GROUNDWATER MANAGEMENT IN BRITISH COLUMBIA

by

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ABSTRACT

Groundwater is a major source of potable water in British Columbia and is used extensively in many areas of the province. However, despite the importance of the resource, groundwater development and use are subject to few constraints. Reliance on common law rights has contributed to the development of problems of overuse and contamination of the resource in some parts of British Columbia.

The objectives of the thesis are to provide an overview study of groundwater and to develop a set of recommendations for improving the management of groundwater in British Columbia. Most of the information used in the thesis is from primary and secondary written material in the fields of law, economics, hydrogeology, and natural resources management. Some primary written and verbal material was obtained from the British Columbia Ministry of Environment staff.

Several groundwater management and regulation schemes which have been recommended in the literature or adopted in other regions of western North America are reviewed and then assessed according to the criteria of feasibility, equity, effectiveness, and economic efficiency. The evaluation of these alternatives forms the basis of the recommendations for management of British Columbia's groundwater.

The thesis recommends that, in areas where groundwater problems have developed or are likely to occur, clearly defined groundwater rights be established by the Comptroller of Water Rights. The Comptroller would conduct hearings into groundwater supply and demand, decide upon a collective withdrawal rate for each area, and then assign rights to
individual users to pump water at specified rates. The thesis further recommends that, once the allocation of rights has been made, the rights would be marketable.
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CHAPTER ONE

GROUNDWATER IN BRITISH COLUMBIA

I. INTRODUCTION

Groundwater is a major source of usable water in British Columbia and a significant feature of the province's natural environment. Despite its importance, however, groundwater has never been the subject of provincial legislation and its use is subject to few constraints. Reliance on incomplete data and on common law rights to groundwater has contributed to problems of overuse and contamination of the resource in some areas of the province.

The objectives of the thesis are to provide an overview study of groundwater and to develop a set of recommendations for improving the management of groundwater in British Columbia. After reviewing the basic administrative, hydrologic, and legal factors that affect groundwater supplies and use, the thesis explores some of the problems experienced by groundwater users in British Columbia and attempts to explain the underlying causes. Several of the groundwater management and regulation schemes described in the literature or used in other regions are then reviewed, and evaluated according to four criteria—feasibility, equity, effectiveness, and economic efficiency. Finally, the findings are used to develop a strategy for managing British Columbia's groundwater.

The remainder of the first chapter provides the basic hydrologic information required to appreciate the groundwater problems examined in later chapters, describes the use of groundwater in the province, and outlines the present administrative system.
II. HYDROGEOLOGY

A. The Water Table

Much of the rain and snow that falls onto land filters into porous ground. Some of this moisture quickly evaporates or is absorbed by plants but, if soil porosity and moisture levels are sufficient, a major portion of the water continues to percolate downward until it is stopped by an impermeable layer. The soil pores above this layer then fill with water, forming a zone of saturation. The term 'groundwater' refers to water in this zone. Water above this zone is simply soil moisture.

The upper boundary of the zone of saturation is known as the water table. It is best defined as the surface along which the fluid pressure in the pores of an unconfined, porous medium is equal to the atmospheric pressure. This surface is approximated by the water level in a well which is drilled or dug in unconfined, saturated material. The water table remains at a relatively constant level if there is a balance between the rate of infiltration (or recharge) and the rate of discharge at the ground surface. If discharge becomes excessive because of increased pumping of water wells, then the water table begins to drop.

In addition to the effect that pumping can have on the general water table, there is a localized effect at each well site. When pumping begins, the water in the aquifer is drawn down, forming a cone of depression around the well. The cone steepens near the well, and becomes deeper as pumping increases until the cone encounters a source of replenishment. If wells are closely spaced, the cone of depression associated with a very deep well may cause nearby shallow wells to become dry.
B. Groundwater Occurrence

Any geologic unit that lies below the water table and can hold and transmit water is referred to as an aquifer. Aquifers can consist of consolidated bedrock or of unconsolidated material such as sand, gravel, or clay. Most of the groundwater used in British Columbia comes from unconsolidated material, but wells can be drilled successfully into either type of aquifer.²

Water moves through consolidated bedrock in three ways: through the fractures in otherwise impermeable igneous and metamorphic rock; through the pores and fractures in sedimentary rock; and through the caves formed by the dissolution of limestone. In British Columbia, the water occurring in rock usually moves through joints and fractures, rather than through pores and caves.³ Within the province's coastal trough (especially on the Gulf Islands and the Saanich Peninsula), wells are often drilled into bedrock.⁴ Only limited water storage is available within the network of fractures, but high yields are possible in areas where there are numerous, large, unclogged fractures.

Unconsolidated rock is material which will eventually become sedimentary rock, but which has not yet become cemented together. The amount of water occurring in unconsolidated material depends to a large degree on the coarseness of the material. If the aquifer consists of very fine-grained material, wells can be difficult to construct and may give low yields. The unconsolidated material is often very permeable, however, and can then produce high yield wells. This is the case on the Fraser Lowland, where approximately 25 percent of the wells drilled in British Columbia each year are located. The unconsolidated surficial
deposits of the Lowland are more than 600 feet thick in most places, and are able to support several large production well fields.\textsuperscript{5}

An aquifer is always underlain by a relatively impermeable layer known as an aquiclude. If an aquiclude also lies above the aquifer, then a confined water reservoir is formed. This water may be under considerable pressure, causing it to flow spontaneously from any well drilled into it. Such wells are known as artesian wells. As water is discharged from the artesian wells, the pressure in the aquifer drops.

An unconfined aquifer does not have an aquiclude overlying it, so the surface of the groundwater is exposed to only atmospheric pressure. Rain and snowmelt can filtrate downward to feed into, and replenish the unconfined reservoir. More complex groundwater conditions often exist where geologic deposits are not homogeneous. In some areas, unconfined, saturated material is found above the general water table. In such cases, a semipermeable or impermeable layer will have isolated some percolating water, causing a perched water table to form.

C. Surface Water - Groundwater Relationships

The level of water in a lake, stream, or other body of surface water is often closely related to the water table. When the water table is low, the surface waters supply water to the adjoining aquifers. This influent action naturally recharges the groundwater reservoirs. Conversely, when the water table is higher than the level of surface water, the groundwater will recharge the lake or stream with an effluent flow. The result of this interrelationship between surface water and groundwater is that withdrawals of groundwater can affect supplies of connected surface water.
In some cases, the effect on the surface water may be noticeable soon after the groundwater is pumped, but in other instances, the impact might not be felt for many years.

There is a second groundwater-surface water relationship that groundwater users living along the coast must take into account. Coastal aquifers contain a saltwater-fresh water interface that slopes away from the sea as it extends downward. Because fresh water is less dense than saltwater, the two remain separate except at the interface. The pressure of the overlying fresh water prevents the saltwater from seeping into the whole aquifer and rendering the groundwater unusable. However, if the amount of fresh water in the aquifer is reduced, then the saltwater will move farther into the aquifer. The advancing seawater may then be drawn into coastal wells.

III. GROUNDWATER USE IN BRITISH COLUMBIA

Groundwater is the main source of fresh water on Earth, and is used for individual domestic and irrigation purposes, and for community and industrial water supplies in many countries. It is often more useful than surface water because it does not usually require treatment and its temperature and chemical content remain fairly constant.

In British Columbia, between 25 and 45 percent of the domestic and municipal water used by people living outside the areas supplied by the Vancouver and Sooke water systems comes from underground sources. Communities south of the Fraser River in the Lower Mainland rely on groundwater supplies for 37 percent of their total daily requirements, while several other municipalities, including North Cowichan, Alert Bay, and
Williams Lake, depend almost entirely on groundwater. Many Gulf Island residents also rely on groundwater for all their needs but, because both surface and groundwater supplies are limited on most of the Islands, water is often used sparingly.

Other groundwater uses in British Columbia include irrigation (in the Keremeos and Cawston areas, for example), and commercial and industrial purposes. In addition, the Fraser Valley Trout Hatchery near Abbotsford depends on the high quality groundwater available in the area.

Demand for groundwater can be expected to continue to increase as the population grows and the provincial economy expands. British Columbia has experienced a high rate of population growth in recent decades, and substantial increases are expected to continue to occur in the coming years. The corresponding increase in demand for water will put a great deal of pressure on the limited supplies of water available in the province's populated areas.

IV. ADMINISTRATIVE ARRANGEMENTS
A. Provincial Jurisdiction over Groundwater

British Columbia derives its chief power over groundwater from section 109 of the British North America Act, whereby the provinces are deemed to be the owners of most of the natural resources within their boundaries. This proprietary power is furthered by the legislative jurisdiction that the provinces derive from section 92 of the Act. This section gives the provinces the power to pass legislation dealing with sixteen categories of subject matter. Among these categories are several under which groundwater legislation could fall: "management and sale of
the public lands", "local works and undertakings", "property and civil rights", and all "matters of a merely local or private nature in the province".15

The federal government has chosen to conduct research and to advise the provinces on some water management issues.16 But, although the federal government has jurisdiction over a number of subjects which might affect groundwater, it cannot regulate or manage a province's groundwater per se. Thus, the responsibility for managing British Columbia's groundwater lies with the provincial government.

B. The Water Management Branch

British Columbia's groundwater comes under the direction of the Water Management Branch of the provincial Ministry of Environment. The Groundwater Section of the Branch is responsible for carrying out a wide range of inventory and assessment programs. In recent years, the Section has monitored the effects of an irrigation well in the Ardmore area of Saanich; reviewed groundwater conditions and potential on several Gulf Islands; studied the effects of proposed developments, such as coal projects and pipelines, on groundwater; reviewed the hydrologic aspects of environmental assessment reports; prepared hydrogeological maps of several sites in the province; and carried out a range of related projects.17

The Groundwater Section is divided into an Engineering Unit and an Inventory and Mapping Unit. The Engineering Unit handles routine groundwater enquiries from the public, conducts groundwater assessment reviews for other government agencies, and studies groundwater supplies. The Unit also operates an observation well network to monitor changes in water level and water quality.18
The Inventory and Mapping Unit is primarily concerned with establishing an adequate data base. At the present time, the chief source of data is the well record information supplied by the water well drillers of the province. The well drillers are not required by law to provide the Ministry with well information, so data collection depends on the cooperation of the well drillers.  

The Inventory and Mapping Unit is also preparing improved hydrogeological maps of some areas. The maps show the occurrence, direction of movement, quality, and quantity of groundwater available in the area and will therefore be useful for the management and protection of the resource. In addition, the Unit undertakes limited studies of groundwater-surface water interactions.

C. Local Governments

The Provincial government has enacted legislation enabling municipalities, regional districts, and the Islands Trust to indirectly control groundwater use. The Municipal Act and the Islands Trust Act give the local governments powers to regulate development and thus control the number, and types of wellusers in a given area.

The Municipal Act allows each municipality to prepare an official community plan. The plan is actually a policy document; zoning and subdivision by-laws are then used to implement the plan. Zoning by-laws can, in theory, protect groundwater supplies by preventing particularly heavy users of water from locating in sensitive groundwater areas and by restricting population density. Further protection is provided by section 729(1)(e) of the Act which requires that subdivisions which are dependent upon groundwater have proved sources of potable water.
The Municipal Act and the Islands Trust Act give all the zoning and subdivision powers of a municipality to regional districts and the Islands Trust, respectively. The regional districts and the trust begin their regulation of land use by developing official settlement plans. In preparing a plan, the local government must consider the suitability of land for various uses and the environmental consequences of implementing the plan. Consideration should also be given to the prevention of pollution of air, water, and land. Therefore, the regional districts and the Islands Trust are required to consider groundwater to some degree in their development plans.


3. Ibid.


5. Ibid.

6. Press and Siever, p. 239.


8. Telephone interview with Mark Zubell, Groundwater Section, British Columbia Ministry of Environment, Victoria, April 1982.


10. Interview with John Foweraker, Groundwater Section, British Columbia Ministry of Environment, Victoria, January 1980.


12. Foweraker, interview.


15. Subsections 5, 10, 13, and 16.


17. Foweraker, interview.

18. Water Investigations Branch, Minutes of Meetings of the Regional Directors, Victoria, Meeting of 6 November 1979; Groundwater Section
19. Ibid.
20. Ibid.
23. Sections 709-714.
24. Section 716.
25. Section 729.
27. Municipal Act, sections 808-810.
28. Ibid., section 810(3).
29. Ibid.
CHAPTER TWO

THE LEGAL FRAMEWORK

I. INTRODUCTION

More than a century ago, it was recognized that the common law doctrine of riparian rights was inadequate to allocate water in the potentially water deficient regions of British Columbia. Since that time, a series of statutes has been passed, putting an end to most riparian rights. However, groundwater has never been included in the legislation and consequently, British Columbia landowners still have common law rights to extract any water underlying their property.

An understanding of this legal framework, and its effect on water allocation and use is requisite to any discussion of management of the resource. To facilitate this understanding, this chapter describes the legislation and cases that determine the legal rights of water users in British Columbia. The chapter begins with a brief history of the province's surface water law, then describes the current Water Act. The case law pertaining to groundwater use is then discussed, and two statutes which affect groundwater use are outlined.

II. THE DEVELOPMENT OF SURFACE WATER LAW

Prior to 1859, the common law doctrine of riparian rights was used to determine the rights of all users of fresh surface water in the colony that was later to become British Columbia. The riparian doctrine gave every owner of property adjacent to a stream the right to have the stream flow
by in its natural state and the right to reasonable use of the water in it. The riparian right to have the stream flow in its natural state through one's property was therefore subject to the rights of other riparian owners to the reasonable enjoyment of the water. Consequently, a legal action could only lie if it was for unreasonable and unauthorized use of the water in the common stream.

This aspect of the riparian doctrine caused water users to have little security of tenure in areas where water was scarce. One riparian owner's 'reasonable' use of water could reduce another's supply at any time. Further difficulties in water allocation stemmed from the fact that 'reasonable' use referred only to use on the riparian land. This constraint prevented the water from being put to its best use in some cases.

As the colony developed, the riparian doctrine was found to be unsatisfactory in the dry interior, particularly because of the demand for water for sluicing and dredging in the gold fields. Water users needed security of tenure and the opportunity to use water on non-riparian lands. Therefore, the doctrine was gradually replaced by statutes, beginning with the Gold Fields Act of 1859. By 1914, British Columbia had a detailed Water Act which required most users of fresh surface water to obtain a licence. The 1939 Water Act, which was basically a reenactment of the 1914 Act has had few amendments to date. The current Water Act, like its predecessors, deals only with surface water.

III. THE WATER ACT

The Water Act vested all rights to the use of British Columbia's surface water in the Crown in the right of the province, thus eliminating
most riparian rights. The Crown issues licences which authorize the diversion and use of water or the obstruction of streams. Riparian owners are not required to have licences for domestic uses, but their use of water is subject to the rights of any licensee. Among licensees, precedence is generally determined by the date of application for water rights. If two licences became effective on the same date then precedence is according to purpose. This system of priority right gives many users limited security of flows. Junior licensees have no protection against senior licence holders and can therefore lose their supplies in dry years.

The Crown will only grant a water licence if there is unallocated water available at the proposed point of diversion and if the applicant can show that he is able to put the water to 'beneficial use'. In cases where reliable information about the supply of unallocated water is not available, or where flows are changeable, the Comptroller of Water Rights may exercise the safeguard of under-allocating the streamflow.

IV. GROUNDWATER LAW

A 1960 amendment to the Water Act provided that, upon proclamation, groundwater could be dealt with as surface water is. However, the amended section has not yet been proclaimed in force. Consequently, groundwater use in British Columbia is still governed by common law.

Traditional English common law distinguished between groundwater located in 'defined and known' channels and percolating groundwater. The owners of land overlying a 'defined and known' channel of groundwater had the same riparian rights as did the owners of land adjacent to surface
In other words the land owners could use a 'reasonable' amount of groundwater flowing in defined channels.

In British Columbia, however, groundwater is rarely found in 'defined and known' channels, so the common law of percolating groundwater has been applied. Accordingly, every occupier of land has had the right to extract as much groundwater as he wishes, regardless of the effect his actions might have on other surface or groundwater users. Because no person owned the groundwater underlying his property until he had it in his possession, no legal action could be brought for damages caused by another's use of groundwater.

Some Canadian courts have begun to depart from this traditional statement of the law and have sought to deliver judgments aimed at more equal rationing of the resource. In 1975, the Manitoba Court of Appeal decided that the common law right to withdraw groundwater must be made subject to the laws of nuisance and negligence. In one of the two majority judgments, Matas, J.A., with whom Freedman, C.J.M. concurred, stated that the common law in Manitoba had been affected by the province's Water Rights Act and that the traditional English cases should therefore not be followed.

More recently, the Ontario Court of Appeal agreed that a person's right to remove groundwater is limited by the laws of nuisance and negligence. At page 615, Howland, J.A. stated: "to conclude that those who abstract percolating water have an unbridled licence to wreak havoc on their neighbours would be harsh and entirely out of keeping with the law of torts as it exists today." The Ontario Court had more freedom to depart from the English common law than British Columbia would in a similar case.
because the Province of Ontario adopted English law as of 1792, while British Columbia received the law as it stood in 1858. Between those dates Acton v. Blundell, the English case which set out the traditional common law rules regarding groundwater, was decided.

Therefore, it is not entirely clear how a British Columbia court would decide a case if one person's withdrawal of groundwater caused damages to his neighbour. Water users in this province probably have the right to withdraw as much groundwater as they wish, regardless of the consequences. If however, the British Columbia courts can distinguish the English cases and follow the decisions of the Manitoba and Ontario courts, then groundwater users in British Columbia will have rights which closely resemble those of riparian owners. Although this would give the water users more protection than they had under the traditional common law rules, the problems associated with uncertainty of flows would remain. A 'reasonable' groundwater user could still reduce his neighbour's supply at any time.

V. RELATED LEGISLATION

Although groundwater users must rely on case law if disputes over the allocation of water arise, there are two provincial statutes that give users some protection against reductions in groundwater quality. Both the Pollution Control Act and the Health Act contain sections designed to protect well users.

The Pollution Control Act prohibits anyone from discharging, or permitting the discharge of any waste material into any water unless he has a permit or the approval of the Director of Pollution Control.
This restriction includes discharging pollution material into any groundwater within the province's jurisdiction.

The regulations made under section 5 of the Health Act provide groundwater quality guidelines, determine how far wells must be located from possible sources of contamination, and set well cleaning requirements. In addition, the regulations prohibit anyone from placing any animal or vegetable matter in or near a domestic water source, and from doing anything else which might render a water supply unfit for domestic purposes.22
CHAPTER TWO

REFERENCES AND NOTES

1. Embrey v. Owen (1851) 6 Exchequer Reports 352.


7. There is some disagreement over the issue of whether riparian owners have rights to use water for domestic purposes or whether they may use it at sufferance only. Supporting the latter view is Schillinger and Ponderosa Trout Farm v. H. Williamson Blacktop & Landscaping Ltd. (1977) 4 British Columbia Law Reports 394. Campbell discusses this issue in more detail.


10. Ibid., p. 257.


18. (1843) 12 Meeson & Welsby 324.


22. In particular, see Regulations 41, 42, and 43.
CHAPTER THREE

GROUNDWATER ALLOCATION PROBLEMS

I. INTRODUCTION

In many parts of British Columbia, groundwater supplies exceed the demands of users and no allocative mechanism is necessary. In some areas, however, a relatively small supply of groundwater must be distributed among competing users. Two issues arise in such cases: first, at what rate should the water be withdrawn and, second, what use should be made of the water (and by whom) at any point in time. Unless groundwater rights are defined in a manner that enables these issues to be resolved, allocation problems are likely to arise.

There are several hydrogeologic and economic factors which affect groundwater allocation and use, and which should be taken into account when devising a groundwater allocation system. Chapter three discusses these factors and their implications for groundwater management, and relates them to groundwater allocation problems which have arisen in British Columbia.

II. PHYSICAL CONSTRAINTS ON GROUNDWATER USE

The common law rule of groundwater ownership was developed at a time when technical knowledge of groundwater was very limited.¹ When physical interdependence among well-owners was recognized, some American courts departed from the common law to rely on new doctrines which acknowledged this interdependence.² Since that time, there has been a
significant increase in scientific knowledge regarding aquifers and groundwater. This improved understanding of hydrogeology has led to recognition of the fact that other physical characteristics of groundwater have implications for its use and management.

Several characteristics which should be considered when choosing an effective groundwater management system are discussed in the following sections. Some of the problems which have occurred in British Columbia because these factors have not been acknowledged are described.

A. The Effects of Land Use

Groundwater supplies are replenished by infiltration of rainwater, and are therefore affected by the condition of the overlying soil. The porosity of the soil is largely determined by natural factors, but certain land uses affect the ability of rainwater to enter the soil. Streets, buildings, and parking lots impede recharge directly and through soil compaction.

Other land uses affect the quality of the water that eventually enters the underground reservoirs. Waste disposal sites and septic tanks pose obvious problems if located near water wells, and pesticides present in leaching waters can filter into groundwater supplies. Fertilizers may increase nitrate and phosphate levels in percolating water, and clearcut logging can lead to an increased flow of chemicals through the soil. As water filters through the ground, many of these contaminants are absorbed by the soil or attenuated in other ways. However, depending on the soil's water content, amount of rainfall, and soil type, leaching water may contain a variety of pollutants when they reach groundwater reservoirs.
The ability of filtrating water to carry pollutants into groundwater reservoirs is evident on Hornby Island, where most residents rely exclusively upon percolating groundwater for their domestic supplies. Because some of the water used and then discarded by residents finds its way into aquifers, detergents and other impurities have been found in well water. Widespread use of septic tanks may cause further quality problems as development of the Island proceeds.

The effects that certain land uses can have on the quantity and quality of available groundwater impede the success of groundwater management systems which consider the resource in isolation. Measures directed at controlling groundwater use cannot protect the resource if factors which impair replenishment are ignored.

B. Groundwater - Surface Water Relationships

Groundwater and surface water constitute one interrelated unit. Attempts to resolve water supply problems must therefore take into account the seawater-groundwater relationships described in chapter one, and the interdependency between groundwater and surface streams and lakes.

The association between the water table and the level of water in a surface stream or lake makes it possible for a new well to interfere not only with other wells, but also with surface water flows. When pumping lowers the water table below the level of an adjoining stream, the stream begins to supply water to the aquifer.

This relationship created problems for surface water users in the Okanagan area several years ago. Licensed users of Kalamalka Lake water found that their water supplies were declining at a time when use of nearby wells was increasing. The surface-groundwater relationship was
so strong that pumping of unlicensed well water was drawing down the lake and threatening licensees' rights.

Integrated management of groundwater and surface water will become increasingly necessary as demand for water grows. The United States National Water Commission has stated that integrated management of surface and ground waters is essential, and that "no one seriously disputes the need for such conjunctive management."

C. Groundwater Movement

The slow rate of underground water movement enables groundwater reservoirs to maintain supplies even during dry seasons, but it also makes depletion and pollution problems difficult to correct. Problems usually become evident after several years of overdraughting or contamination, and it is then too late for quick solutions.

The slow movement, and consequent slow rate of recharge cause groundwater to be a stock rather than a flow of water if withdrawal rates are high. When heavy usage occurs, the resource is 'mined', causing the water table to decline until pumping is reduced. A lowered water table may gradually rise if withdrawals are reduced, but in some cases the water table will never completely recover.

Water quality problems are usually more serious than a lowered water table. If saltwater or pollutants enter a reservoir, wells may have to be abandoned until the contaminants are dispersed. Due to the slow movement of groundwater, it can be many years, or decades, before wells are usable again.

The prolonged effects of overdraughting and contamination illustrate the importance of identifying potential problems. If well-owners
wait until depletion and pollution problems arise, they may be faced with the costly prospect of finding new water supplies.

D. Aquifer Identification

Reliable information about the amount of water in an aquifer and possible fluctuations in the supply is important to groundwater management. In order to obtain this information, hydrogeologic data on aquifer boundaries and capacity, points and rates of recharge, and relationships with surface water are required. However, because aquifers are located underground, this data can be difficult to acquire.

Without adequate information about a supply of groundwater, the amount of water which can be pumped on a sustained yield basis cannot be determined, nor can inter-well effects be predicted. These difficulties are particularly significant in areas with complex bedrock geology and in coastal areas. For example, in 1973, a high yield irrigation well was drilled in the granodiorite area of the Saanich Peninsula. Complaints by other Saanich well users, of reduced flows led to tests which revealed a complex fractured bedrock aquifer system. The interconnected and discontinuous fractures had allowed the irrigation well to interfere with wells more than 3000 feet away, while leaving some nearby wells unaffected. At the time of drilling, the data needed to predict these impacts was not available.

Hydrogeologic data are also required in the many coastal areas of the Province, where saltwater intrusion is a potential problem. Appropriate data would allow water managers to determine the groundwater level necessary to keep seawater out of the aquifers and hence, the quantity
of water that could safely be pumped. Monitoring of the water table would then allow preventative action to be taken before intrusion occurs.

The importance of reliable hydrogeologic data should be considered when devising a groundwater management plan. Means of facilitating data collection should be incorporated into the plan and until sufficient data are available, flexibility should be maintained so that water allocation can be improved when better data are obtained. A rigid system which establishes fixed allocations is inappropriate if there is uncertainty about the water supply.

III. GROUNDWATER USE AND ECONOMIC EFFICIENCY

The economic objective of groundwater management is to allocate the resource in an "efficient" manner, i.e. in a way that generates the greatest net benefit to society as a whole. With regard to a specific underground reservoir, this objective is met when the marginal value of using water is equal for all uses. These marginal values are determined by taking into account all costs and benefits, not just marketable values.

If a single groundwater user has control over an entire underground reservoir, he may consider all costs and benefits and use the water efficiently. However, groundwater resources are often used by a number of well-owners who pump water from a common source. Although the pumpers are interdependent, each user bases his pumping decisions on the costs and benefits he personally experiences. Unless countervailing laws exist, the pumper tends to ignore both the monetary and intangible costs that his use imposes on his neighbours. These external costs may be either increased pumping costs or the less quantifiable costs associated with reduced water supplies.
In British Columbia, groundwater users are not prevented from using water in amounts, or in ways which generate external costs. As a result, well-owners have no protection against reductions in the quantity or quality of groundwater caused by other users' withdrawals. The following cases illustrate some of the problems which arise when significant external costs exist.\(^22\)

In 1969, a Surrey landowner drilled an artesian well which eventually yielded 300 gallons per minute. In the weeks following the drilling, several nearby well owners complained to the Water Resources Service of severely reduced water levels. Because there are no restrictions on groundwater withdrawals, the artesian user was allowing water to flow freely from his well into a ditch. The other well-owners had no rights to continuous groundwater supplies and therefore were forced to either incur additional pumping costs or use less water.

In a second case, the Fish and Wildlife Branch's Fraser Valley Trout Hatchery near Abbotsford was competing with the town of Sumas for groundwater supplies. The Hatchery depends on groundwater, rather than surface water because of the former's high quality and relatively constant temperature and chemical content. Sumas also relies heavily on groundwater and, in 1972, completed a new, high-yield well about 1200 feet north of the Hatchery's well field. At that time, the provincial government was expanding the Hatchery and there was concern over making such an investment without an assured water supply.

The Hatchery expansion was completed in 1977 at a cost of about $7 million. By 1978, aquifer tests showed reduced water levels\(^23\) and in 1979, plans were made to improve the Hatchery's pumping facilities.
As the water needs of Sumas residents increase, a new water source will be required. Until then, however, the aquifer will be "mined" and the Hatchery will incur increased extraction costs.

In both the Surrey and the Sumas cases, owners of high-yield wells imposed costs on other groundwater users. The existence of such external costs affects allocative efficiency in two ways: groundwater users tend to withdraw more groundwater than they would if these costs were taken into account, and future water supplies are insecure.

The tendency to withdraw excessive amounts of groundwater is a result of the pumper's ability to pass some of the withdrawal costs on to his neighbours, while realizing the benefits himself. He perceives the net benefits of pumping to be greater than they are from a social perspective. In the Surrey case, the artesian well-owner's marginal pumping costs were negligible so he had no incentive to refrain from wasting water. The costs that he imposed on other well-owners did not reduce his private net benefits.

In the Sumas case, the town's decision to use groundwater rather than surface water was based on the relative costs of obtaining water. The costs incurred by the Hatchery when the water table declined did not need to be taken into account. If the town was required to internalize these costs, it may have developed an alternative water supply.

A second source of economic inefficiency is the insecurity that groundwater users experience when other pumpers are free to generate external costs. Each well-owner is only entitled to the groundwater that he pumps; he has no rights to the water left in the ground. Because he knows that other pumpers may lower the water table, he is uncertain about
future water supplies. Consequently, the well-owner has an incentive to use the water while he can, ignoring the future value of the resource and the socially optimal rate of withdrawal.

The existence of external costs and the associated insecurity can also lead to inefficient use of resources other than water. The threat of new, deeper wells being drilled by future neighbours may cause a landowner to over-invest in pumping equipment when he drills his well. As a result, expenditures on well-drilling, pumps, and energy may exceed those necessary under an efficient system. In addition, landowners who depend on groundwater supplies may not be able to develop their property without some security of supply.

It is evident from the foregoing discussion that the economic efficiency of groundwater use could be improved by the introduction of measures which reduce the incentive to overdraught and provide water users with security of supply. However, because the socially optimal mix of water uses will change over time, the efficiency objective also requires that water rights be transferable. As economic conditions change, the values of some water uses will increase relative to others. Transfers to the new, higher-valued uses should be permitted in order to maintain efficiency. Under the present British Columbia system, rights to groundwater use are appurtenant to the overlying land and are only transferred when the land is sold.
CHAPTER THREE
REFERENCES AND NOTES


2. Some of these doctrines are discussed in chapter four.


6. Ibid., p. 6.


8. Ibid., p. 99.


12. Foweraker, interview.


15. Ibid., p. 238.


19. The Kingswood well, yielding 300 gallons per minute: Foweraker, interview.


22. The information about these cases is from Foweraker, interview.

23. Recent tests, however, show that the water table has recovered: Zubell, interview.


25. Campbell, Pearse and Scott, p. 252.
CHAPTER FOUR

GROUNDWATER MANAGEMENT ALTERNATIVES

I. INTRODUCTION

Almost every province and state in western North America has introduced some form of groundwater control legislation. As a result, there are a number of different groundwater regulation and management systems in effect. A review of some of these systems, and of strategies recommended in the literature should provide some guidance in the development of a groundwater management strategy for British Columbia.

This chapter examines several of the groundwater management and regulation schemes which have been recommended or adopted in other jurisdictions. In order to assess their suitability for British Columbia the alternatives are evaluated according to: (1) feasibility, given the province's current administrative and legal systems; (2) equity among groundwater users; (3) effectiveness in controlling the physical problems described in chapter three; and (4) economic efficiency.

II. ALTERNATIVES

The laws governing groundwater use in North America are based on four legal doctrines: (1) the common law rule of absolute ownership; (2) the doctrine of reasonable use; (3) the correlative rights doctrine; and (4) the prior appropriation rule. The common law rule of absolute ownership allows owners of land overlying a groundwater reservoir to make unlimited withdrawals of water, regardless of any damage they may cause to their neighbours' water supplies. Dissatisfaction with the rule has
caused most provinces and states in western North America to rely instead on the more restrictive doctrines.

In areas which have adopted the reasonable use rule, a groundwater user may affect his neighbour's water supply if his use is 'reasonable'. The correlative rights doctrine also allows the landowner to make reasonable use of the water, but limits the amount he may withdraw to his correlative share. Many western states now employ the fourth doctrine, prior appropriation, and have adopted priority licensing systems to allocate groundwater.

The common law rule of absolute ownership is currently in effect in British Columbia and has been described in chapter two. The remainder of this section describes the doctrines of reasonable use, correlative rights, and prior appropriation, and discusses the variations and complementary provisions which have been introduced in other western provinces and states. Also discussed is the recommendation of several authors that a pricing mechanism be used to allocate groundwater.

A. The Reasonable Use Doctrine

The reasonable use doctrine limits a landowner's use of groundwater to 'reasonable and beneficial' use but, like the traditional common law rule, it does not require the landowner to consider the effects his use of water may have on his neighbours. If groundwater use is 'reasonable and beneficial' to the user's land, then an affected neighbour cannot maintain an action for damages even if his water supply is depleted.

Determination of what constitutes a reasonable use of groundwater can be a difficult matter. Consequently, courts have held that almost all
uses on overlying land—domestic, irrigation, and manufacturing—have economic or social value and are therefore reasonable. The reasonable use doctrine is in effect in Manitoba and Ontario, and in several of the eastern and midwestern states which do not have groundwater appropriation statutes. Some states have supplemented the doctrine with other water management provisions. Arizona, for example, uses the reasonable use rule to allocate percolating groundwater, but requires that notices of intent to drill wells be filed with government agencies, and allows critical groundwater areas to be designated. The identification of critical areas has a limited effect on groundwater use in Arizona, however, because critical areas are narrowly defined as areas not having sufficient groundwater to provide irrigation of cultivated land. Wisconsin courts have adopted a variation of the reasonable use doctrine and may find a groundwater user liable for damages if his use causes unreasonable harm to other users by lowering the water table or reducing artesian pressure. This more restrictive interpretation of reasonable use was adopted in order to protect small users who have little effect on the water table and who are least able to bear the costs of deepening wells. In looking beyond the reasonableness of the use on the land to the effect on the water table, Wisconsin courts are moving closer to the correlative rights doctrine.

B. Correlative Rights

California has adopted the principle of correlative rights as a means of solving groundwater allocation problems. This principle evolved from the common law rule of absolute ownership in a series of legal cases
that began in 1902. Under the correlative rights rule, all owners of land overlying a common supply of percolating groundwater have co-equal rights to the reasonable, beneficial use of the water on or in connection with their lands. When demand exceeds supply, each water user is entitled to a reasonable share of the water and can apply to the courts to have the respective rights of the co-equal users determined.

Correlative rights are not based on use or lost by nonuse, so one landowner cannot gain priority merely by appropriating the water before his neighbours. Each landowner has an equal right to his reasonable share, regardless of when he commenced use.

The right to reasonable use on the overlying land is paramount to any appropriation for distant use but, after these reasonable needs have been met, any surplus groundwater may be put to beneficial use on other lands. A right to continue using water on distant lands may later be acquired by prescription.

There is a considerable amount of coordination of ground and surface water rights when the waters constitute a common supply (i.e. when the groundwater either flows from the stream or feeds it). The rule of reasonable use is used to coordinate the various rights in such cases.

C. Prior Appropriation

Alberta, Ontario, and many of the western states have adopted groundwater licence systems under the prior appropriation doctrine. The prior appropriation doctrine gives a priority right to the first person who obtains a licence to use groundwater for a continuous, beneficial purpose.
A landowner acquires an appropriative right by first applying to the responsible government agency for a licence to pump water at a specified rate. In most cases, the licence is issued if there is sufficient groundwater available. If a groundwater shortage develops at some later date, priority among users is determined primarily by the dates of the licences, and secondly, by the type of water use. A licensee can lose his priority rights by discontinuing his use of water for a significant length of time.20

There is a considerable amount of variation in the application of licence systems among the various appropriation states and provinces. Some jurisdictions require that licences be obtained by all but small domestic users while others operate licence systems only in problem areas. In some areas, licences are issued whenever groundwater is available, but a few states try to prevent long-run depletion of underground reservoirs.

The Alberta government passed legislation in 1971, requiring all but small-scale domestic users to obtain licences to use groundwater. Prospective groundwater users must provide technical information pertaining to the aquifer and the proposed well, and demonstrate a need for the water.21 Ontario has a less restrictive appropriation program whereby licences are required only for withdrawals of 10,000 gallons or more per day. Smaller wells are subject to the reasonable use rule.22

Several states try to avoid severe aquifer depletion by designating critical areas when problems of well interference or water table decline become evident. In the critical areas, groundwater use is more closely regulated. In Montana, for example, well licences are required in controlled areas for wells of all sizes. Outside these areas, licences are needed only
for withdrawals exceeding 100 gallons per minute. And in Oregon, the State Engineer can prevent further appropriations and reduce licensees' withdrawals in critical areas.

Nebraska has a variety of provisions for managing groundwater use. The Natural Resources Districts may designate critical areas in which groundwater use can be regulated through cutbacks in production, refusals for licences, and any other restrictions deemed necessary. The state recognizes the relationship between ground and surface waters by placing wells within fifty feet of a stream bank under the stream appropriation doctrine. In noncritical areas away from streams, licences are not required and groundwater conflicts are resolved by the courts through application of the Preferential Use Statute which favours domestic users, and then agricultural users, over others.

Some appropriation states are attempting to prevent depletion of underground reservoirs by balancing recharge and withdrawal rates. Idaho allows the department of water resources to adjust pumpage rates in accordance with a 'safe yield' concept. North Dakota also plans to manage aquifers on a sustained yield basis and has required water meters on higher yield wells since 1975 in order to correlate pumpage with effects on aquifers.

D. A Market System

Several authors have recommended that market systems be established to ration water by price. The objective of these proposals is to allow water rights to move toward their highest and best uses by removing the current restrictions on transfers. A competitive market in water rights
would theoretically lead to an efficient allocation of water resources over time.

Markets in water rights exist to some extent within other groundwater allocation systems. The groundwater rights held under the common law, reasonable use, and licensing systems are appurtenant to the land and are bought and sold as part of the land. Under the correlative rights system, purchasers of land gain an opportunity to obtain correlative rights. However, market systems are unique in that they allow water rights to be sold independently of land.

The details of the various market models vary, but all involve competitive markets in which clearly defined rights are bought and sold at market prices. Purchasers receive rights to use certain amounts of water, but do not purchase actual quantities of water. The price paid for a water right is determined by supply and demand and will vary among areas, and over time. In regions where water is plentiful, prices would approach zero. When demand exceeds supply, prices would rise, discouraging wasteful use of water.

For most purposes, surface water is a perfect substitute for groundwater. Therefore, if an efficient allocation of water resources is to be achieved, it is necessary to include both groundwater and surface water in a water rights market. If surface water rights were not marketed, surface water supplies might be overused relative to groundwater supplies.

III. EVALUATION OF ALTERNATIVES

The preceding review of groundwater management systems has revealed a diverse group of measures for allocating, and in some cases conserving
groundwater. In order to assess the suitability of these systems for British Columbia, the four alternatives are evaluated according to the criteria of feasibility, equity, effectiveness, and economic efficiency.

Feasibility refers to the ease with which the various measures could be incorporated into British Columbia's administrative and legal systems, as outlined in chapters one and two. A feasible system can be introduced through the legislature or the courts and, once in place, will operate without excessive administrative costs.

The equity criteria deals with the distribution of costs and benefits among existing groundwater users, and among different generations of users. Judgments about the equity of any distribution of costs and benefits will vary, depending on one's values and interests. However, in this thesis, equity is assessed according to (1) whether the costs of reducing groundwater levels are distributed fairly among existing users, and (2) whether groundwater supplies can be conserved for the benefit of future generations.

In assessing the equity among existing users, preference was given to systems which spread costs among a large number of parties rather than placing an undue burden on only a few well-owners. Furthermore, it was considered fair to ignore length of prior use when reductions in use are required. Although some may consider that priority gained by use is fair, it is not clear that 'junior' users are better able to bear the costs of water reductions.

Effectiveness is measured by each system's ability to resolve the groundwater problems which stem from physical constraints on groundwater use. As discussed in chapter three, these constraints make it necessary for a
system to acknowledge both land-water and surface water-groundwater relationships, prevent severe problems from developing, and be flexible enough to operate without complete hydrogeologic data.

Finally, economic efficiency is assessed according to whether the systems can remove the incentive for individual users to pump more groundwater than is socially optimal, provide wellowners with some security of supply, and allow groundwater rights to be transferred among users.

A. The Reasonable Use Doctrine

The reasonable use doctrine is closely related to the present common law rule and would pose few feasibility problems. British Columbia courts may introduce this doctrine by following the recent decisions of the Manitoba and Ontario Courts of Appeal. Alternatively, the provincial government can pass legislation limiting groundwater use to reasonable and beneficial use. The similarities between the common law rule of absolute ownership and the reasonable use doctrine would allow a smooth transition from one system to the other.

The reasonable use doctrine is more equitable than the current common law rule because it gives wasteful or 'unreasonable' uses of water the lowest priority. However, if all competing uses are 'reasonable', then the distribution of costs and benefits is not considered by the courts. In addition, there are no provisions for conserving groundwater for future users.

The reasonable use doctrine would be no more effective than the common law in dealing with most of the problems associated with the physical characteristics of groundwater. A possible exception is that the threat of legal action for 'unreasonable' use may encourage some groundwater users to
resolve conflicts before severe depletion problems develop.

The doctrine would do little to improve the economic efficiency of groundwater use. Like the traditional common law, the doctrine of reasonable use contains the element of 'capture', so rights are insecure. The incentive to overdraught is somewhat reduced because well-owners are discouraged from wasting or making 'unreasonable' use of groundwater. However, because the courts look only at the reasonableness of the individual uses, depletion of the groundwater supply is still possible. The courts do not consider whether a reasonable use is efficient, nor could such a determination be made without studying all competing uses.

B. Correlative Rights

A system of correlative rights could be established in British Columbia by legislation which limits a landowner's use of groundwater to his correlative share. Transition from the present system would be gradual, however, because individual rights would be determined as allocation decisions are made by the courts. The court adjudications would probably be difficult and costly because of the need to weigh the technical evidence as well as the interests of the various well-owners. In addition, there could be a significant period of time between the application for adjudication and the actual allocation decision.

The correlative rights system is the only alternative reviewed here which requires that equity be considered whenever a particular allocation is determined. When the demand for groundwater exceeds the available supply, the courts consider the reasonable needs of the various parties and the overall equities, and then decide upon a fair method of reducing the
collective rate of pumping. However, such decisions may fail to take into account the needs of future generations.

Correlative rights would probably be more effective than either the absolute ownership rule or the reasonable use doctrine. The system would be very flexible because the allocations are not fixed for a specific length of time. As more complete aquifer information became available, the allocations could be improved in order to prevent problems from developing. However, in some cases the system would not be able to resolve problems before they became severe, because allocations by the court are only made after the need for a change in usage patterns becomes evident. In addition, correlative rights would be difficult to coordinate with British Columbia's surface water licensing system. Unless the collective rate of pumping were set at a 'safe yield' level and surface water had not been overallocated, conflicts would probably occur among users.

A correlative rights system would do more to promote economic efficiency than the absolute ownership and reasonable use doctrines. Under this system, allocation decisions are made by the courts, rather than by individual well-owners. This practice has the effect of regulating both the collective rate of withdrawal and the amount of groundwater pumped by each user. Therefore, the number of inefficiency problems related to the existence of external costs would be significantly reduced.

Correlative rights offer the groundwater user more security of supply than either the absolute ownership or the reasonable use doctrine. Complete security of supply is not ensured (because the correlative shares may be adjusted from time to time), but the beneficial user is usually certain to receive a share of the available groundwater supply. And,
because no user can deplete the reservoir, each well-owner is assured that a future supply will exist to be shared.

Nonuse of groundwater does not reduce one's future correlative rights and therefore, new users are readily accommodated. Rights could be easily transferred to different uses as users' needs change and as new users appear, because transfers of rights take place automatically whenever a reallocation is made. However, a reallocation may not result in 'higher and better' uses of water in an economic sense.

C. Prior Appropriation

A priority licensing system for surface waters has operated in British Columbia for many years. The system could readily be extended to groundwater if the relevant sections of the Water Act were proclaimed. Introduction of a groundwater licensing program would entail certain administrative costs, but it would probably not create any additional administrative problems if the program were phased-in area by area, in manageable units.

The equity of priority licensing systems is mixed. When physical conditions reduce the groundwater supply to the point where all needs cannot be met, the junior licensees bear most of the costs of the water shortage. A more equitable system might require all licensees to reduce their withdrawal rates by the same amount. However, a licensing system could improve the intergenerational distribution of costs and benefits. If the total licensed withdrawals from a particular reservoir are limited to the 'safe yield', then the water supply will not be depleted by existing users.

A licensing system would be an effective means of dealing with some
groundwater problems. It would facilitate joint management of ground and surface waters, and provide water resource agencies with more information about groundwater use. If licences specified withdrawal rates, were issued only when a safe yield could be expected, and were reviewed periodically, most well-interference problems could be avoided. However, hydrogeologic information is needed in order to determine the safe yield of an aquifer and to predict possible well-interference problems. If aquifer information is incomplete, there is a risk that too many licences will be issued, and the water table will be drawn down. Because the allocation of water is fixed for the duration of the licences, overdraught problems cannot readily be corrected.

A priority licensing system would be of limited value in improving the efficiency of groundwater use. Licences specify withdrawal rates and can therefore control some of the problems associated with external costs if the water supply has not been overallocated. Licences also provide senior licensees with security of tenure and with a great deal of protection against physical uncertainty. However, junior licensees' rights are less secure. When all demand cannot be met, holders of senior rights have priority over junior users, although the latter may be able to put the water to higher-valued uses. Even if the senior users made the best use of the groundwater when licences were originally issued, economic changes may have altered the relative values of the various uses. This problem may be compounded if licences also give preference to certain purposes, leaving insufficient water for other uses.

Licensing systems do not usually allow rights to be transferred among users unless the land on which the water is used is also transferred.
Licences are generally appurtenant to the land and are not the personal property of the licensee. To some extent, this feature impedes the transfer of rights to higher and better uses.

D. A Market System

Although market systems in water rights (independent of markets in land) have been discussed in the literature, they have not been adopted by any of the North American provinces and states reviewed here. Hence, introduction of a market in water rights in British Columbia would involve some feasibility problems.

First, an effective market system requires that rights be clearly defined. This task is complicated by the 'flow' characteristic of water and by the fact that the same unit of water can be used many times. In addition, the exercise of rights to use groundwater can affect the quality as well as the quantity of the remaining water, particularly if the point of diversion can be changed. These characteristics make it difficult to establish exactly what constitutes a 'right'.

In the following evaluation, it has been assumed that a water right allows the holder to withdraw a particular amount of water each day, and that within each designated area, rights can be bought and sold freely. It was further assumed that when a right is sold, the new holder can move the point of diversion if he so desires.

Transition to such a market system could be effected by first granting all surface water licensees and all well-owners marketable rights to use water at current rates or, where depletion problems have arisen, at reduced rates. Rights to any remaining water would then need to be sold by the
provincial government. Once in place, the market system would require little government intervention.

The equity of a market system in water rights is dependent upon an acceptance of the present distribution of wealth. If the fairness of the latter is accepted, then a market system is an equitable means of allocating water in the short run. However, equity among generations of water users depends on the collective rate of withdrawal for which rights are initially established. It would be possible to conserve groundwater for future users, but conservation is not an inherent feature of the market system.

If water rights have been clearly defined and transition has been made from the present system, then a market system could deal effectively with some groundwater problems. Joint allocation of ground and surface waters would be possible, and more information about water use would be available. In addition, most well-interference problems could be avoided if rights were initially sold only for withdrawals which balanced recharge rates. However, a great amount of hydrogeologic data would be required to achieve this balance.

Some well-interference problems could still occur when purchasers of water rights change the points of diversion. New, or larger cones of depression could form, adversely affecting the yields of nearby wells. Furthermore, in areas where hydrogeologic information is incomplete, it is possible that too many rights would be established and that excessive withdrawals would be made. A market system is better able to deal with this problem than a licensing system, however. When it becomes apparent that withdrawals should be reduced, the government can purchase the rights of
some users and remove them from the market.

Pricing systems are proposed primarily for their ability to encourage efficient water use and would probably be relatively successful in this regard. Rights would be completely transferable, allowing greater flexibility than is possible under other allocation systems. In addition, water users would have a great deal of security because they could only lose their rights by selling them.

New users would also be accommodated under a pricing system because as demand increases prices would also increase, giving each user an incentive to make more efficient use of water so that he could sell part of his right. Thus, water resources would continually be reallocated to higher-valued uses. However, one disadvantage of market systems is that the value of water is determined solely by the price users are willing to pay for rights. This emphasis on price may result in an underallocation of water to uses which generate nonmonetary benefits.
CHAPTER FOUR
REFERENCES AND NOTES


2. Bosch, p. 435.


5. However, the prior appropriation method is used to allocate the water in underground streams: W.A. Hutchins *Selected Problems in the Law of Water Rights in the West* (Washington: U.S. Government Printing Office, 1942), p. 182.


9. Ibid., p. 437.


11. Groundwater in defined channels is subject to prior appropriation: Hutchins, p. 188.


13. Hutchins, p. 188; Veeman, p. 584.


15. Ibid.


17. Ibid., p. 199.

18. Ibid., pp. 101-203.


22. Ibid., p. 9.


28. Clark, "The Role of State Legislation," p. 483. The term 'safe yield' refers to "the amount of naturally occurring groundwater that can be withdrawn on a sustained yield basis, economically and legally, without impairing the native groundwater quality or creating an undesirable effect such as environmental damage." C.W. Fetter, Jr., Applied Hydrogeology (Columbus: Charles E. Merrill, 1980), p. 385.


32. Ibid., p. 274.
I. SUMMARY

Groundwater is plentiful in most parts of British Columbia and meets a significant portion of the province's fresh water needs. However, because present laws allow landowners to make unlimited groundwater withdrawals, supply problems have arisen in some areas of the province. As the population increases and demand for water grows, these problems are likely to become more severe.

A number of groundwater problems which have occurred in British Columbia were reviewed in chapter three. Several problems stem from the physical characteristics of aquifers: certain land uses can either impede recharge or reduce the quality of percolating water; excessive withdrawals of surface water can cause the water table to drop; saltwater may enter coastal aquifers if the water table declines; quality and quantity problems may be very long-term because groundwater moves slowly; and, because data is difficult to obtain, decisions about allocation and use are often made without complete hydrogeologic information.

A second set of groundwater problems results from the economic behaviour of well-owners pumping from a common aquifer. Pumpers tend to over-use groundwater because they do not experience all of the costs associated with their use of the water. In addition, they have little incentive to economize in their use of water because the benefits of reduced consumption by one user may accrue to other users.
From the discussion of these problems, a set of criteria for evaluating alternative groundwater management schemes was developed. The physical problems indicated a need for a management system which a) considers the effect of land use on groundwater supplies; b) coordinates management of surface water and groundwater; c) avoids, rather than just reacts to problems; and d) maintains flexibility when hydrogeologic information is incomplete. The economic problems revealed the importance of e) removing the incentive to overdraft; f) providing some security of supply; and g) allowing groundwater rights to be transferred among users. In addition to these criteria, the feasibility and equity of implementing the various systems in British Columbia were considered.

The evaluation of alternative systems in chapter four showed that none of the systems meets all of the evaluative criteria. Each system has both advantages and deficiencies, and involves some compromise between features such as equity and effectiveness, or administrative feasibility and efficiency. The alternatives are representative of groundwater management in North America to date, and their deficiencies indicate the degree of difficulty inherent in managing the resource.

The following section describes the writer's proposal for managing groundwater in British Columbia. It is an attempt to combine, and expand upon the more successful features of the alternatives reviewed in chapter four. The proposal meets the evaluative criteria to a large extent but requires that some tradeoffs be made among the criteria.
II. A PROPOSED GROUNDWATER MANAGEMENT SYSTEM

A. Preventative Measures

In many areas of British Columbia, groundwater is not a scarce resource and major changes to the allocation mechanism are unnecessary. However, some preventative measures should be taken in order to avoid future groundwater problems. The availability of information about aquifers and about groundwater use is an important factor in avoiding aquifer depletion and well-interference. The quantity and quality of data available to the Water Management Branch could be improved by requiring well-drillers to obtain licences, and to file data with the Water Management Board after drilling wells. In addition, it would be beneficial to replace the common law rule of absolute ownership with the reasonable use doctrine, in order to discourage waste. The British Columbia courts may make this change of their own accord, or it can be legislated.

B. The Allocation Mechanism

In areas where groundwater shortages have occurred, or appear likely to develop, clearly defined groundwater rights should be established and allocated among the well-owners. Under the proposed system, the collective rate of withdrawal and the initial allocation of rights would be determined by the Comptroller of Water Rights. The water rights would then be marketable.

The process would begin when the Lieutenant-Governor-in-Council proclaimed a critical groundwater area. Such a proclamation could originate from either requests by well-owners or advice from the Ministry of Environment. Use of groundwater in the area would then be subject to
regulation.

The Comptroller of Water Rights would conduct a groundwater allocation hearing to hear the evidence of well-owners living in the designated area, and the submissions of any other affected parties. Evidence pertaining to changes in the level and quality of well water, or in landowners' water requirements would supplement the technical data supplied by the Groundwater Section, and thus add to the Comptroller's knowledge of the demand-supply balance.

In arriving at a decision, the Comptroller would first decide upon the collective withdrawal rate. In many cases, this rate would probably approximate the 'safe yield' level in order to conserve ground-water over the long term. After the collective withdrawal rate has been established, the Comptroller can allocate the groundwater among the well-owners. In areas where shortages have not yet developed, all users who appear to be making non-wasteful use of water would be given rights to use groundwater at current rates. Well-owners who had been wasting water (i.e. pumping water but not using it) would receive rights to a reduced share of the water supply. The rights to any remaining withdrawals would be retained by the government for future sale.

In areas where groundwater problems already exist and the collective withdrawal rate must be reduced, well-owners cannot maintain their current levels of use. In many cases, the most equitable approach may be to first disallow any wasteful withdrawals, and then have all non-domestic users reduce their pumping by the same percentage. Priority for domestic water use (drinking, bathing, and basic household uses) is a standard feature of water legislation and should be extended to the province's groundwater.
In some cases, however, most (or all) well-owners may be using water only for domestic purposes. Under such circumstances, all domestic users should be restricted to the same level of pumping.

Once the initial allocation of rights has been made, groundwater rights would be freely transferable. Water users who wish to pump more water than they have been allocated would be able to rent or purchase rights from other users in the area, without renting or buying more land. The Comptroller's approval would only be required if a significant change in the point of withdrawal was to occur. If a prospective buyer's total rights (after the transaction) would exceed a specified level and if he intended to change the location of the well when he purchased the rights, then the approval of the Comptroller would be required. Without this restriction, one user could purchase the rights of several parties and pump the entire share from one well. The new cone of depression created by his actions could adversely affect his neighbours' wells.

C. Other Provisions

Holders of groundwater rights would be charged annual fees which would vary according to the rate of withdrawal allowed under each right. However, the appropriate level for these charges can only be determined after further study. The fees could be set just high enough to cover the administrative costs of the system, or they could be raised to include some economic rent. The higher fees would provide added benefits by increasing awareness of the value of the water and discouraging the holding of unused rights for speculative purposes.

In some cases, the water supply may be overestimated and as a
result, too many rights will be established. Unless corrected, this situation could lead to a lowering of the water table. Under such circumstances, the Comptroller would require each groundwater user to reduce his withdrawal rate by a certain percentage. These across-the-board cutbacks would leave the relative values of the various users' rights intact and should be acceptable to holders of rights if the risk of cutbacks is well-known.

The system described above deals only with groundwater allocations among users, and over time. The discussion of groundwater problems in British Columbia in chapter three showed that it is also necessary to consider the effects of land use and surface water use on groundwater supplies.

The Health Act regulations provide some protection against land uses which may reduce groundwater quality (see chapter two). In addition, the Municipal Act and the Islands Trust Act give local governments limited control over groundwater use. However, in areas where groundwater is subject to regulation, additional protection of the resource could be effected by strengthening the relevant sections of the latter statutes. Therefore, regional districts and the Islands Trust should be required to consult the Groundwater Section when preparing Official Settlement Plans. In addition, they should be required to obtain certification from the Comptroller that proposed developments will not have significant adverse effects on groundwater supplies.

From the point of view of groundwater management, surface water and groundwater should be subject to the same allocation measures. However, a great deal more study would be required to determine what changes to the surface water licensing system are warranted.
Assuming that the present surface water allocation system will be retained, a certain amount of coordination between groundwater and surface water uses would be possible. In situations where conflicts are occurring between surface water and groundwater users, the Comptroller could first divide the water supply into surface water and groundwater shares. The two allocation systems could then be applied. The collective rate of well-pumping would be limited to the groundwater share of the water supply, and surface water licensees could use only the surface water share.

III. EVALUATION OF THE PROPOSAL

The proposed groundwater management system satisfies the evaluative criteria of feasibility, equity, effectiveness, and efficiency to a large extent. The proposal would involve certain administrative costs, and possible problems in establishing the initial rights. However, no new department or agency would be required, nor would the courts be called upon to allocate the rights. The Comptroller of Water Rights has technical support staff who can gather and present the necessary hydrogeologic information. In addition, rights would be introduced gradually (area by area) as allocation decisions are made. This phasing-in of the system would prevent some administrative problems from developing.

Once the proposed system had been implemented, it would function without any significant administrative costs. The Groundwater Section would continue to monitor groundwater supplies, and the Comptroller would sometimes need to order pumping cutbacks. In other respects, however, the groundwater users themselves would operate the system through their transactions.
The proposed system would provide an equitable distribution of costs and benefits among groundwater users. If, when an initial allocation is made, a reduction in the collective withdrawal rate is necessary, then most users would be expected to lower their pumping rates. And, if depletion problems develop after rights are allocated, then all well-owners share in the cutback. Thus, in either situation, the burden of reduced withdrawals is spread among many users.

An equitable distribution of costs and benefits among different generations of well-owners could also be achieved. The Comptroller could set the collective withdrawal rates at 'safe yield' levels in order to conserve groundwater for future users. If these levels were later exceeded, then the provision for the government to cutback groundwater rights would allow the demand-supply balance to be reestablished.

The proposed system would be capable of resolving many of the problems which stem from physical constraints on groundwater use. The current Health Act regulations, supplemented by more stringent land use planning requirements under the Municipal and Islands Trust Acts, provide some protection against land uses which can adversely affect groundwater supplies. The system also allows groundwater and surface water use to be coordinated by having the Comptroller determine the collective usage rates of both water sources.

The proposal includes regulation of the total withdrawals from an aquifer and thus prevents major overdraft problems from occurring. The system is also flexible enough to operate without complete aquifer information because the government can periodically adjust the collective rate of withdrawal by ordering cutbacks or by selling retained rights.
In addition, the proposed requirements that well-drillers file well data, and that owners of high-yield wells register with the WMB will facilitate data collection.

The efficiency of groundwater use would improve if the proposed system were implemented. Regulation of collective withdrawal rates would reduce the incentive to overdraught and thereby eliminate some external costs. The proposal would also provide groundwater users with greater security of supply than they now experience, because rights would only be lost by users who chose to sell them.

Economic efficiency would be further improved by the transferability of groundwater rights. The initial allocations would probably not allocate water to its highest and best uses. However, because rights would be freely transferable, this approach will not restrict allocative efficiency over time. Users can buy and sell rights as their needs change and as new uses develop. Thus, the rights would gradually be transferred to higher and better uses.

The proposed changes in British Columbia's groundwater law would allow allocation problems such as those discussed in chapter three to be resolved. In the Surrey case, if the system had been in place before the large artesian well was drilled, then the owner of the well could only have withdrawn water at such a high rate if he had purchased the rights of several other well-owners. The latter would only have lost their groundwater supplies if they chose to sell their rights.

If the proposed system were introduced after well-interference problems had developed, then all well-owners would have received rights to some withdrawals. If, as in the Surrey case, one user was wasting water, he would not receive rights to the same proportion of his current
use as would other, beneficial users.

In the Trout Hatchery case, the proposed system would have allowed the Hatchery to buy the rights for any additional groundwater it needed for its expansion. The Hatchery would first have purchased any surplus rights held by the government. If additional rights were needed, the Hatchery could have tried to purchase them from Sumas. If an alternative water supply for the town could have been developed at a cost less than the price the Hatchery was willing to pay for the water rights, then Sumas would probably have sold rights to the Hatchery. The transferability of the rights would allow the party which valued the groundwater most highly to use the available supply.

The proposal discussed above meets the evaluative criteria in many respects. However, there are a number of issues which are not dealt with in the evaluation. Some issues cannot be resolved without further study, while others require very subjective decisions best made at a political level.

A critical question which remains to be answered is: at what rate should groundwater be used? Aquifers can be managed on a 'safe yield' basis, or users can be permitted to deplete the water supply over a specified time period. At issue is the extent to which current groundwater users should be favoured over future users. Future resource use benefits have traditionally been discounted, but there are strong counter arguments for resource conservation.

The second outstanding issue is whether it is appropriate to allow the operation of a market based on private ownership of water rights, given that the resource is essential to life. There may be a public
preference for exclusive government regulation of use of all water rights. However, if market operation is accepted, then it is important that safeguards be designed to ensure that the market functions as intended. In particular, measures directed at prevention of monopoly control over groundwater may be necessary.

The proposed system does not deal with the allocation problems created by natural fluctuations in the water table. In some cases, the amount of water which can safely be pumped will vary from season to season, or year to year. Further study is needed to determine whether rights to the average amount of water should be issued, or whether a more conservative approach is warranted.

Finally, the issue of enforcement has not been addressed. The evaluations of the alternative systems, and of the proposal contain the implicit assumption that once a system is implemented, its rules and regulations will be followed by all groundwater users. However, this is not a realistic assumption and consequently, the effectiveness of various controls, fines, and incentives should be assessed.

IV. CONCLUSIONS AND RECOMMENDATIONS

The information presented in this thesis comprises an overview of groundwater use, problems, and management alternatives. From the first three chapters of the thesis, it is evident that there are groundwater problems in British Columbia which are not dealt with by the current laws. It is also clear from the evaluation of alternative systems, that successful programs of groundwater management are very difficult to devise, and that none of the alternatives fulfills all of the evaluative criteria.
The groundwater management system described in this chapter is suggested as a means of improving the use and protection of groundwater in British Columbia. Although the discussion of the proposal indicates a need for further study into several issues, there is sufficient information in the thesis to recommend that the following changes be made to British Columbia's water law:

1. that well-drillers be required to obtain licences and to file well data with the Water Management Branch;
2. that in areas where groundwater is abundant, well-owners retain common law rights but that the reasonable use doctrine replace the doctrine of absolute ownership; and
3. that regional districts and the Islands Trust be required to consult the Groundwater Section when preparing Official Settlement Plans, and to obtain certification from the Comptroller of Water Rights that proposed developments will not have significant adverse effects on groundwater supplies.

It is further recommended that the groundwater allocation mechanism and the associated provisions described in this chapter be considered as an alternative to the current system, but that the following studies first be carried out:

1. A study to determine whether, and at what rate groundwater reservoirs should be depleted. A major part of this study would focus on the consequences of depletion, and the objective would be to establish guidelines for the Comptroller to follow when determining the collective withdrawal rate.
2. A review of possible methods of minimizing market imperfections and, in particular, preventing monopoly control of water rights.

3. A study of the alternative means of dealing with fluctuations in the water table from a water allocation perspective. The objective of the study would be to set guidelines which can be used to establish the quantity of water available for allocation.

4. A review of methods of enforcing allocation decisions, including a survey of metering alternatives and an analysis of the effectiveness of various fines and incentives.
BIBLIOGRAPHY


