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School Of Community And Regional Planning

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Date: April, 1985
ABSTRACT

This thesis develops a conceptual framework that could be used to understand, assess and balance water resources supply and demand in regions where data are limited. The framework is then applied to a case study of Texada Island in British Columbia.

The flow of water into and out of Texada is calculated using the Thornthwaite water balance method which uses average monthly precipitation and monthly daily average temperature data. The stock of surface water is estimated using existing data on lake volumes in conjunction with the results of analyses of air photographs and topographic maps. After the analysis of maps, reports, and interviews with mining personnel regarding the island's geology, likely aquifers were identified and their approximate water storage capacity was calculated. The present rate of water use was determined from interviews with island residents and industry personnel, field observations, analysis of available data and a review of the relevant literature on water demands by different water using sectors. Finally, to determine whether water supplies on the island were adequate to meet future demands, scenarios were constructed for analysing potential water use to 1996 by various water using sectors.

The results of the supply-demand analysis revealed that on an annual and region-wide basis, water on Texada is abundant and will be adequate to meet expected demands to 1996, and likely beyond. However, there are some local areas that currently experience water shortages during the low flow and peak demand
period during the summer months.

The management options that were determined to be the most appropriate solution to summer water shortages are, in the short-term, trucking in water and selective restrictions on water use during the peak demand period. In the medium- to long-term, the diversion of surface water and the development of groundwater are the most appropriate solutions to water shortages on Texada.

Next steps for planning the management of water resources on Texada Island are suggested. The initial and most important of these involves abandoning the ad hoc approach that now exists for dealing with water resources on the island and adopting a strategic, co-operative and co-ordinated approach involving residents and to a lesser extent, the Powell River Regional District, of which Texada is a part.
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CHAPTER 1
WATER RESOURCES PLANNING AND MANAGEMENT:
AN INTRODUCTION

1.1 THE PROBLEM

The ultimate task of water resources planning and management is the balancing of supply and demand. A supply of water can be considered in terms of its location, its place in time, its quantity and its quality. Similarly, water is demanded at a particular location, at a specific time, in various quantities and of a certain quality. The matching of water supply with water demand requires consideration of each of these properties. However, there are a variety of difficulties facing the analysis and management of water resources, particularly in rural areas and areas that rely on small fragmented watersheds. Such areas frequently lack data upon which to base an analysis or make a decision with respect to their water resources. This thesis develops a framework for understanding, assessing and balancing water resource supply and demand in such areas, and applies this framework to a case study of Texada Island (see Figure 1.1).

Water resource availability in a region is a function of the quantity, timing and distribution of precipitation and of the above and below ground storage potential. On the islands in Georgia Strait, the relationship between water resource availability and precipitation is much closer than in Mainland settings due to the small size of these islands which act to limit their storage capacity. This suggests that it is important that the communities on these islands bring a greater
consideration of the role, potential and limits of water resources into their overall development planning process in order to avoid either a lack of adequately developed supplies or overbuilding of supply facilities, which frequently leads to overuse and eventual exhaustion of supplies. However, the analysis and management of water resources in rural areas is frequently constrained by insufficient meteorologic, hydrologic and water demand data. The collection of such data over time is necessary in gaining a reasonably accurate picture of the behaviour of a region's hydrologic system. However, the collection of data is both costly and time consuming. Rural communities frequently lack the funds to finance the collection of such data and, increasingly, they no longer can afford the luxury of waiting until sufficient data becomes available -- they must act now to ensure the existence of adequately developed water supplies in the future. This thesis, by focusing its analysis on Texada Island, provides an example of analysing water resource supply and demand in areas where data and finances are limited.

1.2 THE CONTEXT

There are many small islands along the coast of British Columbia, the majority of which, like Texada, are rural. The scenic rural islands located in the Strait of Georgia are within relatively easy reach of the large metropolitan populations in southwestern B.C. and northwestern Washington State. The rapid population growth in the Capital and Greater Vancouver Regional Districts during the 60's and 70's exposed these islands to
ever-increasing urbanization pressures. These pressures have included subdivision and summer home development and expansion of the transportation network (e.g. highways, ferries, and marinas). These and other pressures have awakened concerns about the effects such actions are having on the limited resource bases of these islands -- particularly the water resource base. Even now, with the rapid development of recreational homes, some of these islands are facing the threat of contaminated well water due to septic tank run-off or the contamination of surface sources because of inappropriate activities occurring in water supply watersheds.¹ In some cases, groundwater withdrawal rates have exceeded recharge rates in areas where fresh groundwater interfaces with briny groundwater. This has led to the intrusion of salt water into wells in areas so affected.²

Texada Island itself is situated in the Strait of Georgia, 8 kilometers southwest of Powell River which is located on the mainland of British Columbia. The island, although one of the largest in the Strait, is sparsely settled. However, Texada historically has supported forestry and, unlike the other islands in the Strait, mining activities. Mining continues to be the mainstay of the island's economy. Summer home development has occurred to some degree; however, Texada's distance from the metropolitan region to the south has served to diminish its attractiveness for cottagers from Vancouver and Victoria. This has begun to change however, as opportunities for summer home development nearer to the southern market have decreased and people have begun to look further afield to the islands in the mid to northern part of Georgia Strait.
In 1982, a proposal to put garbage from Greater Vancouver in one of the abandoned limestone quarries on Texada raised concerns amongst island residents about the effect such an action would have on the groundwater resource. Historically, planning has been viewed rather suspiciously by island residents. Consequently, development has been allowed to occur in a rather ad hoc manner. However, with this newest threat to their way of life island residents have begun to feel the need to identify their desires and to establish these desires in a plan for Texada. The concern about the threat to the groundwater resource having enlivened residents to get involved in planning for the island, has stimulated a particular interest in the overall state of the water resources on Texada. As a consequence, Texada residents sought out help from the Westwater Research Centre at U.B.C. which has resulted in the writing of this graduate thesis.

1.3 THE APPROACH

Given the difficulties associated with the assessment and management of water resources supply and demand on small islands and in rural areas and the need to bring the consideration of water resources into the overall planning process in these areas, this thesis will

(1) Provide a framework for understanding and assessing water resource supply (Chapter 2) and demand (Chapter 3) in rural regions {PART I},

(2) Apply this framework to the case of Texada Island {PART II} providing an assessment of:
   - both natural and developed water
supplies (Chapter 4);
- the demand for water both in the present and in the future (Chapter 5);
- the limits of the water resource base and the identification of areas on the island where demands are or will be nearing the limits of developed supply (Chapters 5 and 6);
- alternative ways of balancing water supply and demand and the factors, of importance on Texada, to be taken into account when evaluating these alternatives (Chapter 6).

(3) Suggest some next steps to be taken in the planning and management of water resource supply and demand on Texada Island (Chapter 7).

The methods used in researching the thesis consisted of:

(1) A review of the literature on the physical-biological aspects of water resources.

(2) A review of the literature dealing with man’s development and use of water resources.

(3) An examination of reports and files concerned with the geology and water resources of Texada Island.

(4) Field observations and interviews with residents and industry representatives on Texada about the water resource situation on the island.

(5) Analysis of the above and the construction of scenarios to test the sensitivity of estimated supply to changes in the island’s water demand.

We will turn now to PART I and the development of a conceptual framework for examining water resources supply and demand.
PART I
THEORY AND CONCEPTUAL FRAMEWORK

The ultimate task of water resources planning and management is balancing the supply of water resources with the demands for their utilization. This task can often be accomplished in a variety of ways. The aim of the next two chapters is to develop a general framework for examining the issues and alternatives related to planning and management of water resources. Every region is different from every other region in terms of its biophysical characteristics, level of socio-economic activity, rate and character of economic change. These differences have implications for the approaches taken and the alternatives generated for the planning and management of water resources. In Part I, the concepts of supply and demand as they apply to water resources will form the pillars of the analytical framework. In Part II, this framework will be used to specifically examine the water resources planning and management task on Texada Island.
CHAPTER 2
A FRAMEWORK FOR ANALYSING
WATER SUPPLY

INTRODUCTION

This chapter will provide a framework for understanding, analysing, and managing the water supply in a region, and where appropriate to the analysis of the water resources on Texada, will discuss some of the peculiar issues that arise in island environments.

There are many aspects related to the supply of water in a region. These include where, when, of what quality, and how much is available naturally as compared to how much is the result of man's development of supplies on the island. In this chapter we will first consider the concepts and components associated with the natural water supply before moving on to examine the ways man, in various contexts, adapts and develops supplies to suit his purposes.

2.1 THE NATURAL WATER SUPPLY IN A REGION

2.1.1 Water

In this section we will briefly review some basic concepts about the hydrologic cycle, the water balance, salt and fresh water relationships on islands, and the importance of water to island environments.

(1) The Hydrologic Cycle

By definition an island is completely surrounded by water. But unless the island is situated within a large lake it will
nevertheless possess a limited quantity of fresh water. However, this water is always being renewed as it is continuously moving through the hydrologic cycle which "links up all parts of the hydrosphere -- the seas, lakes, and streams, groundwater, soil moisture, atmospheric vapour -- into a single whole" (see Figure 2.1).

The ocean is the Earth's main reservoir of water. Water from the ocean evaporates into the atmosphere where it eventually condenses and falls on the land as precipitation. Precipitation may fall directly into lakes, or into streams draining the land. Alternatively, precipitation may fall directly on the ground where it may infiltrate the soil and recharges the groundwater or, if the infiltration capacity of the soil has been reached, the precipitation may run overland flowing into lakes and streams or directly into the ocean.

(2) The Water Balance

Figure 2.2 is a schematic of Figure 2.1 and is useful in that it distinguishes between stocks (storage) of water and flows of water. While both flows and stocks of water are in reality flows, the renewal times for stocks, while highly variable, do tend to be longer (see Table 2.1).

Stocks of water (the rectangles in the diagram) are where the water is stored either for short periods of time, as in conveyance channels, or for long periods in the case of deep groundwater storage. Later in the thesis, in the examination of the case study area, Figure 2.2 will form the basis of the analysis of water supply (stocks and naturally occurring inflows and outflows) and water demand (outflows generated by the human
FIGURE 2.1: THE HYDROLOGIC CYCLE OF AN ISLAND

- Condensation
- Precipitation
- Infiltration
- Unsaturated zone
- Saturated zone
- Fresh groundwater
- Salt or briny groundwater
- Evaporation in falling
- Transpiration and evaporation from vegetation
- Evaporation from the soil
- Evaporation from lakes, rivers
- Runoff
- Water table
- Moist air mass
- Evaporation from oceans
- Ocean
FIGURE 2.2: SYSTEMS REPRESENTATION OF THE HYDROLOGIC CYCLE AND THE INTERACTION WITH THE HUMAN USE SYSTEM

SOURCE: Adapted from Freeze and Cherry (1979), p.4.
TABLE 2.1: RATES OF WATER EXCHANGE

<table>
<thead>
<tr>
<th>Section of the Hydrosphere</th>
<th>Years Required for Complete Renewal **</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Ocean</td>
<td>3000</td>
</tr>
<tr>
<td>Groundwater</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>(5000)</td>
</tr>
<tr>
<td>Zones of more active exchange</td>
<td>(330)</td>
</tr>
<tr>
<td>Polar Glaciers</td>
<td>8300</td>
</tr>
<tr>
<td>Lakes</td>
<td>10</td>
</tr>
<tr>
<td>Soil Moisture</td>
<td>1.0</td>
</tr>
<tr>
<td>Rivers</td>
<td>0.033</td>
</tr>
<tr>
<td>Atmospheric Vapour</td>
<td>0.027</td>
</tr>
</tbody>
</table>

** Bracketed figures are highly approximate.

Flows of water, particularly outflows and inflows of water (the circles in the diagram), are inputs and outputs from the natural water supply system. The flow of water into the system, that is precipitation, and the flows out of the system, namely evaporation and runoff, balance with each other over the long-term. If, for example in the short-term, say 1985, inputs into the system (precipitation) were less than the combined output from the system (evapotranspiration and runoff), then stocks of water would decline even in the absence of a human use system (demand outflows). However, if in the following year precipitation exceeded evapotranspiration and runoff, then stocks would be replenished and any excess would runoff to the sea. Over the long-term the natural water supply system on an island will balance out in this way. In the analysis of the natural supply of water in the case study area, an attempt will be made to determine the average rates of water inflow and outflow for Texada using the Thornthwaite water balance method. Further discussion of this method will occur in Chapter 4.

(3) Salt and Fresh Water Relationships on Islands.

An island's water resources are significantly affected by their proximity to the sea and by the movement of the tides. Figure 2.3 shows an idealized diagram of the relationship between salt and fresh groundwater on an island. Fresh water is less dense than salt water and consequently 'floats' on the top of the salt water such that it forms a downward facing convex lens. Theoretically, there is an interface of fresh and salt water with brackish water in between. However, the interface
FIGURE 2.4: A more realistic example of the relationships between salt and fresh water on an island. A karstic island showing pockets of fresh groundwater surrounded by salt water.

zone is not necessarily as continuous as depicted in Figure 2.3 for all islands. For example, on karstic islands insulated pockets of fresh water floating on salt may be found inland (see Figure 2.4). The often indefinite knowledge we have of groundwater resources in Mailand environments, is made even more uncertain when considering the groundwater resources of small islands.

2.1.2 Factors Affecting Natural Water Supply

There are several factors that influence the location, timing, quantity and quality of water resources including climate, vegetation, topography, and geology.

(1) Location and Climate

The location of a region on the Earth and in relation to other land masses influences the type of climate it possesses and therefore the timing and quantity of precipitation the area receives. In more specific terms, islands along the south coast of British Columbia have marine west-coast climates, experience a dry season in the summer, and normally do not experience extremes of temperature. Islands immediately east of southern Vancouver Island experience a slight rainshadow effect due to their position relative to the high mountains on the Olympic Peninsula and therefore receive less precipitation than islands just west of Powell River and the Sechelt Peninsula (see Figure 2.5).

(2) Vegetation

Climate is a significant determinant of the vegetation.
Note that precipitation decreases as one moves south-eastward. The islands in the Strait of Georgia receive as much as 50% less precipitation than some coastal areas nearby on the Mainland. Obviously this is significant in terms of the quantities of water available on these islands.

**SOURCE:** The pattern of isohyets on the map were derived from precipitation data for selected places in the Georgia Strait Region taken from *Canadian Climate Normals 1951 - 1980: Temperature and Precipitation — British Columbia* (1982).
Vegetation in turn influences the natural supply of water. For example, a forested watershed will transpire more than the same watershed covered in grasses. Studies have demonstrated that the removal of vegetation from a watershed increases the available supply of water. This occurs because vegetation once removed no longer draws water from the soil and transpires it to the atmosphere so that water either remains in the ground or flows overland into lakes and streams. However, removal of vegetation from a watershed decrease the ability of the watershed to absorb and store water. Consequently, during the dry summer months, runoff is less available because much of the water will have runoff during or immediately after a rainfall event.

(3) Topography

The topography of a region is influenced by and influences the natural supply of water available. Water is a powerful agent in the shaping of landforms, but more importantly the effect of topography is to increase precipitation with altitude. On islands, topography also helps determine how well the island is drained. For example, an island of low relief with numerous depressions and with few outlets to the surrounding sea would likely have lakes and swamps dotting the landscape and a groundwater table very close to the surface. In contrast an island of much greater relief (i.e. one that rises almost straight out of the sea) and which has very few depressions with outlets to the sea would likely have fewer swamps and a less accessible groundwater source (i.e. a deeper groundwater table).
(4) Geology

The geology of a region influences the storage capacity for groundwater. Rocks vary in terms of their porosity and permeability. Impervious and impermeable metamorphic and plutonic igneous rock generally yield low volumes of water unless their formations have been significantly fractured and weathered. The largest yields of water are from rocks such as limestones, dolomites, and calcites. Water circulating in carbonate formations reacts with the minerals in the rocks eroding them and enlarging existing fractures. The geology of an island has significant implications for the water resources on the island. Islands composed of porous and moderately permeable rock formations such as sandstone and porous non-karstic limestone, for example Barbados and Malta, would have significant groundwater storage. The Pacific Atolls, composed of low-lying limestone, have very limited groundwater storage, while the larger raised atolls of low-lying limestone, such as the Caymans and the Bahamas, have moderate storage capacity. The geology of a small island is significant because "due to the limited storage possibilities, the relationship between rainfall and water resources availability is much closer" on an island than in Mainland environments.

Geology also affects the quality of water on an island. Davis and DeWeist (1966) note that:

Very high pH values, that is above 8.5, are usually associated with sodium-carbonate-bicarbonate waters. Moderately high pH values are commonly associated with water high in bicarbonate. Very low pH values, that is below 4.0, are associated with waters containing free acids derived from oxidizing sulfide minerals, usually pyrite, or from water in
contact with volcanic gases containing hydrogen sulfide, hydrochloric acid, and other volatiles.\textsuperscript{14}

Total dissolved solids is another measure of water quality that may be linked to geology. Specific ion concentrations, such as calcium, iron, or chlorides found in water are indicative of the geologic nature of the surrounding region.

2.2 DEVELOPMENT AND MANAGEMENT OF WATER SUPPLIES

Man in using water must operate within the hydrologic cycle.\textsuperscript{15} However, water moves through the different stages of the cycle at various rates and at varying times and locations. As a result man reshapes the hydrologic cycle so that it will supply him with the quality and quantity of water when and where he wants it. In this section we will examine ways of developing the natural supplies of water in a region. There are essentially three categories of options for developing or improving the efficiency of water supply systems, and they are: augmenting supply, improving system efficiency, and planned reuse of wastewater.

2.2.1 Augmenting Supply

The alternatives for augmenting water supply include: the diversion of surface water, the development of groundwater, conjunctive use, trucking in water, the collection of precipitation, and the distillation of salt water (appropriate to coastal areas and islands).

(1) The Diversion of Surface Water
Surface waters, while they exist on islands of favourable topography, tend to be fragmented into a number of small drainage basins which makes assessment and development of surface supplies expensive. Typically spring-fed lakes and streams supply a community's water via gravity systems regulated by small storage dams. In regions where energy is scarce, water for gravity fed water supply systems may be pre-empted for use in the generation of hydro-electric power. However, depending on the physical and hydrological characteristics of the watershed, it may be possible to integrate the use of water for water supply and for hydro power generation.

The small size of drainage basins in some regions and on many islands, limits the water supply capacity of one basin. As demand rises it may be necessary to develop other basins farther away. The higher per unit construction costs of smaller storage dams combined with increasing distances and costs of transferring the water adds to the costs of surface water supply developments in rural regions.

(2) The Development of Groundwater

There are several features that make the development of groundwater supplies attractive, yet such development on islands has to take into account the uncertainties associated with island groundwater resources which were discussed in the last section. An attractive feature in the exploitation of groundwater is the elimination of the need to construct costly storage reservoirs due to the natural reservoir afforded by the ground. Small-scale pumping facilities in many locations allow increments in supply to match increments in demand. This feature
avoids the problem of large 'up-front' capital expenditures and the possibiltiy of long-term underutilization of equipment. The nature of groundwater often allows for its development at or near the point of demand thereby eliminating high transmission costs. Finally, because water has been collecting in the ground for millennia and remains largely untapped in many regions, it could sustain exploitation in excess of recharge, depending on the size and density aspects of demand, over a potentially long period of time. On islands, the development of groundwater resources is appropriate to those that are likely to possess adequate groundwater resources (e.g. non-karstic limestone -- Barbados), a dispersed population, an economy that could not support the development of more costly water supply facilities than those required for groundwater developments (i.e rural areas).

There are many difficulties associated with the development of groundwater supplies in rural areas. In the previous section we discussed the lack of knowledge of groundwater and the uncertainty associated with the behaviour of island groundwater resources. These uncertainties add to the costs of predicting the location of groundwater supplies and to the costs and risks of developing the resource.

In island environments, pumping equipment is susceptible to corrosion. This factor and the frequent isolation of islands many rural regions adds to the costs of maintaining equipment. The exploitation of groundwater in coastal regions can lead to salt water intrusion where greater population densities or economic activity result in overpumping of the fresh water lens
allowing salt water to creep into the wells. Overpumping can also contribute to land subsidence and, in some cases, the drying up of surface waters fed by groundwater. Groundwater has a slower renewal rate than water in other stages of the hydrologic cycle. This is particularly true of deeper reservoirs. Consequently, groundwater resources, particularly in the fragile environments of small islands, face greater risk of pollution and irreversible contamination than surface waters which have a shorter renewal time.²⁰

(3) Conjunctive Use

Conjunctive use involves the integration of ground and surface water supplies into a single water supply system.²¹ The water stored in the ground is used to augment supplies during periods of low surface yields thereby reducing the uncertainty in predicting supplies.²² By co-ordinating the use of surface and groundwater resources for domestic and agricultural uses, "the strength of each overcomes the weaknesses of both".²³ In island environments where the knowledge of where the margins are is critical to ensuring adequate supplies of water, the conjunctive use approach is an attractive option for balancing water supply and demand.

(4) Trucking In Water

Trucking in water refers to the transport of water, by human or mechanical means, from a source of supply, whether natural of developed, to the location of demand. Most often water conveyed in this way is used for domestic or agricultural purposes.
Trucking in water usually occurs in rural and remote areas where water supplied to the home by more sophisticated means is interrupted for one reason or another (e.g. drought). This activity usually involves literally trucking water in using tankers, or individuals filling up containers and transporting them home by car. While trucking in water is a primitive means of water supply, in many areas in the developed world where water quality is poor, many individuals purchase bottled water for their cooking and drinking needs. The purchase of bottled water reflects the level of sophistication that has been reached in supplying water utilizing the method of trucking in water.

(5) Rainwater Collection

The collection of rainwater is the major source of water supply on low-lying islands and islands of small areal extent such as the coralline atolls of the Pacific, as well as being an important source of water supply for sparsely populated rural areas where groundwater is too expensive to develop.\(^2\) On some of the small south coastal islands of British Columbia rainwater, collected and stored during the wet winter months, is used in conjunction with other sources during the peak demand and dry summer season (e.g. parts of Keats Island rely on this method to supplement groundwater supplies during dry summers). While the collection and storage of rainwater can be an efficient and economical way of supplying water for domestic purposes, water stored for long periods can give rise to environmental and health risks.\(^2\)

(6) Desalinization
While large-scale technology for the desalinization of salt water continues to improve, it remains a capital- and energy-intensive means of supplying fresh water in coastal regions. Large-scale desalinization is appropriate for coastal regions with limited groundwater resources, whose economy can support the costs of desalinization and where there is a peaking of demand caused by a seasonal influx of tourists. Islands that have employed large-scale desalinization technology to supply fresh water include Aruba and Curacao in the Caribbean and Guernsey in the Channel Islands. In Guernsey, desalinization is used primarily during the summer holiday season to supplement or 'top off' supplies.

2.2.2 Improve System Efficiency

While augmenting supply has typically been the first choice solution to inadequacies in developed water supplies in the past, the growing lack of alternative sources of supply and associated increased costs has made the economics of improving existing water system efficiencies more and more attractive. The following paragraphs examine three ways of improving water system efficiency.

(1) Reduction of Evaporation and Reservoir Seepage.

Losses of water from reservoirs due to evaporation can be significant, particularly in arid regions. In addition to the costly losses of water, evaporation also acts to reduce the quality of water in the reservoir by concentrating salts and contaminants in the remaining water. Because the rate of evaporation from a reservoir is a function of water temperature,
wind speed, reservoir geometry, incident solar energy, air
temperature, and relative humidity, methods which act to modify
these factors could be useful in reducing evaporation. If a
suitable geologic formation is nearby, then transferring water
from the reservoir to the groundwater storage is one way, albeit
expensive, of reducing losses due to evaporation. Changing the
geometry of the reservoir by making it deeper can also reduce
evaporation, but this also is expensive. Generally speaking,
once a reservoir is constructed the options for reducing
evaporative losses are expensive and seldom economically
feasible except in arid regions where evaporative losses are
extreme. Consequently, concerns about losses of water due to
evaporation are best dealt with prior to the construction of
reservoirs.

During the siting of a reservoir, the permeability of the
surrounding soils and geology is taken into account. However, if
losses due to seepage from a reservoir are costly enough, then
lining the reservoir may be one option for reducing such losses.
Again, such a solution would require that losses due to seepage
be considerable. Therefore it is perhaps best to avoid such a
solution by careful study of the permeability of the site prior
to construction of a reservoir.

(2) Reduction of Leakages From The System

It is not unusual for a water distribution system to lose
or be unable to account for an average of 15 percent of the
water sent into the system. In older systems water lost from
the system can account for over 50 percent of the water
originally sent into the distribution system. Much of this lost
water is due to leaks in the system. While locating and repairing such leaks can be costly, "it has been shown that even at very modest costs of water, it pays to repair large leaks".\textsuperscript{30}

(3) Land Use Changes

Changes to the land use in a watershed or over an aquifer can influence the quality and quantity of water available. For example, clear cutting a portion of a watershed can lead to increased water yields just as manipulation of land over an aquifer recharge area can increase permeability of the overlying geologic structure and so increase the recharge rate.\textsuperscript{31} However, while clear cutting of a watershed may increase water yields, it can also promote erosion and speed up the sedimentation of downstream reservoirs. Land use and water supply management are inextricably linked.

Studies done in Oregon, where the principle tree species is the Douglas fir, have shown that when a watershed is completely deforested, then the increase in annual water yield will be between 20 and 40 percent in the initial years after a clearcut.\textsuperscript{32} However, as noted earlier, such an action also affects the timing and the magnitude of runoff throughout the year.

2.2.3 Planned Reuse

Planned reuse of water, where the wastewater (sewage) from one or several uses is collected and treated so as to be fit for reuse in other applications, is another alternative for the development and management of water resources in a region. While the concept of reuse has attractive features for the
self-contained environments of small islands, the concerns relating to public health, economic feasibility and public acceptance, remain imposing difficulties. While studies have revealed that no adverse health effects have occurred from the use of reused water in domestic supplies, knowledge relating to the control of viruses and bacteria in reused water is uncertain. In addition, little information exists concerning the longer term threats posed by the presence in reused water of heavy metals and organochlorine compounds which are known to be carcinogenic. Clearly, until such time as the risk to the public health of the utilization of reused water for potable supply are better understood, caution will be required in determining the suitability of this means of developing supply in a region.

The economics of reused water is very much a function of the water supply and demand (i.e. use) situation in the region. Regions with growing populations and economies, and with increasingly scarce conventional sources, will find the economics of reuse more and more attractive, particularly for use in activities that do not require high quality water. Reused water can be directed through a series of uses treated or untreated from one process to another such as occurs in some industrial applications. In other situations wastewater can be collected and treated and the resulting effluent can be used in a variety of uses ranging from irrigation to aquifer recharge. Where effluent standards are high such that substantial treatment of wastewater is required prior to discharge, the cost of the additional treatment to prepare the water for reuse as
potable supply is reduced. In such cases the reuse alternative may become more attractive than the development of other, increasingly scarce and costly alternatives. Of course in regions where wastewater treatment consists of no treatment, primary treatment or involves the use of septic tanks, such as in rural areas, planned reuse of wastewater is unlikely to occur except perhaps in some industrial processes.

With respect to the public acceptance of reused water in municipal supplies only time and better information will ensure widespread willing acceptance. However, it should be noted that unplanned reuse in some situations now reaches as high as one-fifth of municipal water supply.  

SUMMARY

The purpose of this chapter has been to provide a broad framework for understanding natural and developed water supplies in rural regions and, where appropriate to the case study of Texada Island, in island environments. Initially a framework for understanding the characteriscs of the natural water supplies was discussed. This included a review of the hydrologic cycle; some introductory comments on the water balance in a region; and a comparison of the theoretical with the actual relationship between salt and fresh groundwater on islands. These ideas will be picked up in Chapter 4 and will be developed in terms of the analysis of water supply on Texada Island.

The second section of this chapter has provided a context for understanding the development and management of water supplies to serve man's needs. There are three classes of options for increasing water supply and they are options that
augment supply, options that improve water system efficiency and so increase the supply of water through the system, and the planned reuse option which obtains additional use out of the same unit of water. Further discussion of these options will take place in Chapter 6 where their applicability to Texada will be examined.

In the next chapter we will examine the demand side of the water supply-demand balance.
CHAPTER 3
A FRAMEWORK FOR ANALYSING
WATER DEMAND

INTRODUCTION

From an economic viewpoint the term 'water demand' means "the amount of water or water-related services that would be used at any given price". Studies have indicated that above the minimum requirements for drinking, cooking, and personal hygiene water demand, like demand for consumer goods and services, decreases as the price increases. Frequently, particularly in rural areas, water pricing policies are either absent or do not accurately reflect the actual cost of the delivered water. Consequently, here in North America legislation and institutions have evolved to ensure its equitable and efficient use. Management of water supplies and demands using the allocative systems that have evolved on this continent require knowledge of the determinants of water supply and demand. The determinants of supply were discussed in the previous chapter and in this chapter the issues relating to demand will be discussed.

3.1 CONCEPTS IN THE ANALYSIS OF WATER DEMAND

There are some difficulties in identifying water demand. Demand for water is a derived demand meaning that since water is a factor in the production of many products demanded by the consumer, water demand will vary as demands for various products change. Water quality is intimately linked to water demand. Therefore factors affecting the quality of water can influence
the quantity demanded by water users. Another difficulty in identifying water demand is the distinction drawn between water withdrawal and water consumption and what this means in terms of the total quantity of water available.³

3.1.1 Classifying Water Demand

In the sections that follow the various ways water demand is classified will be discussed. Figure 3.1 offers a simple picture of the various concepts associated with water demand.

(1) Withdrawal, Flow and On-site Uses

Withdrawal use refers to the actual removal of water from the ground, lake or stream as typically occurs when water is used for domestic (municipal), irrigation, or industrial purposes. Flow use of the water does not involve withdrawal, but rather use of the water as it flows "in a designated channel".⁴ Examples of flow uses of water include hydro-electric power generation, some forms of water-based recreation, navigation and waste assimilation. On-site use occurs when water is used where it is found -- for example the use of water to maintain whole ecosystems for wildlife habitat.

(2) Consumptive and Non-consumptive Uses

A second way of classifying water demand involves separating uses into consumptive and non-consumptive uses. Sewell and Bower (1968) define consumptive use of a water resource as

that fraction of the water intake or diversion that is not returned to the original or some other water course such that it can be used by other users at other points in time and space.⁵
FIGURE 3.1: DIAGRAM ILLUSTRATING THE CONCEPTS OF WATER DEMAND
Examples of consumptive uses include that portion of water used in irrigation that has evaporated or been transpired, or water that has been used in industry for cooling purposes and has evaporated. An upstream user of water is said to be exposing downstream users to a negative externality if, by using the water in any way, he reduces the quantity or quality of the water available to downstream users such that they have to restore the water to its original state prior to their own use of the resource. A non-consumptive use of water permits the use of water for a simultaneous or subsequent use because a non-consumptive use does not affect the quantity, quality, time or space characteristics of the water resource. Examples of such uses include hydro power generation, recreation, navigation, and fisheries. However, these definitions cannot be rigidly applied because there are few uses of water that do not affect its quality, quantity, timing or location in some way.

(3) Sectoral Uses

Finally, the third way of classifying water demand, and the way that will be loosely followed in this thesis, is according to the use to which it is put, that is domestic, industrial, agricultural, recreational, power generation, navigation, or ecosystem uses. However, in adopting this classification it is necessary to keep in mind that the various uses for water resources can occur simultaneously, sequentially or may involve recycling. Therefore the total amount of water required on an island "is not necessarily equal to the sum of individual demands".⁶
3.1.2 Forecasting Demand

In the last chapter the critical factor in the management of water supply in a region was identified as being the reliable assessment of the water resource potential. Critical to the management of water demand is the estimation of current use and the projection of future uses. In remote rural areas or on islands the occurrence of extreme water shortages can lead to serious impacts on health and in some cases even survival; whereas in urban areas economic impacts are the chief concern. In the paragraphs that follow the issues surrounding water demand forecasting will be discussed.

(1) The Requirements Approach

A traditional method of estimating future use for water is the requirements approach. In this approach water use is considered in aggregate terms, that is quantity per capita or per unit of production, and then aggregate demand is extrapolated from the past into the future. The relationship between a unit of output and a quantity of water as a factor in its production is treated as fixed. Similarly, per capita requirements for water are also considered as fixed. In the requirements approach improvements in technology, increased use efficiency, and changes to policies directly or indirectly affecting water use are not taken into account.

(2) More Recent Approaches

More recent methods of forecasting water demand include techniques involving the development of alternative scenarios, multiple regression techniques, and methods based on the
prediction of demand function changes, that is changes in the variables affecting water demand. There are some general characteristics incorporated into all these methods. All of these techniques assume that a functional relationship exists between the "demand for water for any given use" and "(1) population; (2) nature of the economy; (3) technology; (4) social tastes; and (5) policy decisions". Other factors affecting water demand, such as climate and the characteristics of the biophysical system can also be incorporated into these more sophisticated forecasting methods. Generally speaking the following sequence of steps, as outlined in Sewell and Bower (1968), would be part of a sophisticated water demand forecast for a region:

1. An economic base study forecasting activity levels for large sectors of the economy (e.g. pulp and paper, food processing, government, etc.);
2. Identification of variables relevant to each demand sector (user group) and analysis of trends over time (development of historical coefficients);
3. Analysis of alternative ways of meeting demand involving a preliminary system design and costing;
4. Comparison of demand and supply examining financial constraints and pricing policy options;
5. Detailed forecasts of water demands for municipal, industrial, irrigation, recreational and in-stream and flow uses of the water resource.

Although seemingly straight-forward, demand forecasts for water are afflicted by uncertainty. Specifically, water demand forecasts are subject to uncertainty related to

1. natural hydrologic phenomena, which affect the
availability of water resources;

(2) inadequate hydrologic, economic, social, and environmental data;

(3) an ill-defined concept of the future, which tends to increase when the forecast period is increased;

(4) incomplete understanding of the natural, technologic and economic factors influencing resource problems;

(5) imperfect models for analysis of water resources problems.9

However, the affects of uncertainty on forecasts can be dealt with somewhat by identifying areas where uncertainty exists, the origins of uncertainty, the kinds of uncertainty, and by including the uncertainty in the analysis and in the solution.10 This approach forms a sophisticated framework for analysing water use patterns in a region. Because the data required to implement these sophisticated approaches are frequently unavailable, particularly in rural areas, assumptions are frequently made which form the basis for decisions concerning the policies and technical measures most appropriate to managing water requirements in the future.11

3.2 WATER USE

Recall that in Figure 2.2, the schematic of the hydrologic cycle, that one box in the diagram referred to the human demand use system. Figure 3.2 is an expansion of that box and depicts the various human uses for water. This diagram or a variation of it will reappear again in Chapter 5. In each of the sections that follow we will examine all the different uses of water in terms of the factors affecting them and the assumptions that can
FIGURE 3.2: THE WATER DEMANDING SECTORS OF HUMAN USE SYSTEM

- Domestic
- Residential
- Commercial
- Public Uses
- Navigation & Floatation
- Industrial
- Agricultural
- Hydro-Electric Power Generation
- Recreation
be made about their use.

3.2.1 Domestic Use

Considering water use on a global scale, domestic uses are broadly defined to include water for drinking, cooking, personal hygiene and a sense of well-being. Domestic or municipal use, as it is frequently called, includes residential, commercial, and public uses (e.g. fire protection, street cleaning, sprinkling of public parks and water supply to public buildings).

The quantity of water used for domestic purposes varies with the standard of living, climate, culture, and the technology and efficiency of the water delivery system. Because supply systems in North America seldom provide water only for household use but also service industrial, commercial and public uses, the determination of quantities of water used for domestic purposes (used in the strictest sense) is difficult. In terms of total supply, the quantities of water used for these other purposes varies greatly depending on the standard of living, the mix of uses being supplied, and the level of economic activity present.

The quantity of water used by households varies with the technology of the water delivery system. For example, household connections used in urban areas and many rural areas designed to supply 100-350 litres per capita daily. Within individual households the number of faucets influences the quantity of water used for domestic purposes. Households with a single tap, such as might be found in isolated rural areas, use between 20 and 25 litres of water per person daily. In contrast, multiple
tap households in middle-class urban areas use anywhere from 30 to over 300 litres of water per person daily. The wide range of water use evident within these groups is related to the personal habits of individuals within the household, their standard of living and in some cases whether they are living in a rural or urban environment. As standards of living increase so do access to and use of water demanding appliances and the use of water for lawn and garden sprinkling. For upper- and middle-class households, watering the lawn can account for up to 50 percent of total household use.

While the quantities of water required for domestic purposes vary from household to household, the quality required for domestic use is high due to concerns relating to human health. As a minimum, water used for domestic purposes is required to be free of toxic substances and pathogenic organisms. In addition, domestic water is required to be colourless and odour-free, have a near neutral pH level, and have low levels of dissolved solids (mineralization). However, water of this high quality is not always consistently available in many parts of the world. Waste disposal methods in rural areas are frequently inadequate, leading to the contamination of ground and surface water supplies (see Tables 3.1).

In rural areas, aside from the traditional threats to water supplies posed by inadequate disposal of human wastes, increasingly over the last decade there have arisen threats from persistently toxic and carcinogenic substances which have somehow contaminated surface and ground waters. Frequently, this has occurred due to improper dumping and landfill procedures or
<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>APPLICATION</th>
<th>DIFFICULTY OF CONSTRUCTION</th>
<th>COST OF CONSTRUCTION</th>
<th>HYGIENE</th>
<th>WATER DEMAND</th>
</tr>
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<td>Pit Latrine</td>
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<td>low</td>
<td>high</td>
<td>poor</td>
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<tr>
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<td>skilled labour needed</td>
<td>medium</td>
<td>high</td>
<td>moderate</td>
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<tr>
<td>Aqua-privies</td>
<td>anywhere</td>
<td>skilled labour needed</td>
<td>high</td>
<td>low</td>
<td>good</td>
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<td>high density areas</td>
<td>skilled designer and labour needed</td>
<td>very high</td>
<td>moderate</td>
<td>very good</td>
</tr>
</tbody>
</table>

**SOURCE:** Derived from Table in H.J. Popel, "Sanitation Technology for Rural Areas in Developing Countries," Appropriate Technology For Developing Countries, 1982, p. 244.
excessive use of pesticides and fertilizers. There is growing recognition of the need for greater care to be taken in ensuring domestic water supplies are protected from contamination due to poor waste disposal methods.\textsuperscript{17}

3.2.2 Industrial Use

Water for industrial purposes is used for: "cooling; processing; boiler water; and general purposes, including drinking, air conditioning, and cleaning".\textsuperscript{18} Most industrial activities use water in two or more of the ways mentioned with water for cooling often being the most significant use.\textsuperscript{19} The quantity of water required for industrial use varies with the type of industry, the degree of recirculation within the plant, and the amount consumed, that is the amount unable to be utilized by other users at other points in time and space. The percentage share of total water supply required by industry on an island will also depend upon the level and mix of economic activity. For example, industry's share of total water withdrawn by the major three users -- agriculture, industry, and the domestic sector -- can range from less than 5 percent up to nearly 90 percent of total supply.\textsuperscript{20}

Industries that typically demand the largest quantities of water include pulp and paper, primary metals, petroleum refining, chemical products and food processing industries. The establishment and growth of water intensive industries on an island could have significant implications for the island's water supplies. For example, the production of 1 ton of paperboard requires 62 to 376 thousand litres of water; 1 ton of
steel uses between 8 and 61 thousand litres of water; 1 thousand litres of gasoline requires 7 to 34 thousand litres of water; 1 ton of soap requires 960 to 37 thousand litres of water; and between 1,800 and 20 thousand litres of water are required to process a ton of sugar beets.²¹

The considerable ranges in the quantities of water withdrawn by industries producing the same product is the result of differing technologies in use. Newer plants have more water efficient technologies which recycle or recover the water and tend to lose less water from antiquated equipment. However, cost or inadequacy of water supply is seldom the reason behind the sizeable investments required to acquire new technologies. Instead, new technologies are developed and adopted largely to increase production and efficiency. However, as these new technologies are being designed for a plant, some thought is usually given to how these technologies could be modified to deal with the problems of waste generation and disposal so as to better satisfy regulations which attempt to internalize the negative externalities resulting from waste.

For many industries the physical, chemical and biological quality of their water supply is critical to their production processes (see Table 3.2). Therefore water supplied to industry is often required to be of at least moderate quality.

3.2.3 Agricultural Use

Water for agricultural purposes accounts for 80 percent of world consumption, but much of this is utilized for crop irrigation.²² However, the water consumption of livestock is not
<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>TURBIDITY</th>
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<th>HARDNESS</th>
<th>pH</th>
<th>TOTAL SOLIDS</th>
<th>GENERAL REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOILERS (lbs. per sq. in.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>0-150</td>
<td>20</td>
<td>80</td>
<td>75</td>
<td>8.0+</td>
<td>3,000-1,000</td>
<td></td>
</tr>
<tr>
<td>150-250</td>
<td>10</td>
<td>40</td>
<td>40</td>
<td>8.5+</td>
<td>2,500-500</td>
<td></td>
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<tr>
<td>250 &amp; over</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>9.0+</td>
<td>1,500-100</td>
<td></td>
</tr>
<tr>
<td>BREWING</td>
<td>10</td>
<td>--</td>
<td>--</td>
<td>6.5-</td>
<td>500-1,000</td>
<td>must meet National Drinking Water Standards, NaCl-275ppm</td>
</tr>
<tr>
<td>PULP &amp; PAPER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwood</td>
<td>50</td>
<td>20</td>
<td>180</td>
<td>--</td>
<td>--</td>
<td>no corrosiveness</td>
</tr>
<tr>
<td>Kraft pulp</td>
<td>25</td>
<td>20</td>
<td>100</td>
<td>--</td>
<td>300</td>
<td></td>
</tr>
<tr>
<td>Soda &amp; sulfite</td>
<td>15</td>
<td>10</td>
<td>100</td>
<td>--</td>
<td>200</td>
<td></td>
</tr>
<tr>
<td>Light paper</td>
<td>5</td>
<td>5</td>
<td>50</td>
<td>--</td>
<td>200</td>
<td>no slime formation</td>
</tr>
<tr>
<td>TEXTILES</td>
<td>5</td>
<td>20</td>
<td>20</td>
<td>--</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>

**SOURCE:** Derived from American Water Works Association, *Water Quality and Treatment*
insignificant. For example, a pig weighing 34 to 57 kilograms needs 7 to 25 litres of water a day; a lactating Jersey cow needs 27 to 46 litres per day to produce 2 to 14 litres of milk daily; sheep on the other hand grazing on dry range need 2 to 6 litres of water daily.\textsuperscript{23}

The origins of irrigation science lie in ancient times. In operation wherever farming occurs, irrigation systems are controlled by "governments or local authorities and the farmers in many forms of cooperation based on adequate legislation".\textsuperscript{24} Irrigation has become an increasingly significant component of water use in this century. Access to water for irrigation reduces the risk of crop failure due to drought and allows the cultivation of lands that in their natural state would be of little value in crop production. Increased certainty improves the farmer's willingness to invest in fertilizers and high yielding crop varieties for irrigated lands which can result in 30 to 50 percent increases in the yields per hectare.\textsuperscript{25}

There are a number of factors influencing the use of water for irrigation: for example climate, soil, crops, irrigation method, economic conditions and the cost of water to the farmer. This last factor -- cost -- is frequently so low, particularly here in North America, that it is often very difficult to get an accurate estimate of the actual water requirements of a given crop because of the low irrigation efficiency rates these low costs promote. Sampson (1981) estimates that of the 600 thousand cubic decameters per day (dam\textsuperscript{3}/day) that were diverted from streams, rivers and reservoirs for irrigation in the United States in 1975, 352 thousand dam\textsuperscript{3}/day were spilled or lost from
either the delivery system or the farmer's irrigation system.\textsuperscript{26} As water for irrigation becomes increasingly scarce, it is expected that farmers in North America, faced with increasingly expensive water, will be forced to adopt such irrigation technologies as low-head sprinklers and drip irrigation. Both of these technologies are more economical users of the water resource and their use results in less wastage through evaporation.

Some farmers rely on flooding, and furrow and ditch irrigation methods. While effective, these techniques permit greater evaporative losses and are frequently inefficient, diverting more water than is required by the plants for satisfactory growth.

The quality of water required for irrigation is dependent upon the type of crop, amount of water used, soil and climate.\textsuperscript{27} Poor quality irrigation water adds to the difficulty of crops trying to grow in adverse climates. For example, water high in dissolved solids used to irrigate crops growing in hot dry climates results in the plants, because they must use more water, concentrating the dissolved solids in the soil. The elements that cause the greatest distress to crops, if they are present in excessive quantities, include sodium and boron. In general fruit crops, such as apples, avocados, grapes and lemons, are less tolerant to poor quality irrigation water than crops such as beets, date palms, asparagus and lettuce.\textsuperscript{28} On islands, soils are susceptible to becoming excessively saline. Sodium concentrations in soils leads to lower soil permeability and the eventual hardening of the soil. As this occurs
infiltration and recharge of the groundwater will decrease, while runoff and erosion increase. Tolerance for poor quality irrigation water increases with the volume of water used, assuming that the soils are well-drained and salts are capable of being leached from the soil. Clayey soils weaken the tolerance of crops to poor quality water because of their poor drainage characteristics.  

3.2.4 Recreational Use

In recent decades recreational use of water has become the focal point around which all forms of leisure activity are based. Consequently, with the increase in leisure time that has been occurring in the developed world, water for recreational activities is also in high demand. Recreational use of water, which involves the floating of people or boats on the water or the aesthetic enjoyment of water and associated resources, is a non-consumptive use of the water resource (unless the water becomes contaminated during the recreational activity). Because of the non-consumptive nature of water-based recreation, concerns about water quality are primarily related to swimming, aesthetics and wildlife (including fish). Concerns relating to fish and wildlife will be discussed in a later section. In terms of aesthetics, water must appear clean, able to sustain life and be odourless. Water suitable for swimming must appear clean and be relatively free of pathogenic organisms.

When considering the quantities of water needed for recreational purposes there are two major points to bear in
mind. Lakes or streams utilized for recreation are required to have fairly constant water levels throughout the recreation season in order to ensure both a safe and aesthetic recreational experience. Secondly, recreational use of water is a lower priority use than many other uses (e.g. domestic uses). Therefore if water is in short supply, water for recreational purposes will not be made available.

3.2.5 Hydro Power Use

While the generation of hydro power is a non-consumptive use of water resources, such use can involve significant manipulation of the hydrologic cycle and disturbance to the aquatic ecosystems of streams and rivers. Typically, the best and cheapest sites for hydro installations are located where foundation geology is impervious to seepage and where natural waterfalls are found emerging from steep-sided glacial valleys. Such sites can produce enough hydraulic head to generate electric power. The quality of water is not an important consideration in the sitting of a hydro facility, for such a facility neither requires water of high quality nor degrades the quality of the water it uses. Circumstances normally permit the use of water resources for both hydro power generation and other uses such as irrigation and water supply; however, this might not always be possible at smaller scales.

On a global basis hydro power has been used for millennia (e.g. water wheels). With the rapid growth in demand for energy, particularly electrical energy, which began at the beginning of this century, large-scale, more economical and efficient hydro
facilities began to be constructed. In the past, the financial feasibility of small-scale hydro has been negatively affected by large fluctuations in streamflow which affects the potential hydraulic head, and has subsequently been reflected in cost- and mechanical-efficiency of the turbine or other technology being used. A further consideration has been the high turbine discharge required to generate a kilowatt of power. This factor has been reflected in the size of the machinery in use and in the resulting high costs per unit of power. However, there has been a renewal of interest, particularly in the last decade, in small (less than 15 megawatts) and micro (less than 100 kilowatts) hydro power generation. With this interest there has also been an increase in the efficiency and a decrease in the cost of such facilities. In more and more circumstances small-scale hydro is competitive with its large-scale counterpart.

Due to the scale of island hydrology and the remoteness of some rural areas, it is these small and micro hydro alternatives that are either in use or hold the most promise for hydro-electric power generation on islands and in rural areas.

3.2.6 Navigation and Flotation Uses

Water for navigation or the flotation of timber is generally considered to be a non-consumptive use of the water resource. However, such use can degrade the quality of the water it uses. While it is usually desirable for water used in hydro power generation to flow quickly and drop over a waterfall to create enough head to turn the turbines, for navigational and
flotational purposes, water is required to be slower moving with no sudden changes in the regime of the water body.

3.2.7 Ecosystem Use

Natural wetlands, that is swamps, marshes and bogs, provide areas of water storage and slow release, thereby providing a mechanism for maintaining constant stream flow, lake levels, or recharging the groundwater. Wetlands are significant habitat areas for a variety of plant and animal species in addition to functioning as a natural purification system for water. It is known that altering the volume, rate and quality of water flowing in a river, lake or wetland can alter the hydrology and ecosystem in and along the water course. But the precise nature and degree of change such an action would produce for a given water system is difficult to accurately predict. Therefore any manipulation of a region's hydrology needs to take into account the water requirements of aquatic and land-based plants and animals in the region. In addition to the needs for a certain quantity of water, these requirements also include water of a given temperature range, turbidity, pH, and a host of other quality concerns.

In allocating between the competing and complimentary domestic, industrial, and agricultural water supply and recreational, hydro power and navigational uses of water resources, it is necessary to also include the water requirements of the natural environment.
3.3 METHODS OF MANAGING DEMAND

In the past, the solution to water supply-demand imbalances have most often involved increasing the supply of water to water users. However, over time the cheapest and best sources of water have been developed and put into use and frequently they and other sources have become contaminated so that the costs of supplying additional water have increased. Water supply managers are interested in supplying water of acceptable quality by the most cost-effective means. A significant part of the costs of supplying water to water users is the result of attempting to provide the extra capacity required to meet peak demands. Consequently, water supply managers have begun to look more closely at solutions that involve adjusting water demand -- particularly peak demands. Demand-oriented solutions to water supply-demand imbalances can be categorized according to whether they are structural, operational, economic or social methods.

3.3.1 Structural Methods

Structural methods involve the use of physical devices or processes that bring about a reduction in peak flow. The use of mechanical or hydraulic flow regulators cause a reduction of water pressure in a specific part of the water system resulting in less water being delivered over time. The installation of water meters where none currently exist causes users to substantially cut back on their use of water initially; even without changing the price of the water. Just as quickly though, users will increase their water usage. The overall net effect of metering however, is a 10 to 30 percent reduction in residential
water demand. Recycling of water, which includes reuse, successive use and recycling has been shown to be effective in reducing water system demands by industry. Although further evaluation of the cost-effectiveness of the recycling of gray waters in residential and commercial settings is required, some estimates for households suggest a water saving of 26 percent.

Increasingly, residential water users have begun to use water-saving devices and appliances, such as reduced-flush toilets, controlled-flow faucets and shower heads, and low water-using cycles in dishwashers and clothes-washers. Studies have varied as to the degree of water saving to be had from the use of such devices, but estimates range from 32 to 70 percent total saving if such devices are employed.

3.3.2 Operational Methods

Operational methods for controlling demand include pressure reduction over the entire water system, water delivery restrictions during periods of peak demand, elimination of unauthorized uses and selective restrictions limiting the use of water to certain times. The reduction of pressure over the whole water system has been used to curb peak demand. However, there are limits to how much pressure can be reduced in that a certain degree of pressure is required in order to fight fires and to prevent soil water from infiltrating into the pipes and contaminating the water in the delivery system.

Water delivery restrictions and restrictions on use are similar in that they can be selectively applied and have the
affect of reducing peak demands. They differ in that restricting water delivery involves curtailing the amount of water delivered to a particular class of consumer, whereas restricting or prohibiting use relies upon the customer to restrict his or her use to specified times. For example, restrictions on use may involve restricting lawn sprinkling or the filling of swimming pools to certain hours of the day or it may involve restriction of total use during periods of drought.

Every water system has water which is unaccounted for, that is water that is not used for residential, commercial or other similar uses. Most of the unaccounted for water is usually attributed to leaks in the system; however, sometimes this "missing" water is due to illegal connections or meters that have been by-passed. The elimination of such unauthorized uses can result in a water saving.

3.3.3 Economic Methods

Economic methods of managing water demand include changing rate structures, imposing system development cost charges, incentives and or tax breaks for conservation, penalties for excessive use and use of special demand meters. Special demand meters record the rate of water use and as use increases, the rate charged the water consumer increases. The meter can either shut off flow when demand exceeds a certain rate or signal the user when use is excessive.

Penalties for overuse are the opposite side of the coin to incentives for conservation. Penalties which involve fining customers who use water wastefully require a certain amount of
policing and the collection of fines. Incentives for conservation can include reduced water charges to those customers who maintain and repair their part of the water system, install and use water saving devices and who schedule their heavy water using activities in off-peak periods. Development cost-charges or the use of building codes and zoning help to control the growth in the water supply system and ensure that population densities are such that serving consumers is cost-effective.

There are basically five rate structures or pricing policies. A flat-rate structure is fairly common here in British Columbia where many areas are unmetered. A fixed price is charged for water use and is unrelated to the amount or timing of water use. Constant rate schedules require that a system be metered. After a base charge, which everyone pays, customers pay a constant rate for each unit of water used. The incentive to use less water is minimal, particularly when water is inexpensive. Declining block rates are fairly common in metered areas (e.g. industrial areas). As with the constant rate schedules there is a minimum charge; however, with each additional block of water used the price of the additional block decreases. This rate schedule promotes water use. The opposite of a declining block rate schedule is incremental block pricing. This type of structure encourages people to use less water because the more water they use, the more they pay for each additional unit of water -- rates increase with increases in water use. A final rate structure is the differential rate schedule used in conjunction with other rate schedules during
periods of peak demand such as in the summer. Higher water rates are put into effect to reduce demand and maintain system pressure during the peak demand period.

3.3.4 Social Methods

Social methods of reducing water demand usually require perseverance because these methods take a long time to become effective and it is difficult to evaluate their effectiveness directly. Educating the water user and changing public attitudes about water conservation is one social method of reducing demand. It may involve getting water using activities to voluntarily schedule heavy water using activities to off-peak periods. Another social method of reducing demand is to initiate a change in horticultural practices such that people start to plant species that require less irrigation.

Demand-side options for balancing water supply and water demand are most easily implemented when there is a perceived real or potential water supply shortage. Supply-side options will continue to be the first choice options in the task of balancing water supply and demand. However, as the opportunities for their use decrease, water shortages threaten, and water conservation attitudes are adopted, demand-side options will increase in importance to water management.

SUMMARY

This chapter has attempted to build a framework for understanding and managing the demand for water resources in a region. The initial section of the chapter focused on concepts
in the study and analysis of water demand. Concepts relating to the way water is used by consumers (i.e. consumptive, withdrawal or flow uses of water) must be clearly understood in order to accurately forecast demand and avoid over or underestimating demand. Forecasting methods are numerous, but the need to make assumptions and to manage uncertainty in the method is common to them all. These factors are particularly significant when forecasting is done for rural areas where, typically, good data are difficult to obtain.

The second section of this chapter reviews the main categories of uses which are: domestic, industrial, agricultural, recreational, hydro power, navigation and floatation and ecosystem uses of water resources on islands. These uses were discussed in terms of the quantity and quality of the water required in these activities. The final section of this chapter briefly discussed the various methods of managing demand in terms of whether they are structural, operational, economic or social methods of controlling demand.

Part II of this thesis follows and presents an analysis of water supply and demand on Texada.
PART II

CASE STUDY OF TEXADA ISLAND

The following 3 chapters examine the water resource supply and demand situation on Texada Island in British Columbia. The objective in the case study is to attach numbers applicable to Texada to Figure 2.2 (shown again on the next page) — in other words to complete a water supply and demand balance analysis for the island. As has been mentioned before, rural areas like Texada frequently lack the data to carry out such a detailed analysis. In carrying out the analysis in this case study the strategy has been to use the best available information and assumptions based on theory and observations in order to complete the analysis. Throughout the text, an attempt has been made to state explicitly where numbers are based on existing data or where and what assumptions have been made to arrive at conclusions. Where assumptions have been made, the sensitivity of the conclusions being drawn from them have been tested. Where conclusions have been sensitive to the assumptions used to arrive at them this has been stated and shown explicitly in the text or reference has been made to the appropriate appendices. In addition, it should be noted that in estimating or making assumptions about water supply there has been a conscious attempt toward making conservative estimates or assumptions. Conversely, in estimating or making assumptions about water demand there has been a tendency toward making generous estimates or assumptions. In the case of Texada this has been a useful strategy and one that has not seriously affected the
FIGURE 2.2: SYSTEMS REPRESENTATION OF THE HYDROLOGIC CYCLE AND THE INTERACTION WITH THE HUMAN USE SYSTEM

SOURCE: Adapted from Freeze and Cherry (1979), p.4.
outcome of the analysis or the conclusions that have been arrived at.

Having outlined the strategy for the analysis in Part II, Chapter 4 provides an assessment of the island's water balance (the flow) and the total stock (storage) of both ground and surface supplies. In addition, the chapter also examines the capacity of developed supply. Chapter 5 identifies the patterns of existing demand for water and attempts to examine how these are likely to change in the future and the implications of any change. Chapter 6 examines possible solutions to water supply shortages and evaluates them in terms of their social, financial, environmental, technical and legal/institutional appropriateness to conditions on Texada.
CHAPTER 4
SUPPLY: THE WATER RESOURCES OF TEXADA ISLAND

INTRODUCTION

In considering the supply of water resources on Texada Island, first the surface waters and then the groundwater will be discussed. The aims of this chapter are to (1) characterize these water resources, (2) examine the degree and type of development these resources have undergone, and (3) introduce a discussion, to be developed further in a later chapter, on the water resource potential of Texada. In a section near the end of the chapter there will be a brief discussion of the significance of waste disposal practices in changing the quality and ultimately the quantity of available supply.

4.1 THE FLOW OF WATER -- THE WATER BALANCE

In this section the flows or the rate of water moving through the water resource system on Texada will be examined. There are inflows and outflows of water in the system. Precipitation falling on the island is the inflow to the system while evapotranspiration and runoff are the naturally occurring outflows. (The next chapter will examine the outflow to the human use system).

Evapotranspiration is the loss of water to the atmosphere due to transpiration from plants and evaporation from the soil. In the discussion that follows there will be a distinction drawn between actual evapotranspiration, which is the actual water used by plants and the soil, and potential evapotranspiration
which is the water need of the plants and the soil. Under ideal circumstances, when there is enough water to supply plants and the soil with all the water they can use, then actual evapotranspiration will equal potential evapotranspiration. However, when "precipitation is less than the demands for water the actual evapotranspiration is less than the potential and a moisture deficit equal to the difference between these two quantities exists".

Runoff is another outflow from the water resource system on the island. In the case of Texada, runoff refers to the water that is ultimately lost from the system in that it is being discharged to the sea. A portion of runoff prevented or delayed from reaching the sea so as to be used by human systems on the island is the demand outflow. It will be discussed in the following chapter. There are various methods that have been developed for determining either precipitation, evaporation, runoff or some other hydrologic process. However, these methods tend to deal with each of these processes separately. In the 40's and 50's C.W. Thornthwaite, a meteorologist, developed the Thornthwaite water balance method which brings together into one equation or method "the balance between the income of water from precipitation and snowmelt and the outflow of water by evapotranspiration, groundwater recharge and streamflow". In examining the water balance on Texada the Thornthwaite method is attractive because it only requires that there be records of monthly precipitation, monthly mean daily temperatures and some idea about the depth of the soil, the vegetation cover and the general size of the drainage basins on the island. Except for
the temperature figures such data are available or have been estimated for Texada. In the case of monthly mean daily temperature however, the best data available are the figures for the community of Westview on the nearby Mainland. These figures have been used for the analysis. Let us turn first to discuss the pattern of precipitation typical for Texada.

Texada's location causes the island to be subject to maritime Pacific air masses which typically form and move across British Columbia during the fall and winter months. These air masses, originating in the Gulf of Alaska, travel across the northeastern Pacific picking up moisture from the ocean along the way. As they rise over the mountains of Vancouver Island and the B.C. Mainland they release their moisture. Situated in the Strait of Georgia just south of a line between Courtney and Powell River, Texada Island (specifically Gillies Bay) receives an average of 929 millimeters of precipitation a year. This figure can be as low as 700 millimeters in dry years or over 1000 millimeters in wet years. It should be noted that Gillies Bay is situated on the lower and more northerly half of the island. The southern half of the island is higher in elevation and more mountainous. For this reason, it can be expected that the southern area receives twice the annual precipitation that the northern area does. However, because of the strategy of being conservative in estimating supply and because the bulk of human settlement and activity occurs on the northern half of the island, 929 millimeters of precipitation per year will be the figure adopted in the following analysis. Typically, 50 percent of total annual precipitation falls during the period October
through January with May through August being the driest months (see Figure 4.1). While a portion of the total annual precipitation falls as snow, Texada's mild climate and proximity to the moderating effects of the ocean prevent snow from remaining for any length of time. Consequently, there is no snowpack to act as a reservoir of water for the dry period during summer.

Evapotranspiration is a complex process that is dependent upon several factors. Solar radiation drives evaporation and the measure of solar radiation that Thornthwaite relies on in his method is monthly averages of mean daily temperature (see Figure 4.1). Another factor, far less critical than the energy factor, is the "capacity of the air to remove vapor". Although not included in Thornthwaite's calculations of the water balance, wind speed could act as an index to this factor. The third and fourth factors influencing evapotranspiration are the nature of the vegetation and of the soil. Thornthwaite bases his estimates of soil moisture storage capacity on the type and texture of the soil and the depth of the root systems. The density and type of vegetation cover affects the evapotranspiration rates. These factors are incorporated into the determination of the water balance through observations of or, as in the case with Texada, assumptions about the depth of the root zone and the types of vegetation cover.

Partly due to the desire to test the sensitivity of the water balance method and partly due to the uncertainty and variability with regard to the depth and type of soil and vegetation covering the soil, three different levels of soil
FIGURE 4.1: CLIMOGRAF FOR TEXADA ISLAND, B.C.

NOTE: Precipitation data is for Gillies Bay.
Temperature data is for Westview near Powell River (this is all that was available).

SOURCE: Canadian Climate Normals 1951 - 1980: Temperature and Precipitation — B.C.
moisture storage have been used in the analysis of the water balance. An average soil moisture storage of 75 millimeters reflects the lower end of the spectrum although it does not seem to be an unreasonable level because much of Texada is covered by shallow soils and scrubby coniferous forest. A soil moisture storage of 120 millimeters is the mid-range figure and is an average figure for many areas in coastal British Columbia.\footnote{10} Large areas in the northern half of Texada are swampy or are deep depressions which have filled with soils over the millennia and where rich coastal forests have grown and matured. Consequently, a soil moisture storage capacity of 300 millimeters is used as the upper range figure in the analysis of Texada's water balance.

In addition to assumptions about the soil moisture capacity on Texada there is a need to make some assumptions about runoff. Typically, when precipitation falls on a drainage basin some of it evapotranspires, some infiltrates the soil and recharges the groundwater and some runs off and discharges to the sea. That portion of water which runs off often does so at different times and in differing portions depending on a number of factors one of which includes the size of the watershed. On a large watershed (i.e greater than 20 square kilometers) 50 percent of the water available for runoff in one month is detained and actually runs off in the following month.\footnote{11} With smaller more fragmented watersheds, such as exist on Texada, the percentage of runoff water which is detained in one month so as to runoff in the following month is much lower.\footnote{12} For Texada, 15 percent is the assumed detention of available runoff for each month.
based on observations of streamflow on the island year round and adjustments to calculations to coincide with the observations of streamflow by long-term residents. The smaller the amount of water that is detained, the less stable or consistent is the flow of runoff year round.

Each of the three tables that follow uses a different set of figures for soil moisture; however the percentage of runoff detained remains at 15 per cent (see Appendix A for a line by line explanation of figures in the Tables). Notice that while precipitation remains constant the amount of water actually evaporated increases with the soil moisture storage capacity (see line 11 on Tables 4.1, 4.2, and 4.3. In order for the components of the water balance equation \( P = AE + RO \) to "fit" the equation, that is to balance with one another, it can be expected that if \( AE \) increases with increases in the SM storage capacity then runoff must decrease -- and in fact it does (see Tables - line 15). Figures 4.2, 4.3, and 4.4 show graphically the results of the water balance calculations based on the varying assumptions about soil moisture storage and the percentage of water available for runoff that actually runs off. When soil moisture is low, as in Figure 4.2, then evapotranspiration is low while the moisture deficit is larger than when the soil moisture storage is high. When 85 percent of available runoff actually runs off in a given month then during the period May through October, actual runoff becomes negligible. If less than 85 percent of available runoff were to run off in a given month then total annual runoff would remain the same, but the flow of runoff would continue more steadily
### TABLE 4.1: WATER BALANCE FOR TEXADA GIVEN A SOIL STORAGE CAPACITY OF 75 MILLIMETERS

<table>
<thead>
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<th>Figures in millimeters (unless otherwise noted)</th>
<th>JANUARY</th>
<th>FEBRUARY</th>
<th>MARCH</th>
<th>APRIL</th>
<th>MAY</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>OCTOBER</th>
<th>NOVEMBER</th>
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<td>.80</td>
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<td>3. UNADJUSTED POTENTIAL EVAPOTRANSPIRATION</td>
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<td>.7</td>
<td>.9</td>
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<td>3.0</td>
<td>2.9</td>
<td>2.4</td>
<td>1.6</td>
<td>.9</td>
<td>.6</td>
<td></td>
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<td>4. CORRECTION FACTOR</td>
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<td>23.7</td>
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<td>31.5</td>
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<tr>
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<td>-41</td>
<td>-96</td>
<td>-187</td>
<td>-249</td>
<td>-274</td>
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<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
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<td>75</td>
<td>75</td>
<td>75</td>
<td>74</td>
<td>36</td>
<td>11</td>
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<td>+19</td>
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<tr>
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<td>9</td>
<td>17</td>
<td>28</td>
<td>48</td>
<td>77</td>
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<td>39</td>
<td>48</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>129</td>
<td>462</td>
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<td>57</td>
<td>9</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>144</td>
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<tr>
<td>15. RUNOFF (RO)</td>
<td>116</td>
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<td>48</td>
<td>8</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>85</td>
<td>122</td>
<td>462</td>
</tr>
<tr>
<td>16. TOTAL MOISTURE DETENTION (DT)</td>
<td>20</td>
<td>14</td>
<td>9</td>
<td>1</td>
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<td>0</td>
<td>15</td>
<td>22</td>
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</tr>
</tbody>
</table>

In this table the water holding capacity of the soil or the soil moisture storage term (line 9) is assumed to be 75 millimeters because of the shallow depth of the surficial deposits and rugged topography on Texada.

Given the small size of the watersheds on Texada, it is assumed that only 15 percent of the water available for runoff in a given month is retained in the soil and actually runs off in the following month.

Notice that \( P - AE = RO \) (929 - 467 = 462). This is the water balance for Texada under the above set of assumptions.

For a line by line explanation of the three water balance tables, see Appendix A.
## TABLE 4.2: WATER BALANCE FOR TEXADA GIVEN A SOIL STORAGE CAPACITY OF 120 MILLIMETERS

<table>
<thead>
<tr>
<th>Figures in millimeters unless otherwise noted</th>
<th>JANUARY</th>
<th>FEBRUARY</th>
<th>MARCH</th>
<th>APRIL</th>
<th>MAY</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>OCTOBER</th>
<th>NOVEMBER</th>
<th>DECEMBER</th>
<th>ANNUAL</th>
</tr>
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<tbody>
<tr>
<td>1. TEMPERATURE °C</td>
<td>2.8</td>
<td>4.9</td>
<td>6.1</td>
<td>9.2</td>
<td>12.9</td>
<td>15.6</td>
<td>18.2</td>
<td>17.8</td>
<td>14.9</td>
<td>10.4</td>
<td>6.1</td>
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<td>4.1</td>
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<td>4.35</td>
<td>4.67</td>
<td>5.60</td>
<td>5.97</td>
<td>6.84</td>
<td>5.22</td>
<td>3.03</td>
<td>1.35</td>
<td>0.80</td>
<td>0.37</td>
<td>0.37</td>
</tr>
<tr>
<td>3. UNADJUSTED POTENTIAL EVAPOTRANSPIRATION</td>
<td>0.4</td>
<td>0.7</td>
<td>0.9</td>
<td>1.4</td>
<td>2.0</td>
<td>2.5</td>
<td>3.0</td>
<td>2.9</td>
<td>2.4</td>
<td>1.6</td>
<td>0.9</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>4. CORRECTION FACTOR</td>
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<td>23.7</td>
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<td>39.6</td>
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<td>40.5</td>
<td>37.2</td>
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<td>27.6</td>
<td>22.8</td>
<td>21.3</td>
<td>21.3</td>
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<td>5. ADJUSTED POTENTIAL EVAPOTRANSPIRATION (PE)</td>
<td>9</td>
<td>17</td>
<td>28</td>
<td>48</td>
<td>79</td>
<td>101</td>
<td>120</td>
<td>108</td>
<td>76</td>
<td>44</td>
<td>21</td>
<td>13</td>
<td>13</td>
</tr>
<tr>
<td>6. PRECIPITATION (P)</td>
<td>123</td>
<td>93</td>
<td>71</td>
<td>47</td>
<td>39</td>
<td>46</td>
<td>31</td>
<td>46</td>
<td>51</td>
<td>100</td>
<td>140</td>
<td>142</td>
<td>929</td>
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<tr>
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<td>-1</td>
<td>-41</td>
<td>-96</td>
<td>-187</td>
<td>-249</td>
<td>-274</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. SOIL MOISTURE STORAGE (SM)</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>119</td>
<td>81</td>
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<td>120</td>
</tr>
<tr>
<td>10. ΔSM</td>
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<td>-38</td>
<td>-37</td>
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<td>+59</td>
<td>0</td>
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<td>9</td>
<td>17</td>
<td>28</td>
<td>48</td>
<td>77</td>
<td>83</td>
<td>63</td>
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<td>-18</td>
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<tr>
<td>14. TOTAL AVAILABLE FOR RUNOFF</td>
<td>135</td>
<td>96</td>
<td>57</td>
<td>9</td>
<td>1</td>
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<td>15. RUNOFF (RO)</td>
<td>115</td>
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<td>48</td>
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<td>0</td>
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<td>0</td>
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<td>0</td>
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</table>

In this table the water holding capacity of the soil or the soil moisture storage term (line 9) is assumed to be 120 millimeters. This figure is commonly used when calculating water balances along the B.C. coast. Fifteen percent of the water available for runoff is detained and actually runs off in the following month. Notice that in this table P - AE = RO (929 - 507 = 422). The greater soil storage capacity under these assumptions has resulted in less water being available for runoff and greater actual evapotranspiration.
<table>
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<th>JANUARY</th>
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<th>MARCH</th>
<th>APRIL</th>
<th>MAY</th>
<th>JUNE</th>
<th>JULY</th>
<th>AUGUST</th>
<th>SEPTEMBER</th>
<th>OCTOBER</th>
<th>NOVEMBER</th>
<th>DECEMBER</th>
<th>ANNUAL</th>
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<td>1. TEMPERATURE °c</td>
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<td>4.2</td>
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<td>9.2</td>
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<td>.9</td>
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<td>4. CORRECTION FACTOR</td>
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<td>23.7</td>
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<td>79</td>
<td>101</td>
<td>120</td>
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<td>76</td>
<td>44</td>
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<td>664</td>
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<tr>
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<td>123</td>
<td>93</td>
<td>71</td>
<td>47</td>
<td>39</td>
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<td>51</td>
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<td></td>
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<td>300</td>
<td>299</td>
<td>261</td>
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<td>152</td>
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<td>94</td>
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<td>-15</td>
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<td>0</td>
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<tr>
<td>13. MOISTURE SURPLUS (S)</td>
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<td>57</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>116</td>
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<tr>
<td>15. RUNOFF (RO)</td>
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<td>0</td>
<td>0</td>
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<td>14</td>
<td>8</td>
<td>1</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>17</td>
</tr>
</tbody>
</table>

In this table the water holding capacity of the soil or the soil moisture storage term (line 9) is assumed to be 300 millimeters because much of Texada is covered by a mature coniferous forest which typically has a storage capacity of 300 millimeters. Fifteen percent continues to be the amount of water retained of that available for runoff in each month. Notice that with this table \( P - AE = RO \) \((929 - 580 = 349)\). Even less water is available for runoff under the above assumptions than in the previous 2 tables.
FIGURE 4.2: WATER BALANCE FOR TEXADA:
SOIL STORAGE CAPACITY OF 75 MILLIMETERS

SOURCE: Derived from Table 4.1
FIGURE 4.3: WATER BALANCE FOR TEXADA:
SOIL STORAGE CAPACITY OF
120 MILLIMETERS

SOURCE: Derived from Table 4.2
FIGURE 4.4: WATER BALANCE FOR TEXADA:
SOIL STORAGE CAPACITY OF
300 MILLIMETERS

- Precipitation
- Potential Evapotranspiration
- Runoff
- Actual Evapotranspiration

SOURCE: Derived from Table 4.3
throughout the year although considerably reduced during the
drier summer months. Also, if precipitation were double (as it
probably is in the southern half of the island), then runoff is
likely to be continuous through the summer months.

From this analysis of the water balance on Texada, it can
be seen that from the depth of water falling on the island as
precipitation, that is 929 millimeters annually on average, the
depth that actually transpired ranges from 467 to 580
millimeters and the amount that runs off is 349 to 462
millimeters annually over the whole island. The area of Texada
is approximately 15,176 hectares. The total volume of
precipitation falling on Texada is then 140,937 cubic decameters
per year (dam$^3$/year). The total volume of water actually
evapotranspired ranges from 70,843 to 87,984 dam$^3$ per year
depending on the soil storage capacity. Runoff is estimated to
range between 52,943 to 70,084 dam$^3$ per year.

In the Lowland Region alone, the total annual volume of
precipitation is 45,547 dam$^3$. Evapotranspiration in the Lowland
Region ranges between 22,896 and 28,437 dam$^3$ annually, while
runoff ranges between 17,110 and 22,650 dam$^3$ per year (see Table
4.4, Figure 4.5 and Appendix A).

Having now developed some idea about the flow of water on
Texada, we turn now to examine the stock of water resources on
the island by looking at the surface waters (lakes, streams, and
wetlands) of Texada in terms of their location, timing,
quantity, and quality.
### TABLE 4.4: SUMMARY OF WATER BALANCE (FLOW) CALCULATIONS FOR TEXADA ISLAND

1. **PRECIPITATION:**

   (a) Depth of annual precipitation  
   929 millimeters  

   (b) Volume of annual precipitation for all of Texada  
   140,927 $\text{dam}^3$ **

   (c) Volume of annual precipitation for Lowland Region  
   45,547 $\text{dam}^3$

2. **ACTUAL EVAPOTRANSPIRATION:**

   (a) Depth of annual actual evapotranspiration (AE)  
   467 - 580 millimeters

   (b) Volume of annual AE for all of Texada  
   70,843 - 87,984 $\text{dam}^3$

   (c) Volume of annual AE for Lowland Region  
   22,896 - 28,437 $\text{dam}^3$

3. **RUNOFF:**

   (a) Depth of annual runoff  
   349 - 462 millimeters

   (b) Volume of annual runoff for all of Texada  
   52,943 - 70,084 $\text{dam}^3$

   (c) Volume of annual runoff for Lowland Region  
   17,110 - 22,650 $\text{dam}^3$

**SOURCE:** See Appendix A for the derivation of the above figures.

** 1 cubic decameter = 1.233 acre-feet = 334,544 imperial gallons
FIGURE 4.5: SCHEMATIC SUMMARY OF WATER BALANCE FINDINGS FOR THE LOWLAND REGION ON TEXADA

(annual flow in cubic decameters)

SOURCE: This figure assumes that the soil moisture storage capacity is 120 millimeters in depth, for an area of 4905 hectares (the area of the Lowland Region).

SOURCE: See Table 4.4 and Appendix A.
4.2 THE SURFACE WATERS OF TEXADA

4.2.1 Natural Supply

In considering the surface waters of Texada, the island can be divided into two regions -- the Highland region south of Pocahontas Mountain and the Lowlands of the northern portion of the island (see Figure 4.6).

(1) The Highland Region

The Highland region generally consists of vertical relief, elevations ranging up to 885 meters, largely hard porphyrite rocks, and a flatter central area above 500 meters where numerous small shallow lakes and ponds have formed in depressions. Many of these lakes have closed drainage systems, are swampy around their shorelines and experience wide seasonal fluctuations in water levels. Bob's Lake is one of the larger lakes in this region.

No detailed information is available on the water quality of any of Texada's lakes, however, some data have been collected for a few of the larger lakes including Bob's Lake (see Table 4.5). Bob's Lake has a moderately high pH value typically associated with waters high in alkalinity, a low specific conductance value indicative of low concentrations of dissolved solids, and a higher temperature relative to the other lakes sampled -- most likely a reflection of its shallow depth and of the timing of observations. If Bob's Lake is representative of the lakes in the Highland region, then it may be possible to suggest that the water in these lakes is potable, likely suitable for a variety of uses though in the summer months they
FIGURE 4.6:
THE SURFACE WATERS
OF TEXADA
### TABLE 4.5: AVAILABLE DATA ON TEXADA'S LAKES

<table>
<thead>
<tr>
<th></th>
<th>BALKWILL</th>
<th>PRIEST</th>
<th>EMILY</th>
<th>KIRK</th>
<th>MYRTLE</th>
<th>PAXTON</th>
<th>BOB'S</th>
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<tbody>
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<td>ELEVATION (m)</td>
<td>61</td>
<td>55</td>
<td>24</td>
<td>106</td>
<td>85</td>
<td>88</td>
<td>640</td>
</tr>
<tr>
<td>SHORELINE (%forested)</td>
<td>100</td>
<td>50</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>PERIMETER (m)</td>
<td>2200</td>
<td>3800</td>
<td>1100</td>
<td>1400</td>
<td>700</td>
<td>2277</td>
<td>-</td>
</tr>
<tr>
<td>AREA (ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full</td>
<td>11.5</td>
<td>42</td>
<td>7</td>
<td>9</td>
<td>2</td>
<td>9</td>
<td>7.6</td>
</tr>
<tr>
<td>Littoral</td>
<td>5.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>VOLUME (dam³)</td>
<td>720</td>
<td>2280</td>
<td>-</td>
<td>689</td>
<td>-</td>
<td>689</td>
<td>218</td>
</tr>
<tr>
<td>DEPTH (m)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>8</td>
<td>-</td>
<td>6</td>
<td>2.9</td>
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<tr>
<td>Maximum</td>
<td>14.3</td>
<td>16.5</td>
<td>-</td>
<td>20</td>
<td>-</td>
<td>13</td>
<td>8</td>
</tr>
<tr>
<td>pH</td>
<td>8.2</td>
<td>8.7</td>
<td>-</td>
<td>7.8</td>
<td>-</td>
<td>8.3</td>
<td>8.0-8.5</td>
</tr>
<tr>
<td>SECCHI DISC (m)</td>
<td>5</td>
<td>6</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>SPECIFIC CONDUCTIVITY (µS/cm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ surface</td>
<td>105</td>
<td>169</td>
<td>-</td>
<td>133</td>
<td>-</td>
<td>290</td>
<td>80</td>
</tr>
<tr>
<td>@ other depths</td>
<td>86</td>
<td>168</td>
<td>-</td>
<td>122</td>
<td>-</td>
<td>395</td>
<td>85</td>
</tr>
<tr>
<td>(11 m) (14m)</td>
<td>(15m)</td>
<td>(11m)</td>
<td>(14m)</td>
<td>(15m)</td>
<td>(4.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUBSTRATE</td>
<td>mud</td>
<td>mud</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>mud</td>
<td>-</td>
</tr>
<tr>
<td>PROFILE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth (m)</td>
<td>0</td>
<td>6</td>
<td>10</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Temp. (°C)</td>
<td>16</td>
<td>-</td>
<td>6</td>
<td>-</td>
<td>16</td>
<td>-</td>
<td>18</td>
</tr>
<tr>
<td>O₂ (ppm)</td>
<td>9</td>
<td>7</td>
<td>-</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>9</td>
</tr>
</tbody>
</table>

**SOURCES:** Texada Island General Land Use Plan - 1973, Department of Municipal Affairs - Victoria, B.C. B.C. Ministry of the Environment, Lake Management Files, July 2, 1980.
may experience some oxygen depletion.

The Highland region's north-south running topography combined with Texada's narrow width (less than six miles) are reflected in the region's small fragmented watersheds. Consequently, the streams draining the steeply sloping Highland region are frequently short, generate low volumes of water, and the majority are intermittent. Mouat Creek, the largest stream in the region, has several branches which drain the surrounding slopes. The creek's grade is steep and the considerable volumes of water it carries during the wet winter months have caused it to cut a canyon up to 50 meters deep through the soft Cretaceous shales and sandstones it crosses as it nears its outlet into Mouat Bay. Other permanent streams in the Highland region include Russ Creek draining into Northeast Bay and Cook Creek which drains into Cook Bay.

(2) The Lowland Region

The region northwest of Pocahontas Mountain is characterized by elevations less than 300 meters, large areas underlain by limestone formations, rough hummocky terrain and numerous lakes, ponds and marshy areas. A trough running east to west between Pocahontas Mountain and Gillies Bay is occupied by numerous lake-filled depressions and marshes. The remainder of the lakes in the Lowland region are generally larger and deeper than those of the Highland region. The largest lake on Texada is Priest Lake which, along with Balkwill (Spectacle) Lake drains into Sturt Bay via Emily (Turtle) Lake and Vananda Creek. Kirk Lake, which is the deepest lake on the island is part of the Priest Lake drainage system. Paxton Lake to the
south drains eastward into Raven Bay via Myrtle Lake and Rumbottle Creek. Finally, Cranby Lake and Creek flow south into shallow Gillies Bay.

Each of these Lowland Lakes experiences fluctuations in water levels throughout the year -- some more than others. The shoreline areas of these lakes, particularly Paxton and Cranby Lakes, are inhabited by communities of bulrushes, water lilies and other marsh-loving species.\(^{16}\) A few of these lakes support cutthroat trout. The larger streams of the Lowland Region, such as Cranby and Vananda Creeks, are believed to be habitat for steelhead, cutthroat trout, and it is said that salmon use these streams to spawn.\(^{17}\) Despite these positive features, the volumes of water generated by these streams are not great and generally fluctuate considerably during the year.

Again, little detailed data exist on the water quality of the lakes and streams of the Lowland, but some general observations can be made. The total dissolved solids and specific conductivity of these lakes are higher than that for the Highland lakes, while the pH levels range from 7.8 to 8.7 indicating a range from waters higher in alkalinity. While the water in these lakes is potable, it may not be desirable for use in many industries due to the higher hardness (i.e. concentrations of Ca and Mg ions) which causes scaling of pipes carrying heated water or steam.\(^{18}\)

In addition to the lakes, streams and marshy areas discussed above, there are also several abandoned mining quarries that have filled with water. The Number 4 and 5 quarries collectively known as Heisholt Lake are fed by two
small streams and by groundwater. While one of these streams flows year round into Heisholt Lake, though somewhat less significantly in dry months, it is suspected that many of the abandoned quarries on Texada have filled largely due to the movement of groundwater in and out of them. Therefore, these quarries will be discussed in the section dealing with Texada's groundwater.

To sum up, the total volume of surface water in the Highland Region is estimated to be approximately 3950 dam$^3$. In the Lowland Region, total surface supply is approximately 8000 dam$^3$ bringing the total stock of surface water on Texada to approximately 12,300 dam$^3$ (see Table 4.6 and Figure 4.7).

4.2.1 Development of Surface Supplies

The water resources of Texada have been developed to supply users as needs have arisen. Consequently, the nearest, cleanest and cheapest sources of water were developed early. Frequently this has meant the development of surface supplies. As the communities of Blubber Bay, Vananda, and Gillies Bay grew, waterworks systems evolved to supply the water needs of the community. Industries operating on the island utilized the nearest adequate surface supplies or took advantage of the seemingly abundant potable water accumulating in the abandoned quarries. Other residents and activities on the island piped water from nearby streams, springs, lakes, or dug shallow wells or even trucked in the needed water from Vananda. In this section the development of surface supplies will be discussed.

The majority of residents and economic activities can be
<table>
<thead>
<tr>
<th>AREA</th>
<th>VOLUME (in cubic decameters)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Highland Region</strong></td>
<td></td>
</tr>
<tr>
<td>Bob's Lake</td>
<td>218</td>
</tr>
<tr>
<td>Estimated volume of other surface waters in this region. (no data available)</td>
<td>3700</td>
</tr>
<tr>
<td><strong>TOTAL FOR REGION</strong></td>
<td>3918</td>
</tr>
<tr>
<td><strong>2. Lowland Region</strong></td>
<td></td>
</tr>
<tr>
<td>Priest Lake</td>
<td>2280</td>
</tr>
<tr>
<td>Paxton Lake</td>
<td>689</td>
</tr>
<tr>
<td>Kirk Lake</td>
<td>689</td>
</tr>
<tr>
<td>Balkwill Lake</td>
<td>720</td>
</tr>
<tr>
<td>Cranby Lake</td>
<td>617</td>
</tr>
<tr>
<td>Emily Lake</td>
<td>370</td>
</tr>
<tr>
<td>Myrtle Lake</td>
<td>100</td>
</tr>
<tr>
<td>Case Lake</td>
<td>30</td>
</tr>
<tr>
<td>Estimated volume in swamps and streams. (no data available)</td>
<td>2470</td>
</tr>
<tr>
<td><strong>TOTAL FOR REGION</strong></td>
<td>7965</td>
</tr>
<tr>
<td><strong>3. TOTAL FOR TEXADA</strong></td>
<td>11,883</td>
</tr>
</tbody>
</table>

* 1 cubic decameter = 1.233 acre-feet = 334,544 imperial gallons

*a Estimates for these lakes, swamps or streams are based on surface area figures and approximations as to the depth of the water body. The estimates are on the conservative side. The total volume of surface water on Texada could be double (i.e. 24,660 cubic decameters), but it is certainly not less than 11,000 cubic decameters.
FIGURE: 4.7: SCHEMATIC SUMMARY OF THE STOCK OF SURFACE WATER FOR THE LOWLAND REGION OF TEXADA

(Stock of water in the surface waters of the Lowland Region at any one instant in time)

SOURCE: See Table 4.6.
found on the northern half of Texada Island in the region we earlier referred to as the northern Lowland Region. Consequently, the water resources of this region have experienced more development than the water resources in the Highland Region. The Lowland lakes have been the main focus of larger scale developments, while small creeks and springs have been utilized by individual water users.

(1) Lakes

The largest lake on Texada is Priest Lake which has a volume of approximately 2300 dam³. The Vananda Waterworks District has the water rights to withdraw approximately 909 thousand dam³ per day (dam³/d) from Priest Lake in order to supply the residents of the community. They are permitted 330 dam³ (about 300 days worth of supply) of storage for this same purpose. Water from the lake is pumped to a water surge tank (estimated 23 thousand litres of storage) and then gravity-fed to the waterworks system. The population of Vananda was 342 in 1981. There are 178 dwelling units connected to the waterworks system, while the remainder rely on shallow wells.

Cranby Lake, the water supply source for Gillies Bay, was once much smaller and marshier; however, a small earth-filled dam has been constructed at one end of the lake so that the volume of the lake is now estimated to be about 600 dam³. The Gillies Bay Improvement District (GBID) is licensed to withdraw about 227 thousand litres per day (lpd) and to store 382 dam³ to meet the water requirements of the community. In 1981 there were 345 people living in 166 dwelling units in Gillies Bay. However not all these dwellings are connected to the water.
supply delivery system.\textsuperscript{26} Emily Lake is part of the Priest Lake drainage system and over 900 thousand lpd plus 86 dam\textsuperscript{3} of storage has been licensed, primarily for mining use with some domestic use as well.\textsuperscript{27} However, Emily Lake has no users at present. The total volume of Emily Lake is unknown, but is estimated at about 370 dam\textsuperscript{3}.

In the past, water from the Paxton Lakes has been pumped for use by a mining interest on the island. The lakes have a combined volume of 690 dam\textsuperscript{3} -- 3 dam\textsuperscript{3} of which are allocated to this interest.\textsuperscript{28} However, at present it seems that little or no water is being withdrawn from this system even though the pumping facilities, while very likely in need of repair, remain largely intact.

Kirk Lake has approximately the same volume as the Paxton system. A mining interest holds the water rights to approximately 455 thousand lpd of the lake, although no water is being withdrawn for mining use at present. There are a few dwelling units on the shores of Kirk Lake.\textsuperscript{29}

(2) Springs, Swamps and Streams

Water from the remaining springs, streams, swamps and smaller lakes on the island primarily supplies the domestic needs of individual households or small groups of households. Individual licenses rarely exceed 2270 lpd and the total amount of water allocated per source of water seldom reaches 14,000 lpd in these more remote areas. Officially, total allocated use, that is recorded licensed use, on the island is almost 909 million litres per day if storage is included. If storage is excluded then the total is 32 million lpd (see Table 4.7).
### TABLE 4.7: ALLOCATED SUPPLY: SUMMARY OF WATER LICENSE DATA

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>LITRES PER DAY (thousands)</th>
<th>PERCENT OF TOTAL</th>
<th>PERCENT OF TOTAL MINUS THE STORAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOMESTIC</td>
<td>306</td>
<td>.03</td>
<td>.91</td>
</tr>
<tr>
<td>STORAGE</td>
<td>851,000</td>
<td>96.23</td>
<td>--</td>
</tr>
<tr>
<td>INDUSTRY</td>
<td>618</td>
<td>.07</td>
<td>1.85</td>
</tr>
<tr>
<td>MINING</td>
<td>4090</td>
<td>.46</td>
<td>12.26</td>
</tr>
<tr>
<td>WATER WORKS</td>
<td>1200</td>
<td>.14</td>
<td>3.62</td>
</tr>
<tr>
<td>IRRIGATION</td>
<td>27,125</td>
<td>3.07</td>
<td>81.36</td>
</tr>
<tr>
<td>TOTAL</td>
<td>884,339</td>
<td>100.00</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Total:

884,339,000 litres per day = 884 cubic decameters/day [dam³/day]

Total - Storage:

884,339,000 - 851,000,000 = 33,339,000 litres per day or 33 dam³/day

The above table is a summary of the allocations to particular uses found in the Water License files for Texada Island. It is interesting to note that while there is very little farming on Texada that irrigation accounts for 81 percent of total use if the storage term is not included in the calculations.


**NOTE:** All calculations were done in imperial units and I have converted them into metric units. Some rounding of the numbers may have occurred.
4.1.3 The Potential For Future Development of Surface Supplies

The surface water resources of the northern Lowland region on Texada may, in many cases, be nearing total allocation. However, it should be noted that allocation and utilization are two different things in that a water source may be totally allocated to one user, yet that one user may not be utilizing all of the resource they have been allocated. Consequently, existing developed sources in the region could potentially sustain greater use. This possibility and the practicality of reallocating the resource could be investigated to see if the need to develop new sources could be postponed.

The surface water resources of the southern Highland region are not likely to be developed in the short-term due to their distant location and their small size. In addition, much of the southern region has been designated in the Georgia Strait Provincial Forest. Due to the construction of the Cheekeye-Dunsmuir Hydro power line, the roads in the southern Highland region have been upgraded and with the availability of power, the potential for development on Texada has increased. While there appears to be adequate supplies of surface water to meet the short-term requirements of Texada, there are problems emerging which relate to the location of supplies vis-à-vis the location of demands, conflicts between users, the natural quality of some sources, and degradation of existing sources.

While the former two issues will be dealt with in a later chapter dealing with balancing supplies and demands for water resources on Texada, the latter two concerns warrant brief discussion here. The concern about the natural quality of some
of the sources relates primarily to the taste of the water drawn from Cranby Lake which some have described as being "musty" -- particularly in the summer months. While potable at present, it is uncertain how long drinkers of this water will remain content with what is perceived to be poor quality water. This may necessitate that the water be treated in some way to remove the undesirable flavour or that another source of water for Gillies Bay be developed.

The other concern relates to the potential degradation of existing supplies due to inappropriate activities occurring in the source drainage basin. At present there is some concern about the effects that logging in the Cranby Lake drainage basin will have on the water quality in the lake.

These issues will come up again in succeeding chapters, but now let us turn to a discussion of Texada's groundwater resources.
4.3. GROUNDWATER ON TEXADA: THEORY, REALITY, AND POTENTIAL

While few data have been collected on the surface waters of Texada, even less are available on the groundwater resources. There are shallow wells that meet the domestic needs of individuals living beyond the reach of community waterworks systems of Vananda and Gillies Bay; however, there are no records to indicate "well yields, depth to water table, aquifer characteristics, or quality of water".¹ For this reason it is necessary to rely upon information on groundwater that has been generated through informal interviews with the residents and other knowledgeable people employed in mining activities on the island and combine this with assumptions made about the island's groundwater resources based on an understanding of groundwater hydrology and the island's geology. Therefore we will begin in this first section by looking at the theory of groundwater systems and behaviour and by reviewing the geologic history of Texada so that some educated guesses can be made about the location of potential supplies of groundwater. In the second section the observations of island residents about the behaviour of groundwater on Texada will be examined.

4.3.1 Theory

(1) Location

Groundwater is found below the surface of the earth in the saturated zone (refer back to Figure 2.1). Note that the groundwater occupies the saturated zone while soil water occupies the unsaturated zone and that the water table marks the plane between the two zones. The depth to the water table
fluctuates with the seasons -- being lower in the dry summer months and closer to the soil surface in the wet winter months. The majority of wells on Texada are shallow wells, meaning that some of them run dry during particularly dry periods due to the lowering of the water table below the depth of the well.

Groundwater occupies spaces in sub-surface geologic formations. These spaces or openings can be categorized into three general classes:

1. Openings between individual particles as in sand and gravel, referred to as original interstices.
2. Crevices, joints or fractures in hard rock which have developed from the breaking of the rock, called secondary interstices.
3. Solution channels and caverns in limestone, openings, resulting from shrinkage and from gas bubbles in lava. (see Figure 4.8)

The characteristics of these openings, that is their size, density, and nature, affect their ability to hold and store water. Porosity, which is a measure of the water-holding capacity of a sub-surface formation, is defined as "the ratio of pore volume to the total volume of a given sample of material".

2. Movement

Water in all phases of the hydrologic cycle is moving, although at varying rates. Groundwater flows from place to place in response to gradients established by differences in hydraulic head. Hydraulic head has two components the first of which, due to differences in elevation, exerts gravity forces, while the second, due to differences in pressure from point to point, exerts pressure forces. It is the combination of these forces which drives the movement of groundwater. Water always flows from areas of high hydraulic head to areas of low hydraulic
FIGURE 4.8: OPENINGS IN SUB-SURFACE GEOLOGIC FORMATIONS: RELATIONSHIP BETWEEN TEXTURE AND POROSITY

(a) Well-sorted sedimentary deposit having a high porosity; (b) Well-sorted sedimentary deposit consisting of pebbles that are porous which combined with the porosity of the formation means that the deposit as a whole has a very high porosity value; (c) Poorly sorted deposit having low porosity; (d) Well-sorted sedimentary deposit whose porosity has been diminished by the deposition of mineral matter in the interstices; (e) Rock rendered porous by solution; (f) Rock rendered porous by fracturing.

The ease with which water moves through a given porous sub-surface material under conditions of unequal hydraulic head is a measure of that material's permeability. Permeability is an attribute of the porous medium and is independent of the water flowing through the medium. Often confused with permeability, hydraulic conductivity is a function of both the sub-surface material and the groundwater. Table 4.8 shows the range of values of hydraulic conductivity and permeability for various materials which are commonly identified as aquifers and aquitards. Notice that metamorphic and igneous rocks, once fractured have higher conductivity and permeability values than before fracturing. Fracturing, folding, faulting and weathering (eg. the development of solution channels) of geologic materials increases their ability to hold and transmit water.

An aquifer can be defined as "a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients". This rather qualitative definition reflects the frequent use of the term in a relative sense. For example, a formation of sandstone in one geologic system may be an aquifer, while in another system composed of materials such as sands and gravels, which have high porosity and permeability values, may be an aquitard. An aquitard is a geologic material that, while significant to the study of groundwater in a region, is incapable of supporting production wells.

(3) Groundwater in Geologic Systems

Knowledge of the lithology, stratigraphy, and structure of a regional geologic system can lead to knowledge of the location
TABLE 4.8: RANGE OF VALUES OF HYDRAULIC CONDUCTIVITY AND PERMEABILITY FOR VARIOUS GEOLOGIC MATERIALS

<table>
<thead>
<tr>
<th>ROCKS</th>
<th>UNCONSOLIDATED DEPOSITS</th>
<th>PERMEABILITY K (cm/s)</th>
<th>CONDUCTIVITY K (cm/s) (gal/day/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$10^{-15}$</td>
<td>$10^{-11}$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^{-14}$</td>
<td>$10^{-10}$</td>
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<td>$10^{-5}$</td>
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<td>$10^{-1}$</td>
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<td></td>
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<td>$10^1$</td>
</tr>
<tr>
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<td>$10^{-2}$</td>
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<tr>
<td></td>
<td></td>
<td>$10^{-1}$</td>
<td>$10^3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^0$</td>
<td>$10^4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^1$</td>
<td>$10^5$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$10^2$</td>
<td>$10^6$</td>
</tr>
</tbody>
</table>

and character of aquifers and aquitards. Lithology describes the composition and nature of materials (rocks) within geologic systems, while stratigraphy identifies the age and relative positions between various strata within a geologic system. In terms of locating aquifers, one of the more important stratigraphic features is the unconformity. This is a "surface that represents an interval of time during which deposition was negligible or non-existent, or more commonly during which the surface of existing rocks was weathered, eroded, or fractured". The structural characteristics of a geologic system include such features as folds, faults, and fractures which as we have already noted, can improve the hydraulic conductivity of a geologic formation.

While groundwater data for Texada are unavailable, there is considerable information on Texada's geology. Piecing together what has been discussed about groundwater hydrology with the information that is available on Texada's geology and on the behaviour of water in Texada's streams during dry spells, it will be possible to make some educated guesses about the groundwater resources on the island.

(4) Surface and Groundwater Interaction

The behaviour of water levels in Texada's streams throughout the year can reveal some significant information about the groundwater resources on the island. Water flowing in a stream could be the result of overland flow, interflow or base flow. Overland flow is, in part, a form of runoff wherein water reaching the stream channel has moved over the land and into the channel. Overland flow contributes most significantly
to stream flow during and immediately after a rainfall event such as a thunderstorm. Interflow is the movement of soil water through a permeable near-surface layer of soil. Base flow is the portion of stream flow which has originated from groundwater seepage into the stream channel. During dry summers or quite a few days after a rainfall event base flow is likely to be the largest or only contributor to stream flow. When, as is the case with many of Texada's streams during the dry summer months, stream flow stops altogether, this is indicative of a lowering of the groundwater table below the level of the stream bed. If on the other hand the stream continues to have water running in it even after many weeks without rain, this indicates that the stream is being fed by the groundwater and that the groundwater table is above the level of the stream bed. In such areas it is possible to suggest that the groundwater recharge rate is higher than in areas where the streams run dry. This has significance in terms of the long term withdrawal of water from the ground in that the higher the recharge potential the more able is the area to sustain pumping over time.

As was noted on the section on surface water one of the streams which continues to flow throughout the year is Mouat Creek -- although at a much reduced rate during the summer. Although fed by small lakes and a system of swamps it is possible to suggest that the Mouat Creek drainage area may be significant in terms of the availability of groundwater resources.

(5) Geology of Texada

A review of the geologic history of Texada Island provides
us with an understanding of the types of materials that make up the geology of the island, the processes that have altered the porosity and hydraulic conductivity of these materials, and ultimately some ideas about the likely areas to explore for and develop the island's groundwater resources.

Approximately 225 million years ago volcanic activity resulted in the creation of the Anderson Bay formation (see Figure 4.9). It has been hypothesized that this formation, composed of amygdaloid, agglomerate, some small lenses of limestone and tuff, underwent folding and subsidence during the creation of the Karmutsen formation (the second period of vulcanism). This subsidence made possible the deposition and accumulation of the Quatsino Limestone formation. The Karmutsen formation makes up the larger portion of the island. Subsequently, granitic rocks (i.e. quartz diorite) intruded the Karmutsen and Quatsino formations along the east coast of the island. A subsequent intrusion produced the diorite igneous dyke system that, though present throughout the island, is particularly evident in a corridor running between the abandoned iron mines and Vananda. It is thought that the mineralization of this corridor occurred around this time.

During the period that followed, the island was partially submerged which led to the creation of the shale, sandstone and conglomerate formations along the west coast of the island. Evidence suggests that the largest of these formations, in the vicinity of Gillies Bay, rests unconformably on the underlying Karmutsen formation. The glacial period resulted in the repeated coverings and uncoverings of the island by ice and the
FIGURE 4.9: THE GEOLOGY OF TEXADA

SCALE: 1 cm=1.93 mi

SOURCE: Based on maps in McConnell (1914) and Matthews and McCammon (1957).

LEGEND

PLEISTOCENE  
Glacial and Interglacial

CRETACEOUS  
Gillies Bay Cretaceous Basin

JURASSIC - CRETACEOUS  
Diorite and diorite igneous intrusions
Quartz diorite dyke intrusions

LOWER JURASSIC  
Quatsino Limestone Formation

LOWER JURASSIC OR TRIASSIC  
Karmutsen Formation (igneous)
Anderson Bay Formation
accompanying erosion and deposition of materials. Shallow glacial till deposits are common in the northern portion of the island, while the deeper interglacial and glacial deposits are primarily found in the Crescent and northern Gillies Bay areas. Since the close of the glacial period, wind and the movement of water (e.g. waves, streams, precipitation, etc.) have played an ongoing role in affecting the island's geology. In the last hundred years man's activities have been significant in shaping the geology of Texada.

(6) Groundwater on Texada

In attempting to identify areas where groundwater supplies could potentially be developed there are many uncertainties related in part to the complexity of Texada's geology and in part to the complex array of factors influencing the location and movement of groundwater. The Karmutsen formation, which makes up roughly 70 percent of the island, is not likely to yield significant quantities of water over the long-term. Similarly, the quartz diorite intrusions along the east coast are unlikely sites for the development of groundwater resources for long-term use. However, it may be possible under certain conditions to extract water from these materials for a short period of time. For example, a sizeable fracture or fault that runs deeply into either of these formations may yield significant quantities of water for a few days, weeks or months. This water will have been collecting in the fracture for millennia accounting for the quantity available. However, due to the slow recharge rate of the surrounding material and the length of time it took the water to accumulate in the fracture,
use of the fracture as a source of water will be a one time event analogous to mining for a precious metal.

The Quatsino Limestone formation occupies a considerable portion of the northern half of Texada. While limestone is frequently capable of storing significant quantities of water, it is likely to be a poor choice as an aquifer unless it has extensive solution channels or fractures. The activities of man in the area have resulted in the excavation of large limestone quarries which, once abandoned, fill with groundwater, runoff, and precipitation. The water in these abandoned quarries appears clean and fresh and it is thought that the water "comes and goes through faults in the rock formations". It is suspected that groundwater makes up the largest component of the water in these quarries because water levels never fluctuate more than a meter throughout the year. Because of the presence of the quarries with their ready supply of fresh water it seems evident that the Quatsino Limestone formation could be a source of water. However, the development of the quarries would be a first priority due to their certainty of supply. Drilling wells in the limestone is less certain for it is not known where the fractures or solution channels are and without these secondary interstices, limestone is a less attractive source of groundwater.

The Anderson Bay formation occupies a small portion of the southern tip of Texada. Along the contact between the Anderson Bay formation and the Karmutsen formation there may be an adequate source of groundwater. The reason for this supposition is that it is thought that the Texada formation rests
unconformably on the Anderson Bay formation and as was mentioned earlier, aquifers can frequently be found in the area of an unconformity.6

The shale, sandstone and conglomerate formation in the vicinity of Gillies Bay and Mouat Bay also rests unconformably on the underlying formation. This fact combined with its natural porosity, permeability, and hydraulic conductivity, makes this formation the most likely of the geologic formations discussed thus far to be a suitable source of groundwater.

However, the best aquifers on Texada are likely to be the glacial and interglacial tills of both the Crescent and Gillies Bay areas. The Crescent Bay deposits are composed of beds of sand interstratified with silt and have been used as aquifers for industrial and domestic water needs in the past.7

4.3.2 Reality

The purpose of this section is to bring together the observations of some of the residents of Texada and those of the author herself with respect to the groundwater resources on the island. Residents living outside the boundaries of the Vananda or Gillies Bay waterworks districts frequently rely on groundwater, that is springs, shallow wells or deep wells, for their domestic needs.

While in British Columbia a water license is required in order to take water from a spring indicating that springs are considered a surface water resource, a spring is a "concentrated discharge of groundwater appearing as a current of flowing water" (see Figure 4.10).8 There are two main areas on Texada
DEPRESSION SPRINGS - formed at the intersection of the ground surface and the water table.

CONTACT SPRINGS - form where a permeable water-bearing formation overlies a less permeable layer that intersects the ground.

SOLUTION TUBULAR SPRINGS - issuing from tunnels in lava, solution channels in limestone, and fractures in rock.

ARTESIAN SPRINGS - result from the release of water that is under pressure in a confined aquifer and is either at an outcrop of the aquifer or at an opening in the confining layer.

where springs have been licensed and developed for use and these are the area east of and south of an abandoned quarry known as Heisholt Lake and the area southeast of Gillies Bay along School Road (see Figure 4.11). Some of these springs do decrease their yield and in some cases run dry during the dry period in late summer. But others, such as Hogan Spring in the area just northeast of Harwood Point and which yields enough water to supply 7 households throughout the year, seem to have ample water.

The majority of wells on Texada are shallow wells which Todd (1980) defines as wells less than 15 meters deep. Indeed many of the wells on the island are less than 6 meters deep. There are three main areas where people rely on shallow wells. These areas include the Crescent Bay road area, the Blair and Spragge subdivision area and the area along School Road.

(1) Crescent Bay Road

In the Crescent Bay area some residents rely on creeks and some rely on wells to supply their domestic water needs. The wells in the area average around 3 meters deep. The majority of these wells run dry during the summer so that residents must bring water in from elsewhere. Specific data on the water yields of these wells during the various seasons of the year are unavailable.

(2) The Spragge and Blair Subdivisions

The Spragge and Blair subdivisions lie between Vananda and Gillies Bay in a depression which runs between Cranby and Paxton Lakes on one side of the highway and Myrtle and Case Lakes on the other side of the road. While some residents rely on water
FIGURE 4.1: SIGNIFICANT AREAS WITH RESPECT TO GROUNDWATER ON TEXADA ISLAND

KEY

s Springs commonly found in these areas
1 Crescent Bay (aquifer beneath area)
2 Blair & Spragge Subdivisions (swampy in places)
3 High Road (springs)
4 School Road (springs and high groundwater table)
5 Old Texada Mine Workings (flooded, minimal use)
6 Heisholt Lake (abandoned quarries - unused water)
7 Quarry Nos. 2 & 3 (industrial and domestic supply)
8 Quarry No. 6 (still being used)

(see text for amplification)
from Case Lake, the majority of the area's residents take their water from shallow wells of about 6 meters deep. The water table in the area averages about 4 meters deep throughout the year. While water yield varies from place to place in the area, one property owner provided information that suggests that yield from her well would be approximately 455 litres per hour even in the summer. While she experiences no shortage of water during the summer, her neighbours across the road have had to restrict their use on occasion. Some residents in the area have made it a habit to boil their drinking water presumably because they fear contamination of their wells may be occurring as a result of septic tank runoff or seepage. Whether or not this is a problem throughout the area remains uncertain.

(3) School Road

Near the west end of School Road near Harwood Point, residents take their water from springs in the area. At the junction between School Road and the High Road some residents rely on springs and streams, the latter of which frequently dry up during the summer, and some rely on shallow wells which apparently seldom give rise to water shortages in the summer. There is one deep well in the area near the junction of the High Road and the School Road that is 90 meters deep and which is said to be capable of supporting at least 6 or 7 households. In the mid-section of School Road residents at the junction of the main road and a side road leading south near the crest of the hill experience no water shortages in the summer months. One resident's well is only 4 meters deep yet he is able to support himself, his wife, poultry and, at one time, 6 or 7 cattle on
this well with no difficulties.\textsuperscript{56} His neighbours in the immediate area apparently are similarly well endowed with water. However, his neighbours down the road towards Harwood Point have had variable success with their water whether drilling deep wells or digging shallow wells.

We have discussed groundwater as it is found in springs and wells but on Texada with its history of underground mining and more recently of limestone quarrying, the 'groundwater' resource of the island also includes the water which has flowed into abandoned mining sites. This water could have been included in the surface water section; however, it is felt that while the open pits do receive water directly from precipitation and indirectly from surface runoff, in many cases the water flowing into these man-made depressions and tunnels is the result of groundwater flow. Admittedly this is an arbitrary categorization, but one which is well suited to the purposes of this thesis.

There are three areas on Texada where abandoned mine workings have created an additional supply of fresh apparently potable water. These areas include Ideal Cement's property at Welcome Bay northwest of Gillies Bay, the number 4 and 5 quarry northwest of Vananda and otherwise known as Heisholt Lake, and quarries number 2 and 3 at Blubber Bay.

(4) Texada Mine Workings

The previous owner of Ideal's property was Texada Iron Mines which dug extensive tunnels in one portion of their property in order to extract iron ore.\textsuperscript{57} In addition to a system of shafts (vertical tunnels) and drifts (horizontal tunnels)
this operation also excavated large open pits in their efforts to extract the ore. Texada Mines shut down its iron mining operations in the mid-seventies and sold its property to the Ideal Cement Company. Ideal's primary interest was in the limestone on the property. The iron mine workings, although located along the contact between the iron ore bearing rock and the limestone geological unit, were not to be a part of Ideal's active mining operations. Consequently, these workings were abandoned which meant that the continuous pumping that had been necessary to keep the mine tunnels and pits dry during active mining was discontinued. The total volume of these tunnels and pits has been estimated to be about 2500 million litres or 2500 dam$^3$.

Pumping in these tunnels was discontinued in 1977 and 3 1/2 years later in 1980 the system of tunnels and pits had filled to its current level. It is estimated that 2 dam$^3$ of water a day flowed into these mine workings as they were filling. The volume of water in this mine is a little greater than the volume of water in Priest Lake (2280 dam$^3$).

A pump on a floating platform has been set up in one of the pits known as the Paxton Pit. While the Paxton Pit is the primary source of fresh water for the limestone mine, a swamp and possibly a creek system located on the eastern portion of the property near the limestone quarrying operations serve as additional sources of water in summer -- primarily due to their nearness to the limestone quarry. This will be explored further in the following chapter which deals with the use of water.

(5) Heisholt Lake

The abandoned number 4 and 5 quarry, that is Heisholt Lake,
is located adjacent to the highway mid-way between Vananda and Blubber Bay. The quarry has been abandoned for some time, but has since filled with water. It has been suggested that Heisholt Lake acts as a reservoir of water flowing through the rock (limestone) and surfacing at the head of Sturt Creek. The pit is not very deep and its surface area is not more than 1 hectare, giving it an estimated volume of between 92 and 123 dam$^3$ at the most. At one time the lake was used as a fresh water swimming lake, but the company which owns the property where the quarries are located has restricted access apparently for fear of being held liable in the event of an accident. Currently Heisholt Lake is not being used except by a few fish. The presence of trout would suggest that the water quality in the lake is probably pretty good and could potentially be a source of potable water.

(6) Blubber Bay Quarries

In the Blubber Bay area there are three quarries. Number 6 quarry is currently the site of active limestone mining activity, while the number 2 and number 3 quarries have been abandoned and allowed to fill with water. The number 3 pit is 18 meters deep and has a surface area of about half hectare, giving it a maximum volume of 74 dam$^3$. This pit is the domestic supply for approximately 10 homes in Blubber Bay. The water level in this pit drops about 1 meter during the dry period. At one time this pit was acting as a water reservoir for 30 homes in the Blubber Bay area, but with the deepening of the number 6 quarry to the southwest, it has been estimated that the water recharge and supply to the number 3 quarry has decreased
by 50 percent. This is an excellent illustration of how mining activity in one area can affect the flow of groundwater in another area.

The number 3 quarry is connected to the number 2 quarry by a tunnel which causes excess water from the number 3 quarry to flow into the number 2 pit. The number 2 pit is 60 to 76 meters deep with a surface area of about a quarter of a hectare, giving the pit an estimated maximum volume of about 123 dam$^3$. Water from this pit is used in clean-up and the mining operations, then recycled through a settling pond and is eventually pumped back into the number 2 quarry. Consequently, the level of water in this pit does not vary significantly during the year. Although during the wet winter months excess water (estimated at about 18,200 litres total) must be pumped into the sea to prevent the pit from overflowing.

While it is likely that the water in these pits currently is primarily the result of precipitation and surface runoff, there are indications that the groundwater resource in the area around Blubber Bay could be a potential source of fresh water for small numbers of people (e.g. 150 people). This seems supportable in part by observations that there has apparently been significant solution channel development in the limestone formation east-southeast of Blubber Bay. The development of such channels increases the permeability and the water holding capacity of the ground in the area.

Having looked at the theory behind the character and behaviour of groundwater on Texada and in this section reviewed some of what the island's residents have observed about Texada's
groundwater resource, we turn now to draw some conclusions about the areas on the island which may have significance in terms of groundwater and its future development.

4.3.3 Potential

Concluding this section on groundwater it can be suggested that the following areas may have potential for the future development of groundwater as a source of potable supply:

1. The abandoned limestone quarries of the Quatsino Limestone formation and the abandoned Texada iron mine workings. Together the combined storage of the mine and the quarries is estimated to be between 2500 to 2600 dam$^3$.

2. The Gillies Bay and the Crescent Bay Glacial Deposits. They have an estimated storage of 74 thousand and 99 thousand dam$^3$, respectively.

3. The Gillies Bay Cretaceous Basin, the system of which many of the wells and springs in the vicinity of School Road are a part. This area has an estimated maximum storage of 118 thousand dam$^3$.

(See Figure 4.12 for the locations and the extent of these areas; and see Appendix B for the derivation of the above estimates)

Together these sources of groundwater contain approximately 293 thousand dam$^3$ of water. However, due to the depth of the water in the geologic formations and its location it is assumed that only between 25 and 50 thousand dam$^3$ of the groundwater stock are potentially usable by the human water demand system (see Figure 4.13). It should be emphasized at this point that these figures are really only "guesstimates" of usable supply and that they are extremely conservative estimates. It is likely that the stock of groundwater may be at least double these figures. However, as will be seen in the following chapter
FIGURE 4.12: PRIORITY SITES FOR EXPLORATION AND DEVELOPMENT OF GROUNDWATER ON TEXADA

Areal extent of Limestone formation
Quarries with the potential to supply water
Crescent Bay and Gillies Bay Glacial Deposits
The Gillies Bay Cretaceous Basin

(see text for amplification)
FIGURE 4.13: SCHEMATIC SUMMARY OF THE GROUNDWATER SUPPLY IN THE LOWLAND REGION ON TEXADA ISLAND
(all figures in cubic decameters - dam$^3$)

* See explanation of the term "usable" in the text.

SOURCE: See Table 4.9 and Appendix B.
present demand is only a tiny percentage of even the usable groundwater stock. Thus the need for accuracy in these stock figures is reduced.

It should also be noted that these figures represent the storage potential of these areas which is to say they represent the amount of water that is being held in these quarries and geologic units at any one time. But, as has been emphasized throughout this thesis, water is a dynamic resource -- a resource that is constantly cycling through the natural and, when diverted, man-made environments. Therefore an ultimate concern, if we are looking at the potential of the water resource to sustain use over the long-term, is with the amount of water being cycled through the groundwater phase of the hydrologic cycle over a given period of time -- in other words the rate of recharge.

To illustrate this, consider that the abandoned limestone quarries perhaps hold the greatest potential for the development of groundwater on Texada. The Quatsino Limestone formation, of which the quarries are a part, has the largest areal extent of the formations listed above and the areal extent of a formation is an important factor when considering the recharge potential of an aquifer. The size and depth of the quarries together with the behaviour of the water levels in the quarries would seem to indicate that the recharge potential of this area is large enough to be able to sustain pumping over a long period of time at rates not significantly greater than the recharge rate.

While the Gillies and Crescent Bay glacial deposits are highly permeable and porous formations, their limited areal
extent and depth indicates that their storage capacity is not that large and that the recharge potential is therefore also reduced. Consequently, these formations have a limited potential and are perhaps best suited to serving a small group of water users or to acting in conjunction with surface supplies to serve a larger community of users (e.g., in the dry summer months to supplement surface supplies).

The Gillies Bay Cretaceous Basin, though larger in areal extent than the glacial deposits is not significantly larger and has lower porosity and permeability values than the unconsolidated glacial deposits. Consequently, this area is perhaps better suited to serving individual or small groups of households that are dispersed over its area.

While the rate at which water is being cycled is one significant concern another is the rate at which and the length of the period the resource will be used. It is unlikely that Texada is part of a coastal aquifer system, therefore the Texada system probably can not sustain large-scale pumping networks for a prolonged period of time without depleting the stock of water stored in the ground. The carrying capacity of the island's groundwater resources would need to be determined more precisely prior to any plans for large-scale exploitation of this resource. We will come back to this notion of carrying capacity in Chapter 6.

4.4 WASTE DISPOSAL

It has been stated again and again that water is continuously moving or cycling through a series of stages
broadly termed the hydrologic cycle. Some of this water is diverted from the cycle by man to serve his purposes. Eventually however, this water is returned to the natural hydrologic cycle -- frequently in worse shape than before it was diverted. This waste water, as it is called, can contain any number of deleterious substances such that as it re-enters the natural part of the hydrologic cycle it can potentially degrade the aquatic or terrestrial environments it comes in contact with.

The significance of all this to the present discussion of water supply on Texada is that waste water, by coming in contact with the ground- or surface water on the island, may degrade the quality of natural waters to the extent that it in effect reduces the quantities of potable water available. Consequently, prior to it being used the water may need to undergo costly treatment procedures. In the small self-contained environments of islands it would perhaps be better to ensure that wastes -- whether aqueous or solid -- are disposed of in such a way so as to not degrade the fresh water or terrestrial environments on the island, particularly those in or adjacent to current or potential sources of water supply.

On Texada the main threats to water quality, and therefore to the quantities of water available, are the improper installation and maintenance of septic tanks, careless land-use practices in areas adjacent to existing supplies, unauthorized dumping of waste materials into abandoned mine shafts and inappropriate sites for the location of landfills. This subject will be raised again in the following chapters.
SUMMARY

This chapter has generated a picture of the location, quality, quantity and timing of the surface and ground waters of Texada Island. Calculation of the water balance for the Lowland Region found that the total volume of precipitation falling on the region is about 46 thousand dam$^3$. The volume of evapotranspiration from the region is between 22 and 28 thousand dam$^3$, while the volume of runoff is between 17 and 23 thousand dam$^3$ depending on the soil storage capacity. The natural supply of both surface and ground water in terms of the absolute stock of water available is quite substantial. The total volume of the surface water resource on Texada is estimated to be about 12 thousand dam$^3$ and it is quite likely double this amount. The total volume of groundwater in geologic formations that are likely aquifers on the island, though difficult to estimate with any certainty is approximately 300 thousand dam$^3$. However, for various reasons (see Table 4.9 and Appendix B), total usable supply on the island is between 37 and 62 thousand dam$^3$. However, certain areas of the island, even specific sites within areas, can experience an inadequacy of supply during the drier periods during late summer.

Much of the island's population relies on surface waters; however, in the more remote areas or in the areas outside the jurisdiction of either the Gillies Bay Improvement District or the Vananda Waterworks District a great many of the residents rely on shallow wells.

The northern Lowland region has a greater water resource potential and is also more densely settled than the southern
TABLE 4.9: SUMMARY TABLE OF THE NATURAL WATER RESOURCE SUPPLY ON TEXADA ISLAND
(all figures in cubic decameters)*

1. SURFACE WATERS (from Table 4.6)

<table>
<thead>
<tr>
<th>Region</th>
<th>Surface Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highland Region</td>
<td>3946</td>
</tr>
<tr>
<td>Lowland Region</td>
<td>8015</td>
</tr>
<tr>
<td>Total Surface Water</td>
<td>11,960</td>
</tr>
</tbody>
</table>

2. GROUNDWATER

<table>
<thead>
<tr>
<th>Deposits</th>
<th>Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abandoned mines and quarries</td>
<td>293,839</td>
</tr>
<tr>
<td>Ideal's (Texada Mine's) Pits</td>
<td>2500</td>
</tr>
<tr>
<td>Heisholt Lake (Quarry No. 4 &amp; 5)</td>
<td>154</td>
</tr>
<tr>
<td>Blubber Bay (Quarry No. 2)</td>
<td>123</td>
</tr>
<tr>
<td>Blubber Bay (Quarry No. 3)</td>
<td>74</td>
</tr>
<tr>
<td>Crescent Bay Glacial Deposit</td>
<td>98,640</td>
</tr>
<tr>
<td>Gillies Bay Glacial Deposit</td>
<td>73,980</td>
</tr>
<tr>
<td>Gillies Bay Cretaceous Basin</td>
<td>118,368</td>
</tr>
<tr>
<td>Total Groundwater</td>
<td>293,839</td>
</tr>
</tbody>
</table>

TOTAL WATER SUPPLY ON TEXADA

| Total Water Supply | 305,799 |

* These figures are an estimate of the average quantity of water expected to be found at any one point in time.

** The bulk of this 305,800 cubic decameters of water is groundwater and of this may be extremely difficult and costly to extract. Appendix B makes clear the fact that while there may be 294,000 cubic decameters of groundwater in the geologic formations identified as aquifers, the water yield rate of these deposits remains largely unknown. Consequently, in the text there has been a distinction made with respect to groundwater that is likely to be accessible and usable in the near future. Based on those arguments then, the total stock of water on Texada that is likely to be usable in the near future is assumed to be between 37,000 and 50,000 cubic decameters.

NOTE: All calculations were done in imperial units and were later converted into metric units. Some rounding of the numbers may have occurred.
Highland region. Consequently, the potential for the development of both ground and surface water resources is greatest in the Lowland region and more specifically in the area between Vananda and Gillies Bay.

In the chapter that follows the location, timing, quality and quantity of water demands on Texada in both the present and future will be examined.
CHAPTER 5
DEMAND: THE USES OF WATER ON TEXADA ISLAND:
PRESENT AND FUTURE

INTRODUCTION

Texada has a population of approximately 1200 people and a simple economy based primarily on the mining of limestone. Consequently, the major water using sectors on the island are the domestic and industrial sectors. Of much less importance are the agricultural sector and the catch-all sector which includes recreational, power generation and ecosystem uses of the water resource (see Figure 5.1).

The purpose of this chapter is to analyse the present and future requirements for water on Texada Island. The chapter will be constructed of two major sections, the first of which will characterize the present patterns of water use on the island with respect to each of the sectors identified above. The other major section will consider alternative future directions for the economy and the character of settlement patterns on Texada and their implications for water use. This exercise will generate some notions about the magnitude, location and timing (seasonal) of future demands such that when, in the following chapter, the water resource capability of Texada is examined, ways of planning and managing the use of the resource base can be suggested.

In the following section estimates are given for the current annual rate of water demand by various water using sections. In most cases there were no records for the rate of water use. In these cases a variety of methods for estimating
FIGURE 5.1: SCHEMATIC OF THE WATER USING SECTORS ON TEXADA

NOTE: ALL FIGURES IN CUBIC DECAMETERS [DAM\(^3\)]
water demand were used. In some situations my own and residents' observations about the behaviour of water levels during the year combined with eyeball estimates of the size of reservoirs, quarries, wells and storage facilities provided the basis for demand estimates. These estimates were always checked against the findings of the literature with respect to average water use by various sectors. In general the majority of estimates coincided well with expected rates as defined by the literature. However, when discrepancies arose, professionals in the Water Management Branch of the B.C. Ministry of the Environment were consulted to discover possible reasons for the differences between estimated and expected rates of water use.

5.1 PRESENT WATER USE ON TEXADA

In this section, the characteristics of present water use on Texada in terms of the location, timing, quantity and quality of water used by the domestic, industrial, agricultural and, the special category, "other" sectors will be examined.

The evolution of settlement on Texada can be characterized as having gone through periods of "boom and bust". While initially Texada was used by whalers as a place to process blubber (hence the name Blubber Bay), a subsistence fishing and agricultural community followed. The discovery and mining of iron ore, north of Gillies Bay in 1871, set the tone for what was to follow. Gold mining began in the 1880's and continued to expand. This activity centered on the growing settlement at Van Anda, as it was then called. By 1887 limestone was being mined and processed into lime at Blubber Bay and marble was being
quarried at Anderson Bay. In 1919 the boom turned to bust and many of the lode mines closed down; however, limestone emerged as a consistently marketable resource during the depression years. Another brief boom occurred in 1944 when one of the gold mines opened; however, it shut down again in 1952. The latent demand for building products, particularly lumber, in the post-World War II years resulted in a boom in the forest industry on Texada. This industry began to decline in the early 60's when stands of accessible prime timber became scarce. Only a handful of local operators continue to log the island.

In the mid 50's the island economy was kept alive by the development of iron mining in and around the site of the first discovery of iron ore 80 years earlier. Many employees of Texada Iron Mines resided in the small community of Gillies Bay. The iron mining operations shutdown in 1976; however, this event was tempered somewhat by the continued quarrying activity and the marketability of limestone products.

The communities of Gillies Bay and Vananda have remained viable settlements for the mine workers and the increasing numbers of summer and retired residents who have built homes on the island. The majority of the island's population reside in either the community of Gillies Bay, Vananda, or Blubber Bay. None of these communities has a very well-developed commercial sector, which means that island residents are dependent on Powell River and Westview on the Mainland. While very much subject to external controls, whether originating with higher levels of government or with world markets, Texada has to date maintained population levels between 1100 to 2600 people over
the last 20 years. At present the bulk of the population and activity on the island is situated on the northern half of Texada; therefore most of the demand for water originates here as well. However, with the construction of the Cheekeye-Dunsmuir hydro line across the southern portion of the island in the late 70's, this virtually uninhabited region has been made more accessible with the roads hydro has constructed, and power is also more readily obtainable. Much of this southern area has been included in the Georgia Strait Provincial Forest. Consequently, settlement and industry will likely continue to be attracted to the northern Lowland Region.

5.1.1 Domestic Use

Domestic Water use on Texada includes water for residential, commercial, and public uses. Fire protection, water for the school and other public buildings and water for the parks are the public uses of water on Texada.

(1) Public Uses

Harwood Point, south of Gillies Bay, is a park utilized for overnight camping, picnicking, boat launching and beachcombing by island and Mainland residents (mostly from Powell River) primarily during the summer months and on weekends during the spring and fall. The park has 28 overnight camping spots near the beach and 9 overflow sites adjacent to the road up from the beach. There are two water taps, 3 toilets and 2 urinals servicing the park. On a weekend during the peak period in summer the park may have as many as 1000 visitors. At present, two wells, 5 meters deep and 1 meter in diameter, have been dug
in an area fed by a spring. These wells, in turn feed into a 23 thousand litre storage tank. In May each of these wells is capable of supplying 2000 litres per hour. In August this figure drops to 400 litres per hour. Consequently, on a busy weekend during the summer months water use in the park must often be restricted. The other parks on Texada are of a different sort (eg. ball parks and playing fields) so consequently water use is negligible.

The Gillies Bay Improvement District (GBID) and the Vananda Waterworks District are responsible for providing fire protection services in their respective jurisdictions. It is estimated that approximately 350 dwellings are protected under these areas. It has been estimated that each of these jurisdictions may have to answer to 2 fire calls each in a year. The Blubber Bay area has approximately 10 homes which come under the protection of Oregon Portland Cement's operations at the Blubber Bay site. Areas outside these jurisdictions must protect themselves. Total requirements for water for fire protection purposes on Texada, that is the amount of water that must be on hand in the event of fire, is estimated to be approximately 8.6 million litres on any given day assuming a total island population of 1800.

There are very few commercial activities on Texada, and all of these are either in Vananda or Gillies Bay. Consequently, many residents go to the Mainland for their service and retail needs. Water in commercial establishments is typically required for flushing toilets, drinking and cleaning. The largest commercial users of water are likely the hotel, the coffee shop, and the grocery store in Vananda.
There is little or no data available on water use by commercial users on Texada and in the literature commercial water use is typically lumped together with domestic water use as has been done in this thesis. However, there is some indication that commercial water use estimates in the literature are based on the type of business, the number of employees and in some cases the floor area of the building the business is located in. In this analysis each business was considered independently and assumptions were made, based on observations regarding the above 3 determinants of water use, as to the amount of water used by each commercial user. Total commercial use of water on Texada is assumed to be about 14 to 23 thousand litres per day during non-peak periods (September through May) and 29 to 55 thousand litres per day in the peak period June through August (see Table 5.1). This brings total annual demand by commercial users on Texada to between 10 and 20 million litres.

(2) Use in Blubber Bay

Blubber Bay on the northern tip of Texada has a population of 67 people. The economic base of the community is Oregon Portland Cement's (OPC) Blubber Bay limestone quarrying operations. The ferry to Powell River also berths in the bay. Approximately 10 homes currently rely on water from abandoned quarry number 3, while other residents in the vicinity rely on shallow wells for their domestic water needs. These domestic needs include water for drinking, cooking, flushing toilets, and during the summer, lawn and garden sprinkling. Estimates of water use for domestic purposes in the literature vary, ranging
### TABLE 5.1: ESTIMATED DAILY WATER USE BY COMMERCIAL USERS ON TEXADA DURING THE SUMMER MONTHS *

<table>
<thead>
<tr>
<th>WATER USE (litres. per day)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Maximum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. **VANANDA:**

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grocery Store</td>
<td>2275</td>
<td>4550</td>
</tr>
<tr>
<td>Variety/Hardware</td>
<td>230</td>
<td>455</td>
</tr>
<tr>
<td>Service Station</td>
<td>455</td>
<td>910</td>
</tr>
<tr>
<td>Hairdresser</td>
<td>1820</td>
<td>2730</td>
</tr>
<tr>
<td>Insurance/Real Estate Office</td>
<td>115</td>
<td>230</td>
</tr>
<tr>
<td>Hotel - Cafe Lounge</td>
<td>4550</td>
<td>6820</td>
</tr>
<tr>
<td>Post Office</td>
<td>115</td>
<td>230</td>
</tr>
<tr>
<td>Plumber</td>
<td>115</td>
<td>230</td>
</tr>
</tbody>
</table>

Total for Vananda                | 9660    | 16,150  |

2. **GILLIES BAY:**

<table>
<thead>
<tr>
<th>Business Type</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical Clinic</td>
<td>1820</td>
<td>2730</td>
</tr>
<tr>
<td>Bank</td>
<td>115</td>
<td>135</td>
</tr>
<tr>
<td>Grocery Store</td>
<td>1135</td>
<td>1820</td>
</tr>
<tr>
<td>Stationary Store</td>
<td>70</td>
<td>140</td>
</tr>
<tr>
<td>Laundromat</td>
<td>13,640</td>
<td>27,275</td>
</tr>
<tr>
<td>Service Station</td>
<td>455</td>
<td>910</td>
</tr>
<tr>
<td>Cafe/Lounge</td>
<td>910</td>
<td>1820</td>
</tr>
<tr>
<td>Motel</td>
<td>910</td>
<td>1820</td>
</tr>
<tr>
<td>Liquor Store</td>
<td>70</td>
<td>140</td>
</tr>
<tr>
<td>Electrical Contractor</td>
<td>45</td>
<td>90</td>
</tr>
</tbody>
</table>

Total for Gillies Bay            | 19,160  | 36,870  |

3. **TOTAL FOR TEXADA ISLAND:** (peak period)

<table>
<thead>
<tr>
<th>WATER USE (litres. per day)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Maximum</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total for Texada Island        | 28,820  | 40,420  |

* Commercial Users are concentrated exclusively in Vananda and Gillies Bay.

**SOURCE:** The information in this table is based on my own field observations and assumptions, see text section 5.1.1 (1) for amplification.

**NOTE:** All figures have been converted from imperial units to metric units. Some rounding of the numbers has occurred.
from 225 litres per capita per day (lpcpd) to 700 lpcpd. However, from the data available for domestic water use in Gillies Bay and Vananda, it would seem that domestic water use by residents on centralized water systems on the island is considerably higher. This seems to be due to the age and state of repair of these systems and their tendency towards freezing during cold snaps if the water is not left running. Consequently, average daily per capita use of water for domestic users in Blubber Bay is assumed to be 900 lpcpd, which is in keeping with rates in Vananda and Gillies Bay. Therefore total annual water use for Blubber Bay is estimated to be approximately 22 million litres or 22 dam³. In the summer months rates of water use can be expected to increase. A large proportion of this increase can be attributed to the use of water in lawn and garden sprinkling. Water levels in the number 3 quarry typically drop about 1 meter during this period partly due to an increase of evapotranspiration over precipitation, but also because of the increased rate of consumption by community residents. The community relies upon private septic tanks for disposing of their sewage and, as yet, this has not resulted in any known contamination of the water supply.

(3) Use in Vananda

In Vananda there are approximately 342 residents living in 178 households. In addition to residential users there are several commercial users and 1 or 2 industrial users connected to the water supply system which delivers water from Priest Lake.

Vananda is located on rocky outcroppings which surround and
protect Eagle and Sturt Bays. As a result, large lawns and gardens which demand copious amounts of water in the summer are largely absent in Vananda. Many water lines in the 30 year old system are "almost on the surface and a cold snap can leave some residents without water for weeks at a time". Therefore during cold periods such as occurred during December 1983, residents often leave their water running to prevent the pipes from freezing. By examining the pattern of water use over the course of 1983 it can be seen that 2 periods of peak demand occurred (see Figure 5.2). As expected there was a period of peak demand during the dry summer months. During this period demands double mid-winter rates. However, during the cold snap demand again rose as taps were left running.

During 1983, total annual water use in Vanada (minus that water used for non-residential purposes) was approximately 105 million litres or 105 dam³. This averages out to about 855 lpcpd (342 residents using water 365 days a year). This figure seems a bit high; however running the water to keep the pipes unfrozen can account for some of this excessive use.

Vananda residents like to brag that their water is the best tasting on the island and this may well be as it comes unchlorinated from Priest Lake which is fairly deep and cool. However, in the future some disinfection may be necessary because the lake is vulnerable to contamination primarily due to its size, attractiveness and accessibility for recreation.

(4) Use in Gillies Bay

There are approximately 345 residents of Gillies Bay. An estimated 189 homes lie within the Improvement District
FIGURE 5.2: DOMESTIC WATER USAGE IN VANANDA FOR 1983

(monthly average daily consumption rate in thousands of litres per day)

TOTAL WATER CONSUMPTION = 107 million litres for the year.

Assuming that there are approximately 342 people on the Vananda waterworks system, then per capita consumption is about 855 lpcpd.

SOURCE: Derived from data supplied by the Vananda Waterworks District -- pumping records for 1983.
boundaries, and are supplied with water via a waterworks system taking water from Cranby Lake. Residents who live outside the Improvement District boundaries, that is residents along the southeast shore of Gillies Bay, rely either on shallow wells or on springs. Occasionally during the summer months some of these residents must restrict use to some degree. If infilling occurs in this area and, as a result, the number and density of septic tanks increases, contamination of water supplies could emerge as a problem. On the northwest side of Gillies Bay gently sloping glacial and interglacial tills have encouraged the development of a grid layout subdivision of fairly low densities and sizeable lawns and gardens. Consequently, in addition to water for drinking, cooking, cleaning and use in toilets, water for sprinkling purposes makes up a significant proportion of domestic water demand, particularly during the summer months.

The amount of water being drawn from Cranby Lake is measured at the chlorinator device onto charts where another device automatically records the amount of water flowing through the chlorinator at any particular point in time. Analysis of these weekly charts is done at the end of the year in order to fill out the Annual Water Distribution Report required of waterworks districts by the Water Management Branch of the Ministry of the Environment. Figure 5.3 shows the average water usage in litres per day for the Gillies Bay Improvement District in 1983. The figure indicates that water use during the peak period in the summer months can more than triple typical use rates during the wetter winter months. Total annual water use
TOTAL WATER CONSUMPTION = 122 million litres for the year.

Assuming that there are about 335 people on the water supply system, then per capita water consumption is about 1000 litres per day. From calculations elsewhere daily consumption for Gillies has been estimated to be about 1000 litres per capita per day.

SOURCE: Derived from data supplied from the Gillies Bay Improvement District Chart Flow Records for 1983.
for the GBID in 1983 was approximately 120 million litres which averages out to about 1100 lpcpd. This is an unusually high figure for per capita daily use. A more 'average' figure would be somewhere around 455 lpcpd. The excessively high figure of 1100 lpcpd could be due to serious leaks in the distribution system, excessive leakiness of the storage surge tank or perhaps a malfunction of the chlorinator chart flow device. Assuming the latter is the case, then the actual annual domestic water use for the Gillies Bay area, including the area along the southeast shore of the bay (estimated proportion of total use for the area as less than 10 percent), would be approximately 59 million litres or 59 dam³. Another possible partial explanation for this high rate of water use could be that residents in Gillies Bay, like those in Vananda, leave their taps running during excessively cold periods in order to prevent water pipes from freezing.

With respect to the quality of water being demanded and supplied in the GBID the one thing certain is that residents want good quality water, that is water that is aesthetically, chemically and biologically safe and appealing. Whether the water is of a good quality seems to depend largely upon who is being asked and where they live around the bay. It would seem that the quality of the water declines towards the head of the bay, that is towards the bank, the school and the grocery store end of the bay.

(5) Crescent Bay

There are another four areas on Texada requiring water for domestic purposes. On the north end of the island southwest of
Blubber Bay there are 8 to 12 homes out along the Crescent Bay road. These homes rely on shallow wells, springs or streams all of which supply water of good quality. Generally speaking these homes run short of water during the summer as sources dry up, forcing residents to bring their water in with them from work or from town. Many of the homes in the area are situated on a few acres so gardening and small-scale subsistence hobby farming does take place. Total estimated use of water for domestic purposes in the Crescent Bay area is at the most 4 million litres a year or about 4 dam³. These figures are based on an assumed average domestic consumption rate of 400 lpcpd and an estimated 25 to 30 people living in the area. It seems reasonable to assume that the domestic water consumption rate is 100 gpcpd in the smaller settlements on Texada because these areas are relying on individual wells or water systems which do not have some of the problems, mentioned earlier, of the larger centralized water delivery systems. Also this is the rate of domestic water use which the B.C. Water Management Branch uses in their calculations.

(6) The Spragge and Blair Subdivisions

A second area is located 5 miles north of Gillies Bay astride the highway to Vananda. The area is comprised of the Spragge and Blair subdivisions which together have approximately 25 to 30 homes the majority of which rely on shallow wells. Many of the homes in this area are newer and situated on larger lots with large lawns and gardens and often, a few livestock. Some homes in the area have had their wells run dry during the driest part of summer and some residents boil their water due to fears
regarding septic tank contamination of their wells. The estimated annual domestic water requirements of this area are approximately 12 million litres or 12 dam³. This figure is based on the assumption that there are on average 2.7 people per household in this area and that there are 25 occupied dwelling units or households in the area. Domestic consumption is assumed to be about 455 lpcpd.

(7) School Road

In the area between Harwood Point on the west and the High Road on the east there are perhaps 20 to 30 homes and farms on either side of School Road and the High Road. These residences primarily rely on shallow wells or springs for their domestic water supply needs; however, a few residences either pipe their water from streams or pump their water up from deep wells. A few of the residents experience shortages of water in the summer. Most of the homes in this area keep livestock and many engage in subsistence farming. Annual consumption of water for domestic purposes is estimated to be around 8.6 million litres or about 9 dam³. This figure is based on a person per household figure of 2.1, an estimated 25 households in the area and a lpcpd rate of 455.

(8) Lower Mouat Creek

A final area that should be considered is the Lower Mouat Creek area in the vicinity of the now abandoned B.C. Hydro construction camp. There are 8 residences here, 7 of which rely on water diverted from the creek into a 34 thousand litre (approximate size) storage tank. The eighth residence relies
on water diverted from a spring near the creek. While the 7 residences frequently must restrict use and at times truck water in, the eighth residence has an abundant supply of water year round. Lawns and gardens are smaller in this area than in many areas on the island, but household size is perhaps slightly above average. There were a number of small children playing in the area the day I was there. Therefore the average household size is estimated to be about 3.0 persons per household. With a lpcpd rate of 455, annual domestic water consumption will be about 4 million litres or 4 dam³.

Total annual domestic requirements for water on Texada, which includes water for public, fire protection, commercial and residential purposes, is estimated to be between 305 and 314 million litres or 305 and 314 dam³.

5.1.2 Industrial Use

Industrial activities on Texada include mining and forestry. Agriculture and recreation/tourism will be discussed in the following sections.

(1) Logging

Much of Texada has either already been logged or has experienced forest fires within the last 50 years. At present, there are fewer than 6 logging companies operating on the island, most of which are two- and three- man operations. Logging is the primary activity carried out by these companies as all logs are sold for processing off the island either in Powell River or elsewhere on the Mainland. Consequently, current water use by the forest industry on Texada is negligible. Most
of the logging activity on the island takes place south of Pocahontas Mountain primarily on unoccupied Crown land. A large portion of this area has recently been included in the Georgia Strait Provincial Forest where the Provincial Forest Service undertakes the management of the resource. Logging operations in the headwaters of the Mouat Creek watershed are believed to have altered the lower reaches of Mouat Creek. Increased volumes of water coursing down the stream due to the removal of vegetation in the upper reaches of the drainage basin have resulted in the stream banks being undercut, leading to the collapse of trees over the stream and the subsequent disruption of fish habitats.

Some logging does occur on the northern portion of the island, but forest land here is held in private ownership. The area surrounding Cranby Lake, the water supply source for the GBID, is held by Alm Forest Products which is currently logging in the area. There has been some concern about the effects of this logging on the quality of water in the Cranby Lake watershed.

(2) Mining

Currently, there are four limestone mining companies on the island all of which have their operations on the northern half of the island (see Figure 5.4). These companies require water for drinking, the operation of office washrooms and kitchens, the cleaning of equipment and the washing of rock, and, in the summer months, the control of dust on roads into and out of the quarries.

Oregon Portland Cement's (OPC) operations are located in the vicinity of Blubber Bay and Limekiln Bay. OPC relies on
FIGURE 5.4: LOCATION OF LIMESTONE MINING COMPANIES ON TEXADA ISLAND

- Blubber Bay
- OREGON PORTLAND CEMENT
- Vananda
- CANADA CEMENT LAFARGE
- IMPERIAL LIMESTONE
- IDEAL BASIC CEMENT (the old Texada Iron Mine)
- Gillies Bay

SCALE: 1 cm = 1.93 mi
water from quarry number 3 for use in its offices and in the control of dust, while water from quarry number 2 is used in washing rock and cleaning off equipment. Water from quarry number 2 is recycled through a settling pond so only that which evaporates is actually consumed. The estimated total annual use of water by OPC is 9 to 32 million litres, and most of this is for dust control and cleaning equipment.

Ideal Cement is located 2 miles northwest of Gillies Bay on the west coast of the island. An estimated 25 percent of the water used by Ideal during the summer months is for washing rock, general clean-up and supply to the mine offices. Water for these purposes is withdrawn year round from Paxton Pit, which is part of the old abandoned Texada Mines workings (refer back to Section 4.3.2). During the dry periods, June through September, an estimated 75 percent of the total water used during this time is for controlling dust levels on the access roads to and from the quarry. In the early part of summer water is pumped from a swamp into 36 thousand litre tanker trucks until the swamp runs dry. While water from Paxton Pit is also used for dust control purposes, it is not until mid-summer that it becomes the sole source of water for Ideal's operations. Naturally during the wetter winter months dust control no longer is such a problem and therefore water use drops significantly. Total annual water use by Ideal Cement is estimated to be about 82 million litres or 82 dam$^3$ -- about half the estimated volume of Paxton Pit (see Appendix C).

Canada Cement Lafarge is located 1 mile south of Vananda on the east coast of Texada. The quarry employs 16 people and since
the fall of 1983 the quarry has been working only half shifts.\textsuperscript{32} Except for water used in the crusher, all water comes from the Vananda Waterworks system. Water for the crusher is taken from a small pond (estimated volume of 2.5 - 4 dam\textsuperscript{3}) and then recycled though a settling pond. During the period January through May 1983, when the mine was operating 2 shifts, 500 thousand litres of water were used. During the period May through October 1983, 877 thousand litres of water were used, while during October 1983 through January 1984 405 thousand litres of water were used.\textsuperscript{33} Total water use for 1983 by Lafarge is estimated at 1.8 million litres or about 2 dam\textsuperscript{3}. If these figures seem low by comparison to Ideal Cement's water use figures, it should be remembered that Ideal have many more miles of roadways to water than there are on the Lafarge property and Ideal does not recycle any of its water.

Imperial Limestone is located on Spratt Bay just south of Lafarge's property. Fresh water is used only to service the mine office building because salt water is used in washing rock and to control dust when necessary.\textsuperscript{34} The estimated total annual use of fresh water is about 295 thousand litres. This water is withdrawn from a nearby swamp.

Total annual industrial water requirements for water on Texada, considering that the limestone mines are the dominant users of water for industrial purposes is estimated to be between 95 and 118 million litres or 95 and 118 dam\textsuperscript{3}.

5.1.3 Agricultural Use

There are very few farms on Texada due to the island's
isolation, lack of a market, heavy forest cover, poor soil conditions in many areas, and rough hummocky topography. Farms on the island are generally small hobby or subsistence farms focusing on raising a few livestock, maintaining a small orchard and cultivating a kitchen garden. While many people on the island engage in one or more of these activities on their small holdings and so manage to stock their own pantries, the majority of the larger farms on the island are located along the High Road near its junction with School Road. Water required for agricultural use on Texada accounts for a maximum of 5 percent and probably less than 1 percent of total water used on the island.

5.1.4 "Other" Uses

The other uses of water on Texada include recreation, power generation and ecosystem uses. Recreation utilizing the fresh water resource of Texada Island is minimal due to the ready access and abundance of the salt water resource. However, the odd fly fisherman or angler has been known to fish in some of Texada's larger lakes (eg. Kirk, Priest and Emily Lakes) which have populations of cutthroat trout and kokanne. While Texada's lakes and streams are too small for power boats, occasionally a row boat or canoe will be used on one of the larger lakes. Many of these lakes have rather swampy, marshy perimeters which tends to discourage their use for swimming, other water-contact activities, and picnicking. Much of the land around the lakes that is suitable for swimming -- and there does seem to be demand for fresh water swimming -- is held in private
Texada relies on power generated by B.C. Hydro which is transmitted to the island via an underwater cable that was laid in the 1950's. However, a water license was issued in 1979 to generate power on Whittaker Creek. From the data on the licence it is possible to speculate that the intention was to install a micro-run-of-the-river hydro unit for the purpose of supplying electricity for one or two households. While there may be some potential for developing small and micro hydro facilities on a few of Texada's creeks, at present water requirements for power generation are negligible.

It is difficult to estimate the ecosystem's requirements for water because generally speaking the existing ecosystem has evolved to its current state partly due to the water available for its use. Changes to the timing, location, quantity and quality of the water available on Texada can be expected to effect a response by the ecosystem in its attempts to adapt to and survive these changes. The complexity of the hydrologic system combined with the complexity of the ecosystem means that while it is possible to say there is a relationship between the two systems, present knowledge does not yet allow us to easily calculate the effect on the ecosystem that a change in the hydrologic cycle would generate.

While there is a demand for a lake to canoe on or swim or fish in and there is a demand that the ecosystem exerts on the water resources of Texada, these demands can with present information only be acknowledged, but not estimated in terms of millions of litres.
From discussions in this section it can be seen that the residential component of domestic demand and industry, particularly the limestone mining industry, use the greatest amounts of water accounting for approximately 75 and 23 percent, respectively, of total water use on Texada. During the summer months use rates by the domestic sector can frequently triple the rates of the wetter months of the year. Certainly in the limestone mining business water use rates double during the summer months primarily due to the need to keep dust levels down around the quarries. Total present water use on Texada is estimated to be between 405 and 460 dam$^3$ (see Table 5.2).
### TABLE 5.2: SUMMARY OF PRESENT WATER USE ON TEXADA

<table>
<thead>
<tr>
<th>TYPE OF USE</th>
<th>ANNUAL TOTAL</th>
<th>minimum</th>
<th>maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(litres)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>I. DOMESTIC USE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Public uses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) parks &amp; public bldgs.</td>
<td>2,472,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Fire protection</td>
<td>8,437,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Commercial uses</td>
<td>10,456,000</td>
<td>4,250,000</td>
<td></td>
</tr>
<tr>
<td>3. Residential uses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Blubber Bay</td>
<td>22,234,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b) Vananda</td>
<td>107,776,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Gillies Bay</td>
<td>121,833,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Crescent Bay</td>
<td>4,091,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(e) Spragge &amp; Blair Sub'n</td>
<td>12,274,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(f) School Road</td>
<td>8,637,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g) Lower Mount Creek</td>
<td>3,982,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(h) Other</td>
<td>4,546,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL DOMESTIC</strong></td>
<td>305,904,000</td>
<td>314,806,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>or 305 to 315 million litres</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>or 305 to 315 cubic decameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>II. INDUSTRIAL USE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Logging</td>
<td>4,546,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Mining</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Oregon Portland Cement</td>
<td>9,092,000</td>
<td>31,822,000</td>
<td></td>
</tr>
<tr>
<td>(b) Ideal Basic Cement</td>
<td>80,935,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) Canada Cement Lafarge</td>
<td>1,818,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(d) Imperial Limestone</td>
<td>295,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL INDUSTRIAL</strong></td>
<td>96,687,000</td>
<td>119,417,000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>or 96 to 120 million litres</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>or 96 to 120 cubic dam³</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>III. AGRICULTURAL USE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(based on the assumption that agricultural use is at least 1% and at most 5% of TOTAL WATER USE - very approximate)</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>2,728,000</td>
<td>25,458,000</td>
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<tr>
<td><strong>TOTAL AGRICULTURAL USE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 to 25 dam³</td>
<td></td>
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<tr>
<td><strong>IV. 'OTHER' USES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Recreation</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Power Generation</td>
<td>0 non-consumptive</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL 'OTHER' USES</strong></td>
<td>unknown (assumed to be 0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL ANNUAL PRESENT USE BY HUMAN SYSTEMS ON TEXADA [sum of nos. I - IV]:</strong></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>405 to 460 million litres</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>or</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>405 to 460 cubic decameters [dam³]</td>
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</table>
5.2 FUTURE WATER USE ON TEXADA

There are several possible combinations of futures for Texada Island, each of which has implications for the demands on the water resources of the island. In the following sub-section 2 options for future economic development on Texada and 2 options for the pattern of settlement on the island will be considered in general terms. In the final sub-section a quantitative analysis will be done on the effects of various rates of population growth and water use on water demand in Gillies Bay and Vananda.

5.2.1 Future Economic Base and Settlement Pattern

Texada Island, unlike the majority of islands in Georgia Strait, has a strong history of industrial development. The other islands in the strait, such as those in the Gulf Islands Trust, have evolved as places of retreat from the pressures of urban life. Yet these islands, particularly in the summer months, remain very much tied to the metropolitan centres of Vancouver and Victoria as 'cottagers' commute either daily or on weekends from these recreation hinterlands to the urban employment heartland. While Texada has its share of 'cottagers', the often very visible presence of industry and Texada's distance from the urban areas to the south (7 hours via road and 3 ferries) has insulated the island somewhat from the urbanizing pressures that other islands in the Strait of Georgia have been experiencing.\textsuperscript{40} However, increasingly these urbanizing pressures are extending farther and farther afield and Texada too is now feeling these pressures. Consequently, it is possible to see two
potential thrusts for the future economic development on the island.

(1) Industry-oriented Future

The evolution of Texada as an industrial site is one such possible thrust for economic development on the island. Historically, the activities of mining and forestry have been dominant and both people on the island and those at various levels of government view the island as a place of industry. The factors that contribute to Texada's attractiveness as an industrial site are the presence of deep water port facilities, the availability of fresh water, the availability of power via the Cheekeye-Dunsmuir line or potentially natural gas via the Vancouver Island pipeline, and finally the presence of a population that is not hostile to industry and the jobs it provides.

Assuming that there continues to be a market -- or better an expanding market -- there is enough quality grade limestone to not only support existing operations, but perhaps one or two others as well. The existing limestone quarries can continue to expand, although the number 6 quarry at Blubber Bay is hampered by the presence of the Texada Island highway running along its eastern perimeter. In addition to those operators already in existence, Genstar owns a property located on the Lower Gillies Bay (Mouat Bay) limestone deposit. Currently logging is occurring on the property. Although part of the property is located in the Georgia Strait Provincial Forest, the possibility exists that in the future limestone will be mined in the area. As was noted in the previous chapter, water is somewhat limited
in the immediate area; however, if necessary, salt water can be substituted for fresh water in some processes. Currently the only processing of limestone that occurs on the island involves the rock being crushed into various sizes depending upon the use to which it will eventually be put. There has been talk for some time of locating a cement plant on the island. At one time, Oregon Portland Cement (OPC) was considering Texada as a possible site for a cement plant. It was to have employed 200 people, but the plant was eventually located in Seattle.  
Perhaps a somewhat more realistic prospect is the location of a clinker plant on Texada. 

While currently the only producing mines on the island are limestone mines, in the past lode minerals were also being mined. At present, there are apparently some commercial mineralized deposits on the island that may yet be developed if either the technology evolves or the markets improve to the point of making the mining of these deposits profitable. The development of lode mineral mining would likely occur in the mineralized corridor that runs roughly from Cranby Lake to Vananda or in the area on the north side of Priest Lake. Both areas are fairly well watered, but if developed there could be some conflicts over water between the mines and those already relying on these areas for their domestic water needs. In comparing the water requirements of limestone mining with those of lode mineral extraction it has been estimated that if 100 units of water were needed for limestone quarrying, then 2000 units of water would be required for iron mining. In general then, lode mining requires about 20 times as much water as
limestone mining.

Before the decision on the Quinsam Coal project on Vancouver Island, there was some consideration of using Texada's deep water industrial port facilities to transfer the coal from the shallow draft vessels used to transport the coal from the shallow water port facilities near the mine to the deep water vessels capable of docking at Texada. If the Quinsam mine should ever go into production in the future, Texada could be utilized as a break-of-bulk point. Meanwhile there may be other opportunities to utilize Texada's deep water port facilities. Frequently at break-of-bulk points water is required for sprinkling some cargoes (eg. coal at Robert's Bank), for sprinkling roadways or for cleaning cargo holds and other equipment.

While Texada does have potential as an industrial site, the fact that there are other attractive industrial sites along the B.C. coast with which Texada is in competition, combined with the declining or unstable state of both the British Columbia and global economies suggests that an increase in industrial activity on Texada is unlikely -- even well into the future. Even the introduction of new machinery, technologies and management philosophies has and will likely continue to eliminate jobs. Consequently, if the level of Texada's population is to remain constant and a balanced social mix continues to be desirable, then new jobs will be needed to attract and keep people on the island.

(2) Recreation-oriented Future

The above picture points to the possibility, perhaps even
the necessity, of refocusing the vision of an industrial future for Texada to one in which the emphasis is on encouraging the development of Texada as a tourism and recreation site. Because the residents of Texada feel strongly about protecting their natural environment and, to the extent possible, their way of life, the evolution of a carefully planned and managed recreation and tourism sector would strengthen and support these values and at the same time provide some employment.

Historically, tourism activities on Texada have included deer hunting, shellfishing and picnicking. With the development of a Powell River Regional District park at Harwood Point, facilities were made available for visitors to come and camp on the island. While currently visitors to the island are coming primarily from Powell River, the Regional District has increased efforts to attract international visitors and people from other places in B.C. Increasing pressure is coming upon Texada from recreationists such that on weekends during the summer the Harwood Point campground and picnic area is frequently over-crowded. The waters around Texada are visited by boaters sailing or cruising the coast, by sports fishing enthusiasts and by scuba divers who have found that the mixing of cold and warm currents around the island has given rise to wonderfully rich underwater environments. At present however, there are few places or marina facilities where people can stop and set foot on the island. Consequently, little income is generated by these 'visitors'.

While a recreation and tourism oriented future on Texada is possible, the island's capacity is limited. With careful
planning and management this capacity might be extended somewhat while safeguarding the values and lifestyles of permanent residents. Even though Texada would be in competition with other coastal recreational sites, the island's location between the metropolitan centres to the south and the exciting marine and terrestrial environments to the north suggests that the island could sustain the development of some marinas and overnight camping sites, and the commercial services that would complement these facilities (e.g. grocery stores, a sporting goods store, a restaurant, etc.).

The most likely locations for the development of marina facilities would be in Blubber Bay and Vananda. While these two locations have natural harbours, Sturt Bay and Eagle Cove in Vananda are limited by their size, and the ferry at Blubber Bay limits the safety and the effective size of this harbour. However, smaller marina facilities might be more in keeping with the scale of life in these communities. Gillies Bay, particularly the areas adjacent to Harwood Point, is a potential site for the development of additional overnight camping facilities or perhaps a small motel. Again, the scale of such developments is important in order to maintain the attractiveness of the area, ensure adequate water supply and other services and safeguard the lifestyles of permanent residents.

With land for the development of recreational homes becoming increasingly scarce in the south coastal areas islands in the region around Texada are becoming more attractive as sites for second home development. Together with the
possibilities discussed above, the construction of additional summer homes could also form a part of a recreation and tourism oriented future for Texada Island.

From the above discussion it can be seen that one implication for water use of such a future would be an increase in domestic water demand -- an increase that would primarily be concentrated in the summer months. Because presently existing water supply systems are often operating close to capacity during the summer, it can be assumed that, along with the development of recreation and tourism facilities and the construction of additional summer homes on the island, the development of additional water supply sources and waterworks systems will likely be required unless conservation measures are adopted.  

While the type of economic development that occurs on Texada in the future has implications for the location, timing, quantity and quality of water demands, an additional factor influencing water use will be the type of settlement pattern that occurs. Historically, the population on the island has largely settled either in Blubber Bay, Vananda or Gillies Bay. In more recent times it has been possible to identify 5 or 6 additional areas where people have been settling. While there may have been people in these areas before the present, more people appear to be collecting in these settlements because owners in the areas subdivide and make available land that is cheaper than that available in Gillies Bay or Vananda. Also some people come to Texada to really get away from it all. Whatever the reason, a more dispersed settlement pattern is emerging on
the island. In the following paragraphs we will briefly discuss
the implications that a concentrated and a dispersed pattern of
settlement on Texada will have on water demand -- particularly
domestic water demand.

(3) Concentrated Settlement

One of the policies of the Texada Island Proposed General
Land Use Plan of 1973 was to encourage the concentration of
settlement in the communities of Vananda and Gillies Bay.\textsuperscript{53} In
terms of the implications on water resources such a policy would
strengthen arguments for setting aside and protecting existing
and future reserve water supply areas in order to ensure that
future residents of either of these two communities will have
adequate supplies of potable water. For Gillies Bay, Cranby Lake
is the sole source of water and, though not official, Paxton
Lake is viewed as the future source of water for the community.
Currently Priest Lake is the water supply source area for
Vananda. However, Kirk Lake and Balkwill (Spectacle) Lake are
also part of this drainage system and as such are the natural
choice as future supplies should Priest Lake become inadequate
to supply domestic water needs in Vananda. Other potential
options do exist for both these areas, but these will be
explored in the following chapter. The point is that
concentrating settlement in Gillies Bay and Vananda will likely
increase the desire for better quality water as well as increase
the need for more water all of which will likely result in
attempts to ensure that adequate nearby source areas are
protected; the expansion and upgrading of the community water
supply delivery system, particularly in Gillies Bay; and a
generally more visible approach to the planning and management of water resources on the island.

While it is difficult to accurately predict the quantities of water that will be demanded by these settlements in the future we will, in the sub-section which follows, examine the implications that various rates of population growth will have on the quantity of water demanded in Gillies Bay and Vananda.

(4) Dispersed Settlement

A dispersed settlement pattern could attract people to the island who are interested in developing second homes -- particularly if small clusters were developed at attractive sites adjacent to the waterfront. If a dispersed pattern of settlement continues to emerge on Texada, then obviously demands for and sources of water will also be dispersed. Also it can be expected that various sources of water will be utilized such as springs, shallow and deep wells, surface water diversion and perhaps even cisterns. If many of the houses in these dispersed settlements are second or summer homes then water use in these clusters will increase substantially during the summers and on weekends when vacationing residents are on the island. It is possible too that the water systems these residents rely on will be more primitive than those that can be tolerated by year round residents. While the majority of residents may be relying on their own individual water systems, some people, in order to ease concerns about septic tank contamination of their surface supplies or shallow wells and to ensure a continuous supply of water throughout the year, may get together in a co-operative effort to develop a group system such as a deep well. It may be
more difficult to implement measures to protect various dispersed supplies; however, a diversity of supplies can better ensure that residents have a continuous supply of potable water in the event that something happens to contaminate one or two other sources of supply.

This section has attempted to present some general ideas about the future of settlement patterns and of the economy on Texada and the implications that changes in these areas might have for future water demand.

5.2.2 Gillies Bay and Vananda: Growth and Water Demand

In this section we will look carefully at the implications for future water use should residential growth be concentrated in the communities of Vananda and Gillies Bay.

Recall from Chapter 3 that a common method of estimating water demand is the requirements approach wherein water use is considered in aggregate terms, such as quantity per capita per unit of time (eg. lpcpd), and then aggregate demand is extrapolated from the past into the future. In this section a similar approach will be used in that a range of rates of population increase and a range of rates of water use applied to the communities of Gillies Bay and Vananda over a 15 year period will be considered. Because the populations of Gillies Bay and Vananda are very similar -- 345 and 342 respectively, they will be treated interchangeably. In the paragraphs that follow the implications of a 1, 2, and 5 percent annual rate of population increase will be considered for these communities. The 1 to 5 percent per year range allows for fluctuations in population
levels that could be attributable to seasonal lay-offs or
hirings of employees either by the mines or by the logging
industry; the subsequent migration of workers to or from the
island; the influx of cottagers in the summer months; and other
possible explanations for minor temporary increases or decreases
in growth rate of the island's population.

In addition to considering a range of rates of population
growth, a range of rates for the use of water for domestic
purposes by residents in Vananda and Gillies Bay will also be
considered. Recall from section 5.1.1 that residential water use
rates in Vananda and Gillies Bay are currently 855 and 1086
lpcpd. However, in the next 15 years these rates could change.
For this reason a range of rates of residential water use will
be considered in the following paragraphs. The range of per
capita water use rates to be considered will be 455, 910, and
1100 lpcpd. By using such values it is expected that
fluctuations in water use that occur because of the changing
seasons and the introduction of technological innovations or
policy changes that directly or indirectly affect rates of water
use will be accounted for within this range.

In 1981, Gillies Bay had a population of 345 people. Assuming a 1 percent annual increase, Gillies Bay will have a
population of 401 people -- an additional 56 people -- by 1996 (see Table 5.3). Very similar figures result if a similar
forecast is done for Vananda. A net 1 percent annual increase in
the population is very low. However, if births and people
retiring to the island are just offsetting losses due to deaths
and out-migrations due to industry layoffs, then this could be a
TABLE 5.3: DOMESTIC WATER USE FORECAST TO 1996 IN GILLIES BAY AND VANANDA

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<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>low 1%</td>
<td>medium 2%</td>
<td>high 5%</td>
</tr>
<tr>
<td>2. TOTAL DAILY CONSUMPTION</td>
<td>litres per day [lpd]</td>
<td>numbers rounded off to the nearest thousand</td>
<td></td>
</tr>
<tr>
<td>Low 455 lpcpd</td>
<td>165,000</td>
<td>173,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Medium 910 lpcpd</td>
<td>330,000</td>
<td>347,000</td>
<td>400,000</td>
</tr>
<tr>
<td>High 1100 lpcpd</td>
<td>399,000</td>
<td>419,000</td>
<td>484,000</td>
</tr>
</tbody>
</table>

3. 1981 TOTAL ANNUAL CONSUMPTION

| Low 455 lpcpd | 57,296,000 litres |
| Medium 910 lpcpd X 345 people X 365 days | 114,492,000 litres |
| High 1100 lpcpd | 138,518,000 litres |

4. 1996 TOTAL ANNUAL CONSUMPTION

a) Low 1% Population Growth [401]

| Low 455 lpcpd | 66,596,000 litres |
| Medium 910 lpcpd X 401 people X 365 days | 133,192,000 litres |
| High 1100 lpcpd | 161,002,000 litres |

b) Medium 2% Population Growth [464]

| Low 455 lpcpd | 77,059,000 litres |
| Medium 910 lpcpd X 464 people X 365 days | 154,118,000 litres |
| High 1100 lpcpd | 161,002,000 litres |

c) High 5% Population Growth [717]

| Low 455 lpcpd | 119,076,000 litres |
| Medium 910 lpcpd X 717 people X 365 days | 238,152,000 litres |
| High 1100 lpcpd | 287,876,000 litres |

5. TOTAL VOLUME OF CRANBY LAKE:

617 cubic decameters [dm$^3$] or 616,500,000 litres

6. TOTAL VOLUME OF PRIEST LAKE:

2280 dm$^3$ or 2,280,000,000 litres

46.7% 12.6%
likely scenario. If water use rates are and remain at a rate of approximately 455 lpcpd to 1996, then daily water needs in each of these communities will be approximately 182 thousand litres a day (lpd) or 68 million litres (68 dam$^3$) annually. This represents an increase in water demand of 16 percent since 1981. A domestic water use rate of 455 lpcpd reflects current levels of water use in urban areas and assumed use rates for the remote parts of Texada.

Perhaps a more realistic picture of domestic water demand emerges when it is assumed that water use rates are between 910 to 1100 lpcpd. While some people on Texada live rather simply, there are those whose homes reflect a desire for comfort and convenience. Very often this translates into a higher standard of living and, almost causitively, a higher rate of domestic water consumption. Therefore a rate of 910 lpcpd is not extreme and in fact reflects rates in the larger settlements on Texada. During 1983 rates were 1086 and 855 lpcpd in Gillies Bay and Vananda, respectively. This was partially due to the need to keep the water running in the pipes during the cold spell in December. Apparently the threat of frozen pipes occurs almost every year though perhaps not as severely as during December of 1983. However, a water use rate of 1100 lpcpd, although high by urban standards is, in the case of Texada, quite reasonable. Another consideration in justifying these figures is that the water distribution systems in Gillies Bay and Vananda are getting older and with increasing age comes increasing wear and tear leading to greater leakages and losses from the system. This latter argument seems particularly applicable to the
Gillies Bay system, the records of which reflect unusually high rates of consumption. In addition evidence seems to support the notion that domestic water use rates will increase to the year 2000. Based on these rates of water use, daily consumption will range between 182 and 364 thousand litres by 1996. This represents an annual consumption of between 132 and 164 million litres by 1996.

If the population of Gillies Bay or Vananda increases at a rate of 2 percent annually then by 1996 the population will be approximately 464. A 2 percent annual increase in population assumes that employment levels and population levels remain fairly constant if not tending to increase slightly and that the 2 percent increase is comprised primarily of some in-migration as people buy property and set up homes, and of an increase of births over deaths. Domestic water consumption will then range from 77 to 192 million litres annually (see Table 5.3).

A 5 percent annual increase in the either the Gillies Bay or Vananda populations means that there would be approximately 717 people in the community by 1996. This is nearly double the 1981 population. Expansion of mining activities on Texada (eg. the exploitation of the Mouat -- Upper Gillies Bay limestone deposit or the exploitation of lode mineral deposits) could result in a 5 percent annual increase in population over the next 15 years. Total daily domestic consumption would range from 323 to 814 thousand lpd for each settlement. Annually, total domestic consumption would be between 118 and 295 million litres. These figures represent a 79 percent increase in water use by 1996.
While we have estimated the quantity and to some extent the timing of future demand that could possibly be expected between now and 1996 for the communities of Vananda and Gillies Bay, there has not yet been any discussion of the location, seasonal timing, or quality of demand. It is safe to say that demand for high quality water for domestic purposes will continue into the future. However, it is possible to speculate that individual households, indeed particular taps in households, will employ special filters to ensure that the water is potable for drinking and cooking purposes so that the quality of water for other domestic purposes will not need to be as high. Dissatisfied with the present 'musty' taste of the water from the Cranby Lake system Gillies Bay residents may decide to get something done about the quality of their water.

The seasonal fluctuations in domestic water demand were discussed earlier in this section; however, there are some additional points that should be made. During the summer months daily domestic consumption rates tend to increase. While this is partly related to the desire for more water for drinking and personal hygiene, the greatest proportion of this increase in demand is typically for sprinkling. However, sprinkling tends to be one of the more elastic components of domestic demand by which it is meant that use of water for sprinkling around the home is normally very responsive to the amount of water available. If there is an abundance of water available then, if needed, water for sprinkling will be used copiously. However, if water is scarce then water for sprinkling will be used sparingly or the use of it for sprinkling will be foregone.
altogether in favour of its use for more critical purposes, such as drinking and cooking. This of course assumes that some form of restriction is placed on the water (eg. price or, more typically, moral suasion is used).

To sum up the above analysis, it can be expected that in the communities of Gillies Bay and Vananda population increases at rates between 1 and 5 percent annually will lead to increases between 16 and 79 percent in total daily domestic water consumption. This of course assumes that daily per capita domestic water consumption rates remains between 455 and 1100 lpcpd. As noted earlier, evidence has suggested that domestic water consumption rates have risen over time and will likely continue to do so; however, the range of values utilized in the analysis are meant to take this factor into account. It is possible that demands for high quality sources of water to be used for domestic purposes will decrease somewhat if tap filters become a common household appliance. Depending on the abundance of supply and how hot and dry the summer months are, the use of water for domestic purposes will tend to increase during the summer. This is not only due to the influx of summer residents and visitors, but also due to the greater need in summer for water for drinking, bathing and sprinkling purposes.

SUMMARY

This chapter has examined the current and potential future patterns of water demand on Texada Island. At present total annual demand is estimated to be between 391 and 446 million litres or 391 to 446 dam³. Of this, between 68 and 80 percent is comprised of water used for domestic purposes and between 18 and
27 percent of that remaining is used by the industrial sector -- specifically the limestone mines (refer back to Table 5.2 and see Figure 5.5).

During the summer months demand in all sectors more than doubles demand during much of the winter. However, during particularly cold periods water demand can be as high as in the summer for the duration of the cold spell as residents leave their water taps running to prevent them from freezing. In general water demand is primarily concentrated in the Lowland and in particular the corridor connecting and including Vananda and Gillies Bay. The quality of water demanded on the island is generally high. Currently only in Gillies Bay and in the Spragge and Blair subdivision is there concern over the quality of the water. However there does seem to be some debate amongst residents as to whether this is really an issue.

In the second section of the chapter the demand for water in the future was considered. The two main factors affecting future water demand, namely the future economic base and the future pattern of settlement, were discussed. With the current and probable future state of the B.C. and world economy it is likely that, despite Texada's potential for further industrial development, growth will be minimal and decline a real possibility. However, some potential exists for diversifying the island economy so as to include the development of some recreation/tourism facilities. This will require further investigation. Settlement patterns on the island also affect water use in terms of the location of water demand, but also in terms of the development of supplies. Currently on Texada a
FIGURE 5.5: SCHEMATIC SUMMARY OF ANNUAL WATER USE BY THE HUMAN USE SECTORS ON TEXADA

NOTE: ALL FIGURES IN CUBIC DECAMETERS PER YEAR.

* These uses are either assumed to be non-consumptive or use negligible.

SOURCE: See Table 5.2.
dispersed pattern is emerging; however, approximately 50 percent of the island's population continue to live either in Vananda or Gillies Bay, both of which are served by centralized water supply systems.

In the final section of the chapter, the implications of various levels of population growth and rate of residential water use in the communities of Gillies Bay and Vananda till the year 1996 were examined. It was determined that with a 1 percent annual rate of population increase and a 455 lpcpd rate of water use, that annual water demand for either of these communities would have increased by 16 percent by 1996. However, should the annual population growth rate suddenly become 5 percent annually and the rate of water use be 1100 lpcpd, then water demand will have increased by 96 percent by 1996 (see Table 5.3).

In the following chapter ways of balancing supply and demand on Texada will be examined.
CHAPTER 6
BALANCING WATER SUPPLY AND WATER DEMAND ON
TEXADA

INTRODUCTION

The one concept that has been emphasized throughout this thesis is that the goal of water resources planning and management is to balance the location, timing, quantity and quality of water demand with the location, timing, quantity and quality of water supply. The aim of this chapter is to bring together what is known or has been estimated about the supply of water on Texada from Chapter 4, with what is known of has been estimated about current and future demands for water on the island from Chapter 5. From this it should be possible to draw some conclusions about the balance of supply and demand for water resources on Texada Island.

In moving on to a discussion of the management of water supply and demand, the second section of this chapter will consider the situations on Texada that will determine to a large extent the types of solutions that will be most appropriate in dealing with water supply/demand imbalances on the island.

The final section of the chapter will consider some supply-side and some demand-side options for water management in terms of their applicability to local area supply/demand imbalances on Texada.
6.1 SENSITIVITY OF SUPPLY SYSTEMS TO CHANGES IN DEMAND

In Chapter 4 the supply-side of the water resource picture for Texada was discussed. Because almost all demand originates in the northern Lowland Region the discussion which follows will focus on this region. The investigation into the water balance on the island found that approximately 141 thousand dam$^3$ of precipitation falls on Texada in an average year (see Appendix A for the derivations of these and the following figures).

The Lowland Region receives approximately 45 thousand dam$^3$ of this yearly precipitation. Between 23 and 28 thousand dam$^3$ of this are what are estimated to be lost from the water resource system on the island due to evapotranspiration. The remaining 17 to 22 thousand dam$^3$ that falls is lost in runoff to the ocean. While runoff and precipitation are greatest between November and March, actual evapotranspiration exceeds precipitation from late April through September such that a moisture deficit develops during this period. Recall from Chapter 4 that because Texada's watersheds are small and fragmented, it was assumed that 15 percent of the water that is available for runoff in any given month actually contributes to the amount of water available for runoff in the following month. What this means is that while total runoff ranges between 2550 and 3375 dam$^3$ for the period April through September, runoff drops very low during the latter part of a dry summer.

The total stock of water resources on Texada Island, which includes both ground and surface waters, is approximately 308 thousand dam$^3$. Ninety-seven percent of this stock is groundwater, much of which is located in the Lowland Region.
Therefore the total stock of water in the Lowland Region is estimated to be about 302 thousand dam$^3$. However, much of the groundwater is inaccessible at present. Consequently, it is estimated that the total usable stock of water, both surface and ground water in the Lowland Region, is between 43 and 55 thousand dam$^3$.

In Chapter 5 the demand-side of the water resources picture on Texada was examined. It was determined that total yearly demand for water by human systems on the island is between 405 and 460 dam$^3$ — almost all of which originates in the Lowland Region. Sixty percent or between 243 and 277 dam$^3$ of total water use occurs in the six months April through September. During the latter part of summer demand may exceed runoff such that the stock of water in the Lowland Region is slightly reduced. Of course, in the period October through March, demand is much less than the flow from runoff so that with the surplus of water the stock is quickly replenished — usually by mid-November (see Figure 6.1).

If in the future demand should double, the depletion of the stock, which currently occurs to a very minor extent during the latter part of summer, could become more significant. It may take all of the moisture surplus of November and December to replenish depleted stocks; however, there would still be an excess of runoff. In fact, we can conclude that there would be no long-term depletion of the usable water resource stock available in the Lowland Region as long as the yearly depletion of usable stock does not exceed yearly runoff (17 to 22 thousand dam$^3$). In other words, as long as demand does not exceed
NOTE: This diagram is an approximation of the behaviour of the flows and stocks of water in the Lowland Region in response to the approximate behaviour of water demand in the region. The numbers used to draw the graph are approximations based on the calculations in Appendix A.
approximately 17 thousand dam\(^3\) annually, then the usable stock of water in the Lowland Region as a whole, will not be depleted in the long-term (see Figure 6.2).

While there is indeed a more than adequate quantity of water in the Lowland region to supply the total current and foreseeable demands for the entire area, the spatial and temporal distribution of water supply does not always coincide adequately with the spatial and temporal distribution of water demands on the island. Consequently, some areas are experiencing water shortages -- primarily during the summer months. In addition, up until now we have been comparing the amount of usable stock and the amount of the yearly flow of water with the demands of these resources. We have been considering the natural sources of water supply, but not the developed supplies. Discussions in Chapter 2 brought out the point that while there is an abundance of water cycling through the various phases of the hydrologic system, in order for the water to become available to human systems man must first capture and divert the water from the hydrologic cycle to the human water-use system. On Texada, the amount of water that the human water-use system is presently capable of capturing, diverting and distributing is inadequate to meet the needs of the communities on Texada during the dry period in summer, that is the peak demand period. If demand for water should increase in the future and the human water use system remain at its current level, serious shortages of water can be anticipated not only during the summer, but quite likely year round.

The spectre of frequent widespread water shortages in the
FIGURE 6.2: SCHEMATIC SUMMARY OF THE HYDROLOGIC CYCLE AND THE INTERACTION WITH THE HUMAN USE SYSTEM IN THE LOWLAND REGION OF TEXADA ISLAND

- **Evapotranspiration**: 22,900 - 28,400 dam³/year
- **Precipitation**: 45,500 dam³/year
- **Unsaturated Soil Moisture Storage**: 5880* dam³
- **Saturated Groundwater Storage**: 294,000 (total), 37,000 - 62,000 (usable) dam³
- **Surface Water Storage**: 7960 dam³
- **Runoff**: 17,100 - 22,700 dam³/year
- **Human System Demand**: 405 - 460 dam³/year

* This figure assumes that the soil moisture storage capacity is 120 millimeters in depth.

**Source**: This diagram is a compilation of Figures 2.2, 3.2, 4.5, 4.7, 4.13, 5.1, 5.5 and information from Appendices A, B and C.
future on an island with an abundance of water resources makes more explicit the need for some sort of intervention in the current ad hoc individually oriented approach to the development of water supplies on Texada. On Texada, as elsewhere, there emerge a number of alternative ways of balancing water supply with water demand. Before examining some of these alternatives let us examine the context in which such options must be considered.

6.2 THE CONTEXT FOR EXAMINING OPTIONS ON TEXADA

Before moving on to a discussion of the various options available for balancing water supply with water demand on Texada, it is necessary to make explicit the set of circumstances or the context in which these options could be implemented. Not all options will work or be appropriate given the social, financial, environmental, legal/institutional or technical constraints that may be present on Texada. Let us examine these circumstances more closely.

6.2.1 The Social Context

Residents of Texada tend to be independent people. The island is isolated by water and by distance from urban services and from the social and institutional constraints imposed on residents in more urbanized areas. Many residents on the island moved to the island so they could do their own thing free from the types of constraints imposed on people and activities elsewhere. Island residents are used to doing things for themselves as is evidenced by some of the creative means some
residents have developed to supply themselves with water. However, water supply systems which serve more than a few households or businesses, require a certain amount of joint communal effort. In considering the options to improve the water supply/demand picture on the island or in a particular area, the dicotomy between the island resident's tendency to be independent and the joint effort necessary in developing or improving water systems must be remembered.

Options requiring a large degree of community organization and commitment could be avoided initially until such time as these types of options become a natural progression and the residents feel that the benefits of joint action outweigh the cost to their independence. As the water supply needs evolve over time and joint communal effort becomes more of a necessity, then residents could look for ways of balancing independent action with co-operative action.

6.2.2 The Financial Context

Lower cost options are going to be important in the short to medium term on Texada for two reasons. Due to the provincial government's restraint program and the general shortage of cheap financing, loans and or monies for costly water supply improvement projects on Texada are unlikely to be made available during the next 5 years. Secondly, while it may be possible to organize residents and begin to set aside funds for community improvement projects it will probably require at least 5 to 10 years lead time before the community will be able to afford and implement any options requiring significant financing. While the
more costly options are impractical as short term solutions to water supply/demand difficulties, efforts to organize and plan for future needs could be started immediately to ensure that a full range of options are available in the future.

6.2.3 The Environmental Context

Residents of Texada are concerned with using the natural environment in a way that, whenever possible, avoids its unnecessary destruction or change. Residents have had to get used to the great open pit limestone quarries on the northern half of the island and in fact see these mines as necessary to the community's economic survival. However, at the same time residents fought long and hard to prevent the establishment of a solid waste landfill in one of the abandoned quarries because they suspected it would lead to a contamination of their water supplies.

The development of water supplies, particularly surface water sources, does not occur without some environmental impacts, for example, flooding. Options to improve the water supply/demand situation on Texada will need to take into consideration the desire of island residents to protect the natural environment on Texada.

6.2.4 The Legal and Institutional Contexts

The legal and institutional arrangements in a region can constrain or promote certain options for improving the water supply and demand situation in that region. On Texada, the Gillies Bay Improvement District and the Vananda Waterworks
District have been useful in ensuring the supply of water to their respective communities. The lack of similar organizations elsewhere on the island has contributed to the difficulty of developing centralized water supplies in these other areas.

Limestone mining companies located on large areas on the northern half of the island, along with the presence of a few logging companies on private land add complexity to potential options for improving the water supply and demand situation in certain areas on Texada. It may be that rights to use the water on or under these lands or rights-of-way may be required to operationalize certain options.

6.2.5 The Technical Context

Texada's remoteness, population and physical characteristics make the use of certain technologies more feasible or appropriate than others. For example, options for improving the water supply/demand situation that involve the use of technologies requiring day to day maintenance by a trained technician are unlikely to be suitable for Texada. In other cases, the stage of development of the water supply system may prevent the use of certain options that in a more complex or a different type of system would be appropriate. For example, the implementation of certain types of pricing policies would not be feasible unless the water supply systems on the island were first metered. Currently only a few businesses and industries in Vananda are metered. The technical context can constrain or promote the implementation of certain options that are available for balancing water supply and water demand on Texada.
6.3 OPTIONS AVAILABLE FOR BALANCING WATER SUPPLY AND DEMAND

In chapter 2 and 3 the various options that are available for balancing water supply and demand were examined. In this section some of these methods as they relate to areas on Texada Island will be looked at more closely. Most of the methods of interest on Texada involve tinkering with the supply side; however one or two demand options will be considered as well.

6.3.1 Augmenting Supply

Recall from chapter 2 that there are several ways to augment water supply and they are: surface water diversion, development of groundwater, conjunctive use, trucking in water, rainwater collection, and desalinization. In this section only the first 4 options will be discussed.

(1) Surface Water Diversion

On Texada, the options to divert surface water include increasing the storage capacity of Cranby Lake by raising the level of the dam, piping water from Paxton Lake to the Cranby Lake system during the the low flow months in the summer, and piping water from Paxton Lake to the nearby Blair and Spragge subdivisions.

To increase the storage capacity of Cranby Lake the existing dam at the southeast corner of the lake will need to be raised. The economic investment required to carry-out such an action would likely be significant due to the need for engineering and design feasibility studies and the need to acquire private land that will be flooded by the raising of the dam. The magnitude of the economic investment and the fact that
additions to the water supply resulting from the action will be utilized by Gillies Bay residents will require that additional water cost charges be levied to cover costs and, if possible, provincial government funding for any proposed project be formally sought by the Improvement District. Paying for the project and acquiring the rights to flood a certain amount of private land around the existing lake will require a fairly high degree of cooperation, consensus and commitment by Gillies Bay residents and the private forest company that owns the land around the lake.

Raising the level of the dam will result in additional flooding of the area surrounding the lake -- the exact extent of the flooding requires further study. However, given the apparently gentle topography around the lake, a small increase in the height of the impoundment will likely result in considerable amounts of land being flooded. The littoral (shallow) zone of the lake would be increased relative to the profundal (deep) zone, which could increase the productivity of the lake and perhaps speed up the lake aging process.

Increasing the storage capacity of the lake is a rather big step and one which, due to its complexity and cost, is unlikely and probably unnecessary in the short-term. However, this option may become more attractive in the medium- to long-term should water demands in Gillies Bay increase significantly.

Another surface water diversion option for the Gillies Bay Improvement District is the piping of water from Paxton Lake to Cranby Lake. In the short- to medium-term, transferring of water from Paxton to Cranby Lake could occur during the low flow
months of summer. As water demands exceed the storage capacity of Cranby Lake over longer periods of the year, additional amounts of water could be piped from Paxton Lake.

The economic investment required for this project will likely be moderate. The distance between the two lakes is scarcely a mile, thus limiting the cost for pipeline material and the man-hours required to build it. While Paxton Lake is slightly higher than Cranby Lake it may still be necessary to pump the water, particularly during the summer months when the water level in Paxton Lake drops as evaporation exceeds flows to the lake.

The environmental impacts of such an action will most likely occur during the construction phase. These impacts will be noticeable over the short-term, but will probably be reversible and so should not be long lasting. While there has been considerable concern about transferring water from one drainage system to another, in this case such an action will probably have a minimal impact. This question of impacts however, should be examined more closely prior to taking action with this option.

The Gillies Bay Improvement District represents the interests of the residents of Gillies Bay and Ideal Cement hold the water rights to Paxton Lake, therefore a high degree of consensus among residents and between the community and company officials will be required to gain agreement on a proposal to transfer water between the lakes.

Currently residents in the Blair and Spragge subdivisions rely primarily on individual shallow wells, some of which fail
to supply adequate quantities of water during the driest part of summer. Future difficulties could arise in this area as more homes are built. Additional septic tank systems could threaten the quality of the groundwater and additional wells could result in an area-wide lowering of the groundwater table. Such an occurrence could mean that many more homes would run short of water for longer periods of time in the summer months.

One solution to these problems is the diversion of surface water from nearby Paxton Lake. If only one or two individuals who are now running short of good quality water were to lay plastic hose from the lake to their homes the cost would be minimal. However, if, as suggested above, the entire community reaches the point where piping water from Paxton Lake to all the homes in the subdivisions became a seriously considered option, then costs could become very high due to the need to construct a water delivery system from house to house and perhaps install some form of water disinfection device for the system.

Regardless of the magnitude of the water piping system proposed it can be expected that the long-term environmental impacts will be minimal, although in the short-run the laying of the pipeline could disrupt the physical environment somewhat. If this option were to be seriously considered, studied and implemented on a community-wide basis, then there would need to be a high level of cooperation, consensus and commitment by area residents. In addition, area residents would need to come to some agreement with Ideal Basic Cement who currently hold the water rights to Paxton Lake.

Piping water from Paxton Lake to a network delivery system
in the Blair and Spragge subdivisions is quite a large-scale solution to what is currently a small-scale water shortage problem. Although with the threat of septic tank contamination of the shallow wells in the area, what is now a small-scale water quantity and quality problem could suddenly flip-flop to become a serious issue if contamination of the water supply were to suddenly reach dangerous levels. Therefore, this option might be worth considering now for implementation in the medium to long-term.

2) Development of Groundwater

While several individuals or small groups on Texada rely on groundwater emanating from springs or from groundwater in shallow wells, the actual development of groundwater supplies is at a very minimal level. In Chapter 4 it was discovered that there appears to be considerable potential for further development of such supplies.

Recall from Chapter 5 that the Crescent Bay area relies primarily on shallow wells that normally run dry during the summer months. Also the area is underlain by an aquifer that is capable of providing an adequate supply for existing residents and may be capable of supporting further subdivision development in the area.

While some costly test wells will need to be drilled prior to the development of groundwater supplies on Texada, there is already some local knowledge about the behaviour of groundwater as a result of the mining activities on the island.

In some ways the economics of groundwater development are favourable for this area. The smaller scale of groundwater
installations makes them more amenable to being developed incrementally -- a factor in their favour should the Crescent Bay area experience additional settlement. A further consideration is that groundwater is available right underneath the Crescent Bay area, whereas surface water in adequate quantities is much farther away. Consequently, the transmission costs in groundwater development will be low. However, groundwater must be pumped up out of the ground thus increasing the energy costs of groundwater development in the area.

Environmental impacts related to the development of groundwater supplies in the Crescent Bay area are likely to be minimal. However, should overpumping occur the potential for salt water intrusion exists. Therefore care will need to be exercised in ensuring that pumping in excess of the replenishment rate does not occur for a prolonged period.

While the development of groundwater involving the establishment of deep wells is unlikely to occur until more people move into the Crescent Bay area, perhaps in the short- to medium- term there is a need for a temporary or stopgap measure such as trucking in the needed water. This alternative will be examined a little later.

(3) Conjunctive Use

The conjunctive use approach may provide a suitable solution to current and future water supply difficulties in the Gillies Bay area. All the advantages and disadvantages that were involved in groundwater development apply here. Initially wells would need to be drilled, possibly involving the purchase or leasing of land for well sites and a storage tank. While initial
costs could be high this solution is attractive because it involves minimal environmental impact and offers the potential for incremental additions to the supply system.

(4) Trucking In Water

During the summer months many areas on Texada must bring water in from elsewhere. Typically this is done on a small-scale in that individuals, visiting or working in Vananda, will fill up water jugs before returning home. Occassionally residents in these water-short areas may have a tanker truck bring water in from Vananda to fill up small storage tanks.

Currently trucking in water offers a rather ad hoc solution to the problem of inadequately developed supplies in certain areas of the island. Residents in these areas, for example Crescent Bay, could improve their "water supply delivery system" by organizing themselves, constructing communal storage tanks, and approaching the trucking in of water as a joint venture. By organizing in this way residents could better monitor growth in their community's water demand and so generate alternative solutions to meet these and future demands.

6.3.2 Improve System Efficiency

The three ways of improving the efficiency of a water delivery system include reducing evaporation and reservoir seepage, reducing leakages from the delivery system and altering the land use in the watershed. In this section we will consider the latter 2 methods and their applicability to Texada.

Recall from chapter 5 that the amount of water consumed on a per capita basis in Gillies Bay as recorded by the chlorinator
charting device was exceedingly high. A possible factor contributing to this excessive use is leakiness in a water supply delivery system that includes a very leaky surge tank and possibly water mains and pipes that are also quite leaky. While discovery and repairing of these leaks may be costly, the costs of augmenting the water supply in Gillies Bay must be weighed against these costs. It may be that repairing the existing system will require less community organization, environmental disruption, and money than acquiring a new water supply source and diverting water from it to Gillies Bay.

In chapter 2 it was learned that land use and water supply management are inextricably linked. On Texada, the forest land around Cranby Lake is beginning to be logged. The Oregon studies showed that where, like Texada the principle tree species is the Douglas fir, that completely removing the forest from a watershed can result in an increase of between 20 and 40 percent in the watershed's annual water yield during the initial years after the clearcut. Consequently, it can be expected that logging the Cranby Lake watershed will increase runoff the amount of which would depend on the quantity and timing of annual precipitation and the degree and timing of logging. However, such an action may lead to an increase in the rate that the Cranby Lake reservoir is silting up and possibly speed up the growth of plants in the reservoir -- already perceived by residents as contributing to poor tasting water in the reservoir. This option may occur without any initiative being undertaken by residents because the forest around the lake is owned by a private logging company that is already active in the
area.

6.3.3 Reuse of Wastewater

The potential for reuse of wastewater on Texada is minimal due to the widespread use of septic tanks in residential areas and the current practice of reuse by 3 of the 4 limestone mining companies on the island. However, there is some potential to reuse wastewater in Ideal Cement's rock cleaning and crushing operations. Most of Ideal's current demand for water is for the control of dust on their access roads. It is likely that should water supply become a serious limiting factor in Ideal's operations that reuse of water in their crushing operation would not make that much difference to their water supply needs. However, it could be a part of a solution to the problem.

6.3.4 Demand-side Options

System pressure reduction and selective use restrictions for implementation in either Gillies Bay or Vananda are two demand management options that may be worth considering for Texada in the event of a short-term water shortage. They are flexible, inexpensive and usually easy to implement during periods of drought when water customers are more sympathetic to the idea of restricting their water use.

SUMMARY

Current annual water demand in the Lowland Region on Texada is between 405 and 460 dam$^3$, total useable stock is between 43 and 55 thousand dam$^3$, and yearly flow (runoff) ranges between 17
and 22 thousand dam$^3$. What this means is that there is currently no overall shortage of water on the island. In fact, unless yearly demand exceeds approximately 17 thousand dam$^3$, then the stock of water on Texada will not be depleted over the long term. Despite these encouraging statistics, it is true that certain areas on the island experience water shortages during the peak demand period in late summer.

This chapter considered the water planning and management context on Texada. In planning and managing water supply and demand on the island, and in choosing alternative solutions to water supply and demand imbalances, 5 option contexts must be considered. These option contexts are the social, economic (financial), environmental, legal/institutional and technical situations on Texada. Consideration of these contexts helps to narrow the types of options that are appropriate for the island.

In the latter part of this chapter several solutions to water supply/demand imbalances in various local areas on the island were examined. Generally speaking it was found that while a variety of the options considered could probably be implemented, those supply-side options involving diversion of surface water, development of groundwater, and conjunctive use are perhaps the most appropriate in the medium- to long-term. Trucking in water, and the demand-side options involving reducing water system pressure and the use of selective restrictions are some possible short term solutions for dealing with peak demand in the summer months. One of the key things to come out of this chapter is the recognition of a need to move from an ad hoc approach to a more ordered and planned approach
to developing and supplying water in order to ensure the continued existence of adequate supplies and quality of water in various regions on Texada.

Given this recognition the following chapter will briefly consider some of the limitations of the thesis and what some next steps might be in the continuing task of water planning and management on Texada Island.
CHAPTER 7
NEXT STEPS

Before moving on to suggest what further actions could be taken by the residents of Texada in the planning and management of water resources on the island it seems sensible to first summarize the findings of this thesis and to take note of its limitations.

7.1 THE FINDINGS OF THE THESIS

This thesis set out to develop a way of looking at the water resources in rural regions. Because of their rural character these regions frequently lack hydrologic and water demand data thus making it difficult to assess the water resource situation in these areas. In Part I of the thesis, a simple conceptual framework was developed for understanding the behaviour of water on islands, the ways in which supplies are developed and managed, the various concepts associated with water demand, the requirements of various water-using sectors and the techniques for managing demand. It was suggested that some useful conclusions could be drawn if this framework were used to assess the water resources of a region.

Texada Island in the Strait of Georgia became a test case. Relying on existing data and, what proved to be the most helpful, local knowledge of various aspects associated with the water resources, it was possible to paint a fairly clear picture of the overall water resource situation on the island.

In examining the water resource potential on Texada it was determined that, on an island-wide basis, water is abundant.
Currently, water demand for the Lowland Region on the island is about 450 dam$^3$ while the annual flow of water is over 17 thousand dam$^3$. Even if demand should exceed 17 thousand dam$^3$, there remains a great reservoir in the ground that could, if its quality were protected, sustain the community for a very long time.

While this is an encouraging conclusion it was also discovered that residents in many areas of the island experience shortages of water during the summer months. These people typically rely on shallow wells, springs or seasonal streams for water and in the summer months the groundwater table drops causing these sources to dry up. Consequently, either there is a lack of natural supplies in some areas or water supplies at certain sites on the island are inadequately developed to supply residents with water year round.

At this point it became obvious that ways of balancing water supply and water demand needed to be investigated. On Texada there are constraints related to the social, financial/economic, environmental, technological and legal/institutional contexts on the island. Consequently, in the short-term, the most appropriate alternatives for improving the water supply-demand balance on the island are likely to be trucking in water on the supply-side, and on the demand-side reducing water system pressure and using selective restrictions during the summer months. In the medium- to long-term, given that it is the spatial and temporal distribution of water sources combined with the lack of developed supplies in particular locations that is the most troubling water resource
problem on the island, it seems appropriate to implement those supply-side options that involve the diversion of surface water, development of groundwater and conjunctive use.

While water quality on Texada was not specifically examined in this thesis, it became obvious during the course of the analysis that for some source areas (e.g. Spragge and Blair Subdivision, Cranby Lake and Priest Lake) threats to their water quality exist or will likely emerge in the future. When the quality of a water source comes into question, so does its usefulness in supplying water to certain types of users. Consequently, in some areas it may become necessary to abandon use of the septic tank disposal method in favour of a more centralized sewage treatment method in order to preserve the water quality of nearby water sources.

7.2 THE LIMITATIONS OF THE THESIS

This thesis does not attempt to generate a water resource plan for Texada, but rather provides an assessment of the water resource potential on the island. This assessment is not based on abundant hard data, of which there are very few, but rather on available local knowledge and "quick and dirty" estimates based on field observations and an understanding and application of the various theories of relevance to the assessment of water resource supply and demand.

Where the analysis of the water resource situation on Texada is perhaps the weakest is in the assessment of groundwater supply and behaviour, particularly at the local area level. When it comes to groundwater, the fact that water
"should" be present in an area does not guarantee that it will be there, especially when the geologic unit beneath the area is composed of limestone and the degree of solution channel development is unknown. While it was possible to observe the behaviour of surface supplies over the course of a year and to some extent glean information about groundwater from residents' observations with respect to their wells, the fact that groundwater is essentially hidden from view means that the location of and quantity of groundwater supplies is based largely on educated guesswork. However, throughout the analysis of water supply and demand on Texada uncertainty in the analysis has been dealt with through the use of sensitivity analyses, that is by testing the significance of findings in terms of the conclusions that have been drawn from them. From such analyses, it is possible to say that the findings and conclusions of the thesis are robust.

This thesis does not specifically examine the institutional context for planning for water resources on Texada, as the history and the process of planning on the island is being examined in another thesis (see McWilliam Thesis). Instead, this thesis provides information about water on Texada that points the way to actions that could be taken in order to facilitate future planning and management of water supply and demand as one part of a more comprehensive planning process on Texada.

7.3 NEXT STEPS FOR WATER RESOURCES PLANNING ON TEXADA

While in general terms the overall water resource supply and demand picture on Texada looks good, there are areas where
difficulties with the water resources have or will arise. Certain areas on the island (e.g. Crescent Bay, parts of the School and High Road areas, Mouat Creek and the Blair and Spragge subdivision areas) are experiencing shortages of water during the dry periods in summer. In other areas, such as parts of Gillies Bay and the Blair and Spragge subdivision, there are some doubts about the quality of water used for domestic purposes. Another problem or potential problem with respect to the water resources on Texada relates to the types of land uses permitted in the water supply watersheds and groundwater recharge zones. For example, the Priest Lake watershed which supplies Vananda with water, primarily for domestic use, is currently unprotected and has a few cottages on the lake. The concern here is that currently Vananda does not treat its water at all (i.e. no disinfection, no filtration). These three problem areas could, in my view, be the focus of initial planning and management of Texada's water resources. The purpose of this section is to suggest what some next steps could be and who could be involved.

One of the primary difficulties in the planning and management of water resources in rural areas like Texada is the lack of information upon which to base management decisions. While Texada is in a much better position than it was a year ago in this regard, there remain significant gaps in information which could become critical if water demands were to increase. In terms of the problem areas outlined above, the following information gaps exist:

1. WATER QUANTITY PROBLEMS IN SUMMER
a) specific location of water short sites  
b) site specific cause and timing of shortages  
c) site specific magnitude of water shortage in an average year  
d) yield and location of water sources in the area

2. QUALITY PROBLEMS PERCEIVED

a) areal extent of perception and its significance to area residents  
b) chemical and biological data on suspected water sources  
c) chemical and biological data on delivery systems supplying water of questionable quality

3. LAND USE THREATS TO WATER QUALITY

a) location of problem or potential problem areas  
b) nature and magnitude of threat to water quality (eg. logging, waste disposal, etc.)  
c) chemical and biological data on the water quality of the suspected affected sources of most concern to residents.

Having identified the information gaps that I believe to be the most significant at this time, let us consider some possible low cost actions that could be taken to fill these gaps. To fill the information gaps with respect to water quantity problems during the summer, the areal extent of the perception of water quality problems, and the location of land use threats to water quality [1(a-d),2(a) and 3(a), respectively], it has been suggested, and I would recommend, that an island-wide survey of residents be undertaken. The survey would ascertain the following site-specific information:

- precise location of lot and house on the lot  
- household and property size  
- land use of property  
- whether seasonal or permanent residents
• the type and location of water source relied upon (e.g., groundwater - shallow well, surface water - creek diversion, etc.)

• estimated yield of water source and/or the estimated use of water (both winter and summer estimates)

• type and timing of water quality problems, if any

• type and precise location of waste disposal system (i.e., septic tank)

• the significance to the resident of any water quantity shortages and/or quality problems experienced by either themselves or by their neighbours

• location of any perceived problems or potential problems with respect to land use threats to water quality on the island.

While there may be additional information that would be useful in determining more precisely the extent of residential water resource supply problems, the above list could be the focus of an initial survey. Ideally the whole island should be surveyed, but if this were not possible, then those areas not relying on a centralized water supply system should have priority.

Specifically, it is in the Crescent Bay, School/High Road, Lower Mouat Creek and the Blair and Spragge Subdivision areas where shortages of water in the summer and water quality problems or potential water quality problems are the most serious, and that a lack of adequate information is constraining rational actions to solve these problems.

Because of the current financial pressures and priorities in both the government and private sectors, it may be unreasonable to expect that there will be a lot of money available to hire consultants to carry out such survey work. A possible alternative might be to get a university student
involved either through one of the summer student employment programs of the provincial or federal government, or through graduate or honours thesis work.

The remaining information gaps [2(b-c) and 3(b-c)] will likely require the services of specialists either in the private sector or through the Water Management Branch Laboratories of the Ministry of the Environment. Due to the potential costs involved, it is recommended that Texada residents, in co-operation with the Regional District Planner, determine what information gaps are the most critical and how pressing a problem they present for acting to solve the particular problems in question. In this way, residents of Texada, through the Powell River Regional District, would be better prepared to convince the MOE to carry out some chemical and biological analysis of the water sources that are causing the most concern to island residents.

With the data collected through the survey and hopefully some chemical and biological data on water sources most worrisome to residents, Texada residents could begin to precisely define the most serious water resource supply and demand problems facing the island both in the short and long term. They could then begin to work toward the resolution of these more serious problems. This may involve examining more carefully the cost and feasibility of some of the options for balancing water supply and demand that were discussed in Chapter 6. Alternatively, other options might be suggested by the survey. Whatever occurs with respect to balancing water supply and demand on Texada in the future, it will, of necessity,
require that the more or less ad hoc approach that has been taken in dealing with water resources on the island in the past be abandoned in favour of a more strategic, co-operative and co-ordinated approach.

During 1984 Texada residents together with the planning staff of the Powell River Regional District have been working in various committees putting together a plan for Texada. One of the committees consisted of interested residents from various parts of the island who examined the water resource situation in some of these areas. The community planning exercise is essentially over and the Texada Island plan has been drafted -- parts of it utilizing information generated by earlier drafts of this thesis. With this thesis as a foundation, the island-wide water resource committee and other interested residents should be encouraged to continue, using the recommendations listed above to guide their next steps in the planning and management of Texada Island's water resources.
NOTES

NOTES CHAPTER ONE


2 Salt water intrusion into wells is apparently a problem for some residents on Gabriola during the summer months.

NOTES CHAPTER TWO


2 C. W. Thornthwaite and J. R. Mather, Instructions and Tables For Computing Potential Evapotranspiration and the Water Balance, publications in Climatology, v.10 n.3 (Centerton, New Jersey: The Drexel Institute of Technology Laboratory of Climatology, 1957).


5 Strahler and Strahler (1978), plate D.2.


14 Davis and DeWeist (1966), p. 76.


21 Holtz and Sebastian (1976), p. 28.
22 Holtz and Sebastian (1976), p. 28.


27 Holtz and Sebastian (1976), p. 29.
28 Holtz and Sebastian (1976), p. 29.


31 Holtz and Sebastian (1976), p. 31.


34 Holtz and Sebastian (1976), p. 41.


NOTES CHAPTER THREE


7 Sewell and Bower (1968), p. 18.


10 Cunha (1981), p. 194 and see also literature on uncertainty (e.g. Holling, Hickling, Mason and Mitroff, Rittel, and Dewey).

11 Howe (1968), p. 43.


14 Biswas (1977), p. 53 -- taken from "Demand for Water" Figure 3.

15 Biswas (1977), p. 54 -- taken from Table 5.


20 Howe (1968), p. 44.


27 Davis and DeWeist (1966), p. 120.


32 See for example, Linzell (1979) and Noyes (1980).

33 Sargent (1979), pp. 40-41.


NOTES CHAPTER FOUR

1 Strahler and Strahler (1978), p. 463.


3 Thornthwaite and Mather (1955), p. 10.


158-159.


10 Dr. Olav Slaymaker, personal communication, May 27, 1984.


12 Dunne and Leopold (1978), pp. 243-244.


14 McConnell (1914), pp. 4-5.

15 McConnell (1914), pp. 4-6.


19 Chuck Childress, Texada Director of the Powell River Regional District, comments on an earlier draft of Chapter Three, April 1984.


22 Vananda Waterworks District, Brief to the Greater Vancouver Regional District Regarding the Proposed Vancouver Sewerage and Drainage Landfill at Genstar's Grilse Point Site on Texada, 1982, p. 1.

23 This information is taken from an earlier draft of the Texada Island Proposed General Land Use Plan 1973 wherein there was an inventory of the waterworks systems on the island.


26 Harry Barclay, Gillies Bay Improvement District Board Member, Interview May 1, 1984.

27 Water License Data (1983).
28 Water License Data (1983).

29 Childress (May, 1984).

30 Childress (May, 1984).

31 Texada Island Proposed General Land Use Plan 1973, p. 11.


37 Freeze and Cherry (1979), pp. 26-27.

38 Freeze and Cherry (1979), p. 47.

39 Freeze and Cherry (1979), p. 47.

40 Freeze and Cherry (1979), p. 145.

41 Freeze and Cherry (1979), p. 146.


45 This information is the result of discussions with Harold Diggon, Operations Manager - Ideal Cement Company, Interview, May 1, 1984; Frank Walters, Plant Manager - Blubber Bay Quarries (Oregon Portland Cement), Interview, May 2, 1984; and Mike Pero, Retired Plant Manager - Blubber Bay Quarries (Domtar), Interview, May 1, 1984.

46 Matthews and McCammon (1957), p. 47.
Matthews and McCammon (1957), p. 58.


This information is based on locating water license data on a map of Texada and analysing the information.

From an informal discussion with an unknown resident who relies on this source.

Christine Woolcot and her neighbour Peter who live in the Crescent Bay area.

Ted Fox, Resident of the Spragge Subdivision and part-time well digger, Interview, May 2, 1984.

Unknown resident of the Blair and Spragge subdivision, May 1, 1984.

Bruce Finlay, Resident of Spragge Subdivision and member of the Water Resources Sub-committee of the Settlement Planning Commission, Informal Discussion, May 2, 1984.

Mr. and Mrs. L. Hrushak, Residents of School Road Area, Interview, May 3, 1984.

Mr. and Mrs. L. Hrushak (May, 1984).

The information in these paragraphs regarding the history, geology and water resources of the property now owned by the Ideal Cement Company is derived from separate interviews with Harold Diggon (May, 1984); K. John Dove, Retired Mine Geologist - Texada Iron Mines, May 1, 1984. Both these men worked for Texada Mines before the property was sold to Ideal Cement.

L.M. Lavkulich, A.A. Bomke, R.E. Hardy, et. al., Pedological Inventory of Three Sulfide Mine Areas in B.C. (University of British Columbia - Department of Soil Science, 1976), pp. 4-5.

Pero (May, 1984).


Information supplied by Frank Walters, Blubber Bay Quarries, May 2, 1984.

Pero (May, 1984).

Walters (May, 1984).

Pero (May, 1984).

Walters (May, 1984).
NOTES CHAPTER 5


2 This section which briefly recounts the history of settlement and economic development on the island is based on similar discussions in: Rob McWilliam, The Role of Public Participation in Rural Planning, First Draft Master's Thesis (SCARP UBC), Chapt.4:1-5; and Texada Island Proposed General Land Use Plan -- 1973, (Municipal Affairs Planning Services -- Victoria, B.C.), pp.16-21.

3 Chuck Childress, Texada Director of the Powell River Regional District Board, Comments on an earlier draft of Chapters 4 and 5, April (1984).

4 The discussion of the park at Harwood Point is based on: My own on-site observations, May 2-3, 1984; Discussions with John Zaikow, Chairman of the Parks Board, May 2, 1984; and Discussions with Joe Cawthorpe, Park Caretaker, May 2 and 3, 1984.


6 Barclay (May 4, 1984).

7 Barclay (May 4, 1984).

8 Barclay (April 30, 1984).

9 Using the National Board of Fire Underwriters Formula for the amount of water required for fire protection services based on a population of 1800 for all of Texada:

\[ G = 1020 P \left(1 - .01 P\right) \]

where \( G \) = the fire demand rate in gallons per minute (gpm),
\( P \) = the population in thousands -- in this case 1.8 thousand.


11 Mike Pero, Retired Plant Manager - Blubber Bay Quarries,
The Greater Vancouver Waterworks District estimates domestic water use for urban residents to be approximately 50 imperial gallons (455 litres) per person per day. The Water Management Branch of the Ministry of the Environment in calculating water needs in licensing water use for domestic purposes uses the figure 500 gpd (2275 litres) per household. The household is assumed to include 4 to 6 persons and use is defined as enough water for flushing toilets, drinking, cooking, personal and household cleaning and the irrigation of a quarter acre. This information supplied by Mr. N. Singh, Technician - Water Management Branch MOE, May 15, 1984. These figures in effect work out to between 80 and 125 gallons (360 and 1250 litres) of water per person per day.

The use of private individual septic tanks is the primary means of dealing with waste in the GBID; however, approximately 10 homes at the head of the bay are tied into a sewage lagoon system that appears to function quite well.

This conclusion has been arrived at through discussions with Harry Barclay, Chuck Childress, Harold Diggon and Mike Pero, all of whom are residents of Gillies Bay; with John Zaikow of Vananda who is a real estate agent on Texada; and with various people living on the island whether in Gillies Bay or elsewhere.

The discussion of water use in the Crescent Bay area is based on the analysis of maps and water license data;
on-site observations May 2 and 3, 1984; and discussions with area residents: Christine Woolcot, May 2, 1984; and Kirby Woodhead, May 3, 1984.

24 Bruce Finlay, Spragge Subdivision Resident and Member of the Water Resources Sub-committee of the Texada Settlement Planning Commission, Discussion May 2, 1984.

25 Information about the Mouat Creek area is based upon a discussion with Alex Smith, Mouat Creek Resident, May 3, 1984 and on on-site observations, May 3, 1984.

26 McWilliam Thesis (April, 1984), Chapt.4:p.4.

27 This hypothesis arose out of on-site observations and discussions with Alex Smith, May 3, 1984).

28 These concerns were voiced in a meeting of the Water Resources Sub-committee on May 2, 1984. Concerns were primarily related to the possibility that logging immediately adjacent to Cranby Lake would speed up the already well-advanced lake aging process which is believed to be part of the perceived problem with water quality in the lake.

29 Frank Walters, Plant Manager - Blubber Bay Quarry, Division of Oregon Portland Cement Company, Interview May 2, 1984.

30 Walters (May 2, 1984).

31 All information regarding Ideal Cement's operations on Texada came from an interview with Harold Diggon, Operations Manager May 1, 1984.

32 All information regarding Canada Cement Lafarge's Texada operations came from an interview with George Kilroy, Quarry Foreman May 2, 1984.

33 These figures were quoted to me from the water bills Canada Cement Lafarge had received from the Vananda Waterworks District, in the interview with George Kilroy, May 2,1984.

34 Unfortunately the day I wished to see the Imperial Limestone Mine Manager he was unable to meet with me; however, I spoke with the office receptionist over the telephone and she provided the information about Imperial's operations.

35 Discussion in this section is based upon on-site observations and conversations with Harry Barclay, May 1-4, 1984.

36 B.C. Ministry of the Environment, Lake Management Files, (Fisheries Branch - MOE, July 2,1980) and McWilliam Thesis (April, 1984), Chapter 4, p. 9.

37 Bruce Findlay, Spragge Subdivision Resident and Member of
the Texada Settlement Planning Commission, at a meeting May 3, 1984 where recreational resources on Texada were being discussed.

38 Comment made at the Settlement Planning meeting, May 3, 1984.

39 Harry Barclay, Comment on an earlier draft of Chapters 3 and 4, March, 1984.

40 Some of the more development-oriented interests on the island have suggested that there has been and is a demand for development of recreational property on the island, but such development has been discouraged or "suppressed" by the industrial interests and to some extent by those who having found Texada for themselves want to protect the island and have it remain as it is.

41 This discussion of the industrial future of Texada is based on interviews: with the mining personnel: Harold Diggon, Frank Walters, George Kilroy; with the real estate agent John Zaikow; and with Chuck Childress, the Texada Director on the Powell River Regional District Board -- May 1 - 3, 1984.

42 Pero (May 1,1984).


44 Powell River News, front page articles reporting on the possibility of locating a cement plant on Texada Island, Wednesdays, December 1 and 29, 1982.

45 The production of cement involves the reduction of limestone into 'clinker'. The clinker is ground up and then combined with other materials. A clinker plant is the initial stage in the production of cement.

46 McWilliam Thesis (April, 1984), Chapt.4.

47 Peter Styles, Mine Manager - Ideal Cement Company Texada, Interview May 1, 1984.

48 Diggon (May 1, 1984).

49 Books, such as Alvin Toffler's The Third Wave, Naisbett's Megatrends, and the ongoing discussions and research by governments, universities and research groups, indicates that the developed world has passed through the industrial age into the post-industrial or "information" age. In the information age primary industries no longer are able to generate the employment opportunities they once did. Because of greater amounts of leisure time people are increasing their demands for recreation and travel. The service sector is becoming and in many cases has become the growth sector of the information age economy.
51 The Priest-Lake drainage system which supplies Vananda is an exception, being capable of supporting a town of at least twice the current size of Vananda -- even during a dry period.

52 These areas include the Spragge and Blair subdivisions, the School Road area, the Crescent Bay area, Mouat Bay, and as I understand Davie Bay.

53 Texada Island Proposed General Land Use Plan - 1973, p. ?.

54 Census of Canada (1981).

55 Annual Water Distribution Reports for GBID, (1984) and from discussions with Mr N. Singh (May 15, 1984).


58 Grima (1972), p. 46.
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II. INTERVIEW SOURCES


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APPENDIX A

WATER BALANCE
EXPLANATORY NOTES, TABLES
AND CALCULATIONS
WATER BALANCE EXPLANATORY NOTES

The water balance as defined and used by Thornthwaite and Mather (1957) refers to the balance between the input of precipitation and the output of evapotranspiration. From knowledge of the behaviour of precipitation and evapotranspiration over the course of a year it is possible to determine "the magnitude of other related moisture parameters, the water surplus, water deficit, soil moisture storage and water runoff" (Thornthwaite and Mather 1957, p. 186).

To calculate the water balance for an area it is necessary to have the following information:

a) mean monthly or daily air temperatures
b) mean monthly or daily precipitation
c) the necessary conversion and computational tables
d) some idea of the water holding capacity of the soil in the area

The following is a line by line explanation of the various terms used and steps taken in calculating the water balance for Texada. (See Tables 4.1, 4.2 and 4.3 for results of these calculations).

FOR TABLES 4.1, 4.2 AND 4.3

LINE 1 TEMPERATURE - there are no temperature data available for Texada Island, therefore mean air temperature data for the Powell River Westview Station are being substituted in the water balance analysis. Source: Canadian Climate Normals 1951 - 1980 Temperature and Precipitation -- British Columbia (1982).

LINE 2 I - HEAT INDEX - is the sum of the monthly i values which correspond roughly to mean monthly temperature. These values are taken from Table A-1 following. Adding the 12 monthly i values gives the I value which is used in determining the unadjusted daily potential evapotranspiration.

LINE 3 UNADJUSTED DAILY POTENTIAL EVAPOTRANSPIRATION - is taken from Table A-2 following. These figures are based on different mean monthly air temperature and the corresponding I value.

LINE 4 PE - POTENTIAL EVAPOTRANSPIRATION is defined by Thornthwaite and Mather (1955), p. 15 as "the amount of water which will be lost from a surface completely covered with vegetation if there is sufficient water in the soil at all times for use of the vegetation". The unadjusted daily PE values are adjusted for month and day length by multiplying them by a CORRECTION FACTOR (LINE 5) taken from Table A-3 Latitude 49 degrees
LINE 6 MONTHLY PRECIPITATION (rainfall and snowfall) for Gillies Bay on Texada Island. Source: Canadian Climate Normals (1982).

LINE 7 P-PE - precipitation minus potential evapotranspiration is calculated and entered into line 7. From this it is possible to determine those periods of moisture deficiency (negative values of P-PE) or moisture surplus (positive values of P-PE).

LINE 8 ACC POT WL - ACCUMULATED POTENTIAL WATER LOSS - is the cumulation of negative values of P-PE only for those months showing a moisture deficit. These values are summed month by month till the end of the dry season.

LINE 9 ST - STORAGE is the amount of water retained in the soil after various amounts of accumulated potential water loss. Different soils have differing abilities to retain water based on their type, texture and the rooting depth of vegetation. In the analysis a range of values for ST have been utilized (i.e. 75 mm, 120 mm, and 300 mm - see Table A-4) due to the variability and uncertainty with regard to the soil on Texada. Notice that the ST term remains the same (at capacity) until April when a negative value for ACC POT WL is reached. Ignoring the sign these values are used with Table A-5 as PE values to determine the amount of water retained in the soil. The figures from Table A-5 are entered into LINE 9 - the ST term.

LINE 10 △ST - CHANGE IN SOIL MOISTURE - is the change in soil moisture from one month to the next. If the water holding capacity is, for example, 120 millimeters, then any additions to storage cannot exceed this figure, that is the capacity of the soil.

LINE 11 AE - ACTUAL EVAPOTRANSPIRATION - is the actual amount of water lost from the soil and from plants. When precipitation is greater than potential evapotranspiration (the water needs of the plants), as it is during the wet winter months on Texada, then AE is equal to PE. However, if precipitation is less than PE, then the water needs of the plants must be partially supplied from stored soil water. In this case AE is determined by adding precipitation (LINE 6) and the amount of water withdrawn from the soil (LINE 10) ignoring the signs.

LINE 12 D - MOISTURE DEFICIT - is the difference between PE and AE (see note above).

LINE 13 S - SOIL MOISTURE SURPLUS - during the year a soil moisture deficit develops and then, as the rainy season
begins, the deficit is reduced as precipitation that infiltrates and is stored in the soil. As soil storage capacity is reached additional precipitation must drain away and this is termed the soil moisture surplus. It is calculated by subtracting LINE 10 (Δ ST) from LINE 7 (P-PE) - ignoring the signs - when LINE 9 (soil moisture storage) is less than at capacity, which in this case is 120.

LINE 14 AVAILABLE RUNOFF - is the amount of water available for runoff in a given month. Starting in the first month that has a moisture surplus after the dry period (in this case November), 15 percent of the total available runoff from the previous month is added to the moisture surplus of the current month to give the value for total available runoff for the current month and so it goes for the entire year.

LINE 15 RO - RUNOFF - is the moisture surplus that drains away to groundwater, streams, lakes and other water bodies. For each month that there is a moisture surplus, only a certain proportion of the surplus will drain away, the rest will be carried over until the next month. Thornthwaite and Mather (1957) suggest that for large watersheds approximately 50 percent of the moisture surplus will runoff in one month while the other 50 percent will be retained until the following month. On Texada the watersheds are small and fragmented consequently it is assumed that 85 percent of the moisture surplus in one month runs off while only 15 percent is detained and contributes to runoff in the following month. To calculate runoff, subtract 15 percent from the total available for runoff for the corresponding month.

LINE 16 TOTAL MOISTURE DETENTION - the amount of surplus water in the process of running off which has been detained for a month.
### TABLE A-1: MONTHLY VALUES OF I CORRESPONDING TO MONTHLY MEAN TEMPERATURE (°C)

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**SOURCE:** Thornthwaite and Mather (1957), p. 208.
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**Table A-2: Values of Unadjusted Daily Potential Evapotranspiration (mm) for Different Mean Temperatures (°C) and I Values** (after Thornthwaite and Mather 1957, pp. 218-219)
### Table A-3: Mean Possible Duration of Sunlight in the Northern Hemisphere Expressed in Units of 12 Hours

| Latitudes | J | F | M | A | M | J | J | A | S | O | N | D |
|-----------|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0°        | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|
| 5°        | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|
| 10°       | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|
| 15°       | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|
| 20°       | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|
| 25°       | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|
| 30°       | 25.2| 24.9| 24.6| 24.3| 24.0| 23.7| 23.4| 23.1| 22.8| 22.5| 22.2| 21.9| 21.6|

### Source: Thornthwaite and Mather (1957), p. 228.
### TABLE A-4: PROVISIONAL WATER HOLDING CAPACITIES WITH DIFFERENT COMBINATIONS OF SOIL AND VEGETATION

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<tr>
<th>Soil Type</th>
<th>Available Water</th>
<th>Root Zone</th>
<th>Applicable Soil Moisture Retention Table</th>
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<td></td>
<td>MN/M  in/ft</td>
<td>M FT</td>
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<tr>
<td>Shallow-rooted crops (Spinach, Pea, Barley, Beets, Carrots, etc.)</td>
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<td>100 1.2</td>
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<td>150 1.6</td>
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<td>Silt Loam</td>
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<td>.62 2.06</td>
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<tr>
<td>Clay</td>
<td>300 3.6</td>
<td>.25  .83</td>
<td>75 3.0</td>
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<tr>
<td>Moderately Deep-rooted crops (Corn, Cotton, Tobacco, Cereal grains)</td>
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<tr>
<td>Fine Sand</td>
<td>100 1.2</td>
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<td>.50 1.67</td>
<td>150 6.0</td>
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<tr>
<td>Deep-rooted crops (Alfalfa, Pastures, White clover)</td>
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</table>

These figures are for mature vegetation. Young cultivated crops, seedlings, and other immature vegetation will have shallower root zones and, hence, have less water available for the use of the vegetation. As the plant develops from a seed to a young sapling to the mature form, the root zone will increase progressively from only a few inches to the values listed above. Use of a series of soil moisture retention tables with successively increasing values of available moisture permits the soil moisture to be determined throughout the growing season.

### TABLE A-5: SOIL MOISTURE RETAINED AFTER DIFFERENT AMOUNTS OF POTENTIAL EVAPOTRANSPIRATION HAVE OCCURRED — EXAMPLE: 300 mm SOIL MOISTURE CAPACITY.

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**Source:** Thornthwaite and Mather (1957), p. 302.
SUMMARY OF
WATER BALANCE CALCULATIONS (FLOW FIGURES)

NOTE: All the calculations below were first done as shown below. The final values in each case have been converted from imperial units into metric units. Some rounding of numbers may have occurred.

1. TOTAL AREA OF TEXADA (based on planimetry) approximately 37,500 acres or 15,169 hectares

2. TOTAL VOLUME OF WATER FALLING ON TEXADA (Precipitation) \( \{V_p\} \)

\[
V_p = A \times D_p
\]

Area - \( A = 37,500 \) acres
Depth - \( D_p = 929 \) millimeters annually or 3.0479 feet (see Line 6 of Water Balance Tables).

\[
V_p = 37,500 \text{ acres} \times 3.0479 \text{ feet/year}
\]

\[
V_p = 114,296 \text{ acre-feet/year} \text{ or } 140,927 \text{ dam}^3/\text{year}
\]

3. TOTAL VOLUME OF WATER ACTUALLY EVAPOTRANSPIERED \( \{V_e\} \)

\[
V_e = A \times D_e
\]

Area - \( A = 37,500 \) acres

a. Assuming 75 mm soil moisture:
Depth of Evapotranspiration - \( D_e = 467 \) mm annually or 1.5321 feet (see Line 11 of Tables)

\[
V_e = 37,500 \text{ acres} \times 1.5321 \text{ feet/year}
\]

\[
V_e = 57,456 \text{ acre-feet/year} \text{ or } 70,843 \text{ dam}^3/\text{year}
\]

b. Assuming 120 mm soil moisture:
Depth - \( D_e = 505 \) mm or 1.6634 feet (see Line 11)

\[
V_e = 37,500 \times 1.6634 \text{ feet/year}
\]

\[
V_e = 62,377 \text{ acre-feet/year} \text{ or } 76,911 \text{ dam}^3/\text{year}
\]

c. Assuming 300 mm of soil moisture:
Depth - \( D_e = 580 \) mm or 1.9029 feet (see Line 11)

\[
V_e = 37,500 \text{ acres} \times 1.9029 \text{ feet/year}
\]

\[
V_e = 71,358 \text{ acre-feet/year} \text{ 87,984 dam}^3/\text{year}
\]

4. TOTAL VOLUME OF RUNOFF \( \{V_r\} \)

\[
V_r = A \times D_r
\]

Area - \( A = 37,500 \) acres
a. Assuming 75 mm of soil moisture
   Depth of Runoff - Dr = 462 mm or 1.5157 feet
   (see Line 15)
   Vr = 37,500 acres x 1.5157 feet/year
   Vr = 56,840 acre-feet/year or 70,084 dam³/year

b. Assuming 120 mm of soil moisture
   Depth - Dr = 422 mm or 1.3845 feet
   Dr = 37,500 acres x 1.3845 feet/year
   Dr = 51,919 acre-feet/year or 64,016 dam³/year

c. Assuming 300 mm of soil moisture
   Depth - Dr = 349 mm or 1.1450 feet
   Dr = 375,000 acres x 1.1450 feet/year
   Dr = 42,938 acre-feet/year or 52,943 dam³/year

5. TIMING OF RUNOFF - assumes that 85 percent of total runoff for one month actually runs off in the same month.

   a) % of total annual runoff running off in 6 wettest months (October-March):

      given 75 mm soil moisture capacity: 98.1%
      given 120 mm soil moisture capacity: 97.9%
      given 300 mm soil moisture capacity: 97.7%

   b) % in 6 driest months (April-September)

      given 75 mm soil moisture capacity: 1.9%
      given 120 mm soil moisture capacity: 2.1%
      given 300 mm soil moisture capacity: 2.3%

6. TOTAL DEMAND - is the total annual demand for water from all water using sectors on Texada (see Table 5.2).

   Total water demand on the island is between 405 to 460 dam³/year (from Table 5.2)

   A very large part of this demand originates from the Lowland Region. Assume that 100% of present water demand on Texada originates in the Lowland Region.

7. STOCK OF SURFACE WATER IN LOWLAND REGION

   8000 dam³ (from Table 4.6)

   Demand is 5.0 to 5.7% of surface stock

   e.g. (405/8000) x 100 or (460/8000) x 100

8. FLOW OF WATER IN LOWLAND REGION
a. Area of Lowland \( \{A\} \)

approximatley 19 square miles or 12,120 acres (from planimetry) or about 4900 hectares

b. Volume of precipitation \( \{V_p\} \)

Depth of precipitation - \( D_p = 929 \text{ mm or } 3.0479 \text{ feet/year} \)

\[ V_p = A \times D_p \]
\[ V_p = 12,120 \text{ acres} \times 3.0479 \text{ feet/year} \]
\[ V_p = 36,940 \text{ acre-feet/year} \text{ or } 45,547 \text{ dam}^3 \]

d. Volume of Actual Evapotranspiration \( \{V_e\} \)

Depth of AE - \( D_e = 467 - 580 \text{ mm or } 1.5321 - 1.9029 \text{ feet/year} \)

\[ V_e = 12,120 \text{ acres} \times 1.5321 - 1.9029 \text{ feet/year} \]
\[ V_e = 18,569 - 23,063 \text{ acre-feet/year} \]

e. Volume of runoff \( \{V_r\} \)

Depth of runoff - \( D_r = 349 - 462 \text{ mm or } 1.1450 - 1.5157 \text{ feet/year} \)

\[ V_r = 12,120 \text{ acres} \times 1.1450 \text{ or } 1.5157 \text{ feet/year} \]
\[ V_r = 13,877 - 18,370 \text{ acre-feet/year} \]

It can be seen from these calculations that DEMAND (a flow) is between 1.2 and 2.3% of SUPPLY (runoff -- a flow)

9. TIMING OF DEMAND

Using figures which are available for the Gilies Bay Improvement District (from Figure 5.2) as reflective of the timing of total demand on Texada, then during the period October through March, 40 percent of yearly demand occurs, while during the period April through September 60 percent of total demand occurs.

So during Oct.-Mar. 40% x 328 to 372 acre-feet/year = 131 to 149 acre-feet or 162 to 184 dam$^3$.

And during Apr.-Sept. 60% x 318 to 362 acre-feet/year = 191 to 217 acre-feet or 245 to 275 dam$^3$.

10. GROUNDWATER

A. Percentage of total demand that relys on groundwater

25 - 35% of residential demand (an assumption based on
field observations)

Total residential demand (from Table 5.2): 60,064,000 gallons or 221 acre-feet or 26 dam$^3$.
25% of 221 acre-feet is 55 acre-feet or 68 dam$^3$
35% of 221 acre-feet is 77 acre-feet or 95 dam$^3$

Total demand is between 328 and 372 acre-feet (405 and 460 dam$^3$); therefore the percentage of total demand relying on groundwater is approximately 15 - 24 percent.
APPENDIX B

CALCULATIONS OF THE VOLUME
OF GROUNDWATER ON TEXADA
GROUNDWATER STORAGE

The following formulas and calculations determine the amount of water stored in the Crescent Bay and Gillies Bay Glacial Deposits and the Gillies Bay Cretaceous Basin. It has been determined that these formations are the most likely aquifers on the island. The following formula:

\[ V = A \times D \times N \]

where \( V \) = volume of water in the deposit  
\( D \) = the assumed depth of the deposit  
\( N \) = the assumed porosity of the deposit.

This only tells us the amount of water held in the aquifer, it does not tell us at what rate the aquifer can yield water. This knowledge would require the drilling of test wells and generally more precise data on specific areas of these aquifers. The calculations below are based on very rough and ready estimates and are meant only as a rough approximation of the water held in storage by these formations.

CRESCENT BAY GLACIAL DEPOSIT

1. AREA:

Area = length of the aquifer \( \times \) its width  
\( A = 1.25 \text{ miles} \times 1.25 \text{ miles} \text{ or } 2200 \text{ yards} \times 2200 \text{ yards} \)  
\( A = 4,840,000 \text{ sq. yards} \)

2. DEPTH

estimated depth of aquifer (from discussions in McConnell, 1914) is 200 feet or 67 yards

3. POROSITY

\( N \) = Porosity. Porosity is the "holes in the geologic formation where water is stored. If a porosity (\( N \)) value is 10, this means that 10 percent of the volume of the formation is "holes" and is capable of holding water. Because we are talking here about saturated formations, the holes are assumed to be filled with water. \( N \) values range from 25 - 60 percent for glacial deposits (see Freeze and Cherry, 1979, p. 37 or Table B-1). Therefore assume the figure 40 percent is representative for this deposit.

4. VOLUME

\[ V = 4.8 \text{ million sq. yards} \times 67 \text{ yards} \times 40\% \]  
\[ V = 322 \text{ million cubic yards} \times 40 \text{ percent} \]
V = 129 million cubic yards

V = 129 million cubic yards x 168 gallons/cubic yard

V = 21,600 million gallons

V = 21,600 million gallons x 0.271357 acre-feet/gallon

V = 79,704 acre-feet or 98,275 dam³

GILLIES BAY GLACIAL DEPOSIT

1. A = AREA

A = length x width
= 1.5 miles x 0.75 miles
= (1.5 x 1760 yards/mile) x (0.75 x 1760 yards/mile)
= 2640 yards x 1320 yards
= 3,484,800 square yards

2. D = DEPTH

D is again assumed to be 200 feet or about 67 yards

3. N = POROSITY

In this case porosity values range from 25 to 60 percent of the total volume of the rock. Let us assume 40 percent is representative of the porosity throughout the formation.

4. V = VOLUME

V = 3.5 million square yards x 67 yards x 40 percent
= 235 million cubic yards x 40 percent
= 94 million cubic yards
= 94 million cubic yards x 168 gallons/cubic yard
= 15,758 million gallons
= 15,758 million gallons x (1/0.271 million gallons/acre-foot)
= 58,698 acre-feet or 72,375 dam³

GILLIES BAY CRETACEOUS BASIN

1. A = AREA

A = length x width
= 5 miles x 0.5 miles
\[ = (5 \times 1760 \text{ yards}) \times (0.5 \times 1760 \text{ yards}) \]
\[ = 8800 \text{ yards} \times 880 \text{ yards} \]
\[ = 7,744,000 \text{ square yards} \]

2. \( D = \text{Depth} \)

\[ D = 67 \text{ yards (see explanations above)} \]

3. \( N = \text{POROSITY} \)

The range of porosity values for cretaceous shales such as the Gillies Bay Basin range from 0 to 30 percent.

4. \( V = \text{VOLUME} \)

\[ V = 7.7 \text{ million square yards} \times 67 \text{ yards} \times (< 30 \text{ percent}) \]
\[ = 515.9 \text{ cubic yards} \times (< 30 \text{ percent}) \]
\[ = 0 \text{ to } 154.7 \text{ million cubic yards} \]
\[ = 0 \text{ to } 154.7 \text{ million cubic yards} \times 168 \text{ gallons/cubic yard} \]
\[ = 0 \text{ to } 26,000 \text{ million gallons} \]
\[ = 0 \text{ to } 26,000 \text{ million gallons} \times (1/0.271 \text{ million gallons/acre-foot}) \]
\[ = 0 \text{ to } 95,813 \text{ acre-feet or } 0 \text{ to } 118,137 \text{ dam}^3 \]
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**SOURCE:** Derived from Table 2.4 in Freeze and Cherry (1979), p. 37.
APPENDIX C

CALCULATIONS OF WATER USE BY IDEAL CEMENT
WATER USE BY IDEAL CEMENT COMPANY

GIVEN: 25 percent of total annual water used is for washing rock, clean-up and office use during the summer.
75 percent of total annual water used is for sprinkling roads June through September (3 months).
The holding capacity of the tanker truck used in sprinkling is 8000 gallons. During the summer the truck fills up every 30 minutes for a 16 hour day. (the above information supplied by Harold Diggon, Operations Manager Ideal Cement).

1. SUMMER USE

a. for sprinkling roads (given: 25% of Total Summer Use)

3 months (90 days) - weekends (24 days) = 60 days

BUT, 1 month (30 days) of dry days so only 30 full days of sprinkling

Tanker truck: 8,000 gallons/half hour or 16,000 gallons/hour

16,000 gallons/hour x 16 hours/day x 30 days = 7,680,000 gallons.
16,680,000 gallons is the use of water for dusting roads during the summer. This represents 75 percent of total summer use.

b. for cleanup and normal operations (given: 25% of Total Summer Use)

LET X = Total Summer Use

X = 7,680,000 + .25X

X - .25X = 7,680,000 + (.25X - .25X)

.75X = 7,680,000

X = 7,680,000/.75

X = 10,240,000 gallons (TOTAL SUMMER USE)

Water use for cleanup and normal operations during the summer:

.25 x 10,240,000 gallons = 2,560,000 gallons (66 days)
Rate of use per day: 38,788 gallons/day

C. Total Summer Use: 10,680,000 gallons
2. Water Use for the remainder of the year:

9 months = 275 days - weekends (80 days) = 195 days

Normal Operating Water Use Rate: 38,788 gallons/day

195 days x 38,788 gallons/day = 7,563,660 gallons

3. Total Annual Use By Ideal Cement:

TOTAL SUMMER USE + WATER USE FOR THE REST OF THE YEAR

= 10,240,000 gallons + 7,563,660 gallons

= 17,803,660 gallons annually or 65.6 acre-feet or 80.8 dam$^3$