V 1P5 (Telephone 416-965-4211) under Section 41, Ontario Water Resources Act.
   Where damming or diversion works are involved in the taking of water, the submission of a copy of the plans which are required by the Ministry of Natural Resources under the Lakes and Rivers Improvement Act would be desirable. The applicant must also indicate how he proposes to maintain downstream flow during and after the construction [illegible] the pond or reservoir and any subsequent taking of water where applicable.
6. Complete Section E using a separate column for each source from which water is to be withdrawn. Maximum Taking in One Day can generally be determined by multiplying the rated pump capacity by the maximum time of daily operation.

   Conversion Factors
   1 foot = .3048 metres
   1 Imperial Gallon = 1.2 U.S. gallons
   1 Imperial Gallon = 4.54 litres
7. Any additional information considered by the applicant to be helpful should be submitted with the application.
   Examples of additional information are:
   1) Pumping test data for wells
   2) Proposed procedures or principles of operating a dam — the reasons for and times of storing and releasing water, the maximum and minimum water level elevations proposed in a reservoir, a storage capacity curve of a reservoir, operating rule curves for release of water
   3) Details of water supply problems in the area
   4) Details of the nature of a pond that is filled from a well to indicate whether it is fed in part by ground-water seepage or surface runoff
8. All Applications must be signed and dated. When an Application is signed by an agent or official of the applicant, the status of the agent or official must be clearly defined.
9. It is the policy of the Director in issuing Permits to impose the General Terms and Conditions appearing on the back of the Application. If you wish to bring special reasons or circumstances to the attention of the Director as to why certain of the General Terms and Conditions should not be imposed in issuing your Permit, cross out the underlined sentence in the Application and enclose a letter to the Director setting out the reasons and special circumstances.

Appendix III - General Flow Diagram of the Permit Process

GENERAL FLOW DIAGRAM OF
THE PERMIT PROCESS



Appendix IV - Water Balance Tabulations for Canadian Climat Stations

WATER BALANCE TABULATIONS FOR CANADIAN CLIMATE STATIONS

K. Johnstone and
P.Y.T. Louie
Hydrometeorology Division
Canadian Climate Centre
Atmospheric Environment Service

The climatic water balance refers to a climate-based accounting of the water gains and losses at a location or region. As developed by Thornthwaite and Mather (1955) the air temperature and precipitation are used to compute a water budget that tabulates the additions, losses, and changes in water storage at a location.

The method of computing the terms of the daily or monthly water budgets, and many examples of budget applications, were discussed by Mather (1978). Phillips (1976) summarized a number of these applications and explained the terms of a monthly water balance that was applied to the 1941-1970 normals for more than 1500 Canadian climate stations.

This note describes a more recent version of the water budget procedure. This new version offers improvements and greater flexibility than the previous budget procedure by Phillips (1976). Daily temperature and precipitation for the period of interest are the required inputs. The use of daily climatic data permits better modelling of snowmelt and improves the accounting of snow storage which are of particular importance in the Canadian climate. The use of daily data also permits the budgeting time-step to be varied from seven days to one month, providing a more detailed tabulation of the variation of the water balance components. By computing the budget for the entire period of interest, a time series of each component is derived. From these time series, statistical parameters such as means and standard deviations for each component are computed. A sample output is shown in Table 1.

The water budget procedures used in this version are summarized in Figure 1. The following sections briefly discuss the data requirements, the budget components and the model applications and limitations.

This note has been prepared to assist users with the interpretation of the outputs of this revised water balance procedure. Requests for water balance tabulations for selected stations or questions pertaining to the technique should be directed to:

Atmospheric Environment Service

4905 Dufferin Street

Downsview, Ontario

M3H 5T4

Attention: Hydrometeorology Division

Data Requirements

The basic data requirement is a complete daily record of temperature and precipitation for the station and period of interest. Such daily data are available for over 2,500 climate stations in Canada which are maintained in computer compatible form in the Atmospheric Environment Service National Climatological Archives. The data set used should be as continuous as possible. Any large gaps in the data record would require re-initializing the budget and render parts of the derived budget unreliable.

The only other data requirements are the station latitude and an estimate of the water holding capacity of the soil. The soil water holding capacity values will be discussed in more detail in the next section.

Explanation of Terms

Terms used in the climatic water balance procedure are explained in the following paragraphs. All units are millimetres unless otherwise indicated.

Period (PRD)

The period refers to the time step (in days) for which the budget components are computed and tabulated. A period length from seven days to one month can be selected. Although seven days is the shortest time step for which the budget is computed, it is necessary to compute some budget parameters on a daily basis, hence the requirement for daily data. These parameters include snowmelt, potential evapotranspiration and the classification of daily precipitation as rain or snow.

Temperature (TEMP)

Mean air temperature (in degrees Celsius) is an average of the mean daily temperatures during the period.

Precipitation (PCPN)

Accumulated precipitation during the period.

Rain (RAIN)

The accumulated precipitation on days with a daily mean temperature greater than the critical temperature CTEMP. CTEMP is generally set at -1° C.

Precipitation occurring on days with a daily mean temperature equal to or less than CTEMP is added to the snow storage.

Snow Storage (SNOW)

Snow storage is the water equivalent of snow at the end of the period. It is calculated by accumulating, over the winter, the precipitation on days with a mean daily temperature less than CTEMP. The snow storage is depleted by the snow melt routine.

Snow Melt (MELT)

The snowmelt during each period is the accumulated daily melt. The daily melt is computed when there is snow on the ground and the daily temperature is greater than 0° C:

Daily Melt =

$$(1.88+0.007*P)*(9.0*T/5)+1.27$$

(Corps of Engineers, 1956) where P is the daily precipitation and T is the daily mean temperature. This melt equation was developed for a forested basin. Other similar degree-day type melt equations may be used.

Potential Evapotranspiration (PE)

Potential evapotranspiration is the amount of water that would be evaporated or transpired from a vegetated surface if there is sufficient moisture in the soil at all times for the use of the vegetation (Thornthwaite and Mather, 1955). The potential evapotranspiration for the period, PE, is the accumulated daily potential evapotranspiration.

The daily potential evapotranspiration is given by:

$$PE = ADJ*0.533(10\ T/I)^{A},$$

where ADJ is an adjustment factor to correct for the length of the day (sunrise to sunset), T is the daily mean temperature,

I is the Thornthwaite heat index given by

$$I = \sum_{j=1}^{12} (T_j/5)^{1.514}$$

where T_j is the mean monthly temperature for month j, and

$$A = 6.75x10^{-7} I^3 - 7.71x10^{-5} xI^2 + 1.79x10^{-2} I + 0.49$$

<u>Water Holding Capacity (WHC) and Soil Storage (SOIL)</u>

The water holding capacity of the soil is the maximum amount of water that can be held in the capillaries of the soil for the use of plants. The water holding capacity of the soil depends on the composition, structure, and depth of the soil and the type of vegetation surface (Phillips, 1976). Values of water holding capacity based on soil texture for Canadian climate stations have been provided by Agriculture Canada (Kirkwood et al., 1983). These values range from 100 mm for sandy soils to 280 mm for clay. In this water budget model, the soil is assumed to have a two-layer structure. The upper layer has been set to 40 per cent of the soil water holding capacity but can be specified at some other level if required.

The soil storage gives the status of the soil moisture level at the end of the period. When the total available free water (i.e. rain plus snowmelt) exceeds the evapotranspiration demand for the period, the excess water is added to the soil storage until the WHC is reached. When the evaporative demand exceeds the total available free water for the period, moisture is drawn from soil storage The soil storage is therefore a good indicator of the moisture condition for the location since it incorporates antecedent conditions, the moisture supply, and the moisture demand for the current period.

Actual Evapotranspiration (AE)

Actual evapotranspiration is the total evapotranspiration for the period. When the total available free water equals or exceeds the PE for the period, AE is set equal to PE. When the total available free water is less than the PE for the period, water is drawn from soil storage to satisfy the evaporative demand. The rate at which water can be drawn from soil storage is defined by a drying curve and depends on the soil moisture level at the end of the previous period. The drying curve assumed in this water budget model is illustrated in the insert in Figure 1.

Moisture Deficit (DEF)

The deficit is the amount by which the available moisture fails to meet the demand for water. The deficit is computed by subtracting the PE from the AE for the period in question.

Moisture Surplus (SURP)

Surplus water is the excess after the evaporation needs of the surface have been met (AE equals PE) and soil storage has been returned to the WHC level.

Accumulated Precipitation (ACCUM PCPN)

The total precipitation since the beginning of the water year (October 1 to September 30).

Assumptions

The simplicity of the water budget procedure described here arises from a number of assumptions that were made about the physical processes involved.

The shortcomings of these assumptions are briefly discussed in this section.

Potential evapotranspiration (PE) was estimated using the empirical Thornthwaite equation. This equation does not directly account for the significant short-term controls on evapotranspiration rates that are exerted by humidity, wind, radiation, or plant physiology. However, Calder et al. (1983) have found that sophisticated meteorological PE models that incorporate some of these factors do not necessarily result in improved soil moisture predictions. The Thornthwaite model includes a seasonal variation of PE that was found to be necessary for good model performance by Calder et al. (1983).

Many methods of estimating the amount of soil moisture given up for evapotranspiration during a time step have been proposed. In assessing a number of these methods, Calder et al. (1983) found that a layered soil structure and moisture withdrawal scheme similar to the method used in this budget performed better than other methods that were not optimized. Locally optimized procedures are preferable to the method now used, but the data necessary to optimize the method are generally unavailable.

The assumption that precipitation falling on days with a mean temperature smaller than -1° C accumulates as snow is meteorologically reasonable. But the assumption does not take into account changes in the form of precipitation during the day and the -1° C threshold may not be the appropriate choice for the meteorological conditions of any given day or station location. For simplicity, a single critical value is used throughout a budget computation, but may be changed from application to application.

The daily snow melt equation was derived by the U.S. Corps of Engineers (1956) for the total melt, during rain, in a heavily forested basin and has been converted to metric units. The equation was derived from data collected in the mountains of the western United States and may not be the best for application at stations in other portions of North America.

This water budget does not account for the errors in precipitation measurement, infiltration rate of the soil, snow ablation, surface or sub-surface runoff, nor other aspects of the real-world water balance. Moreover, the application of the snow melt and other budget equations to make inferences about the components of the water balance for a river basin involves the assumptions that the equations are appropriate for the basin concerned and that the input data are both appropriate and representative for the basin. Consequently, the components of the water budget procedure should only be regarded as indices of the main components of the water balance. The budget outputs were not expected, nor were intended, to provide point or basin specific estimates of actual conditions.

Applications

The original Thornthwaite water balance (Thornthwaite, 1948) was developed for the classification of climates. Because of its simplicity and basic data requirements, it has gained worldwide popularity. The revised version of the Thornthwaite water balance (Thornthwaite and Mather, 1955) has been applied to a wide variety of problems. In water resource planning, annual and monthly water budgets have been used to obtain quantitative estimates of evapotranspiration, moisture deficit and surplus of a region. For operational applications such as irrigation scheduling, computing drought/forest-fire indices and climate monitoring in near real-time, water budgets have been used on a weekly and even daily basis. The reconst.uction of past water balances has been found to be a useful diagnostic tool in studies on climatic change and on the influence of man on the hydrological cycle.

For a more complete discussion on water budget applications, two references are recommended. Mather (1978) discussed in detail the application of water budgets in environmental analysis. Carter et al. (1973) have compiled an extensive annotated bibliography on the application of water budgets in geography.

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[1]The soil .ter holding capacities were provided in computer compatible form by R Stewart.

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