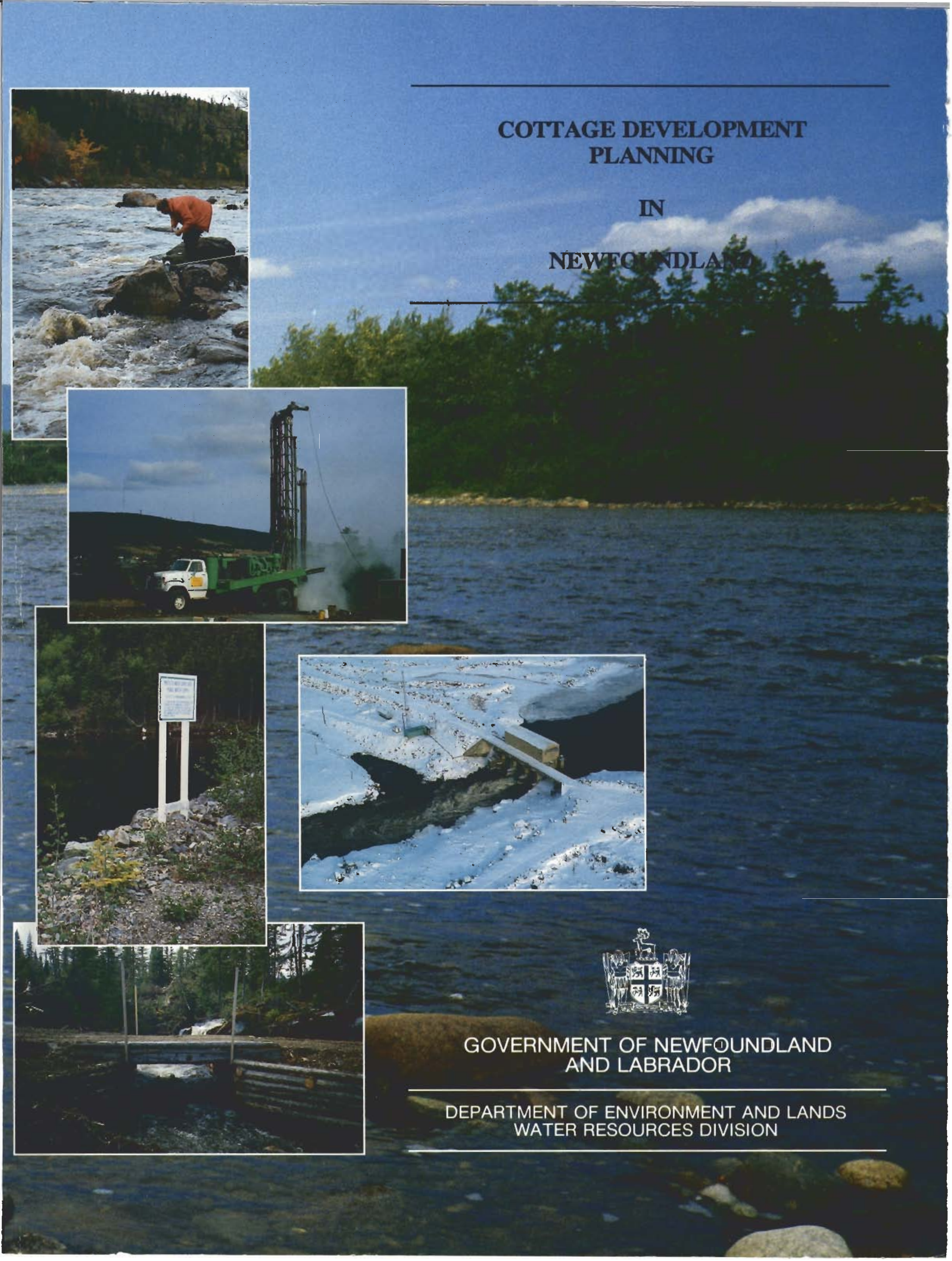


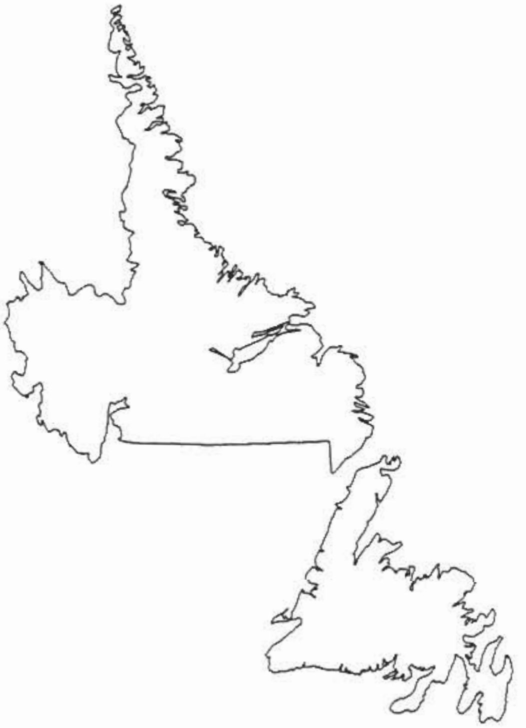
COTTAGE DEVELOPMENT PLANNING IN NEWFOUNDLAND

GOVERNMENT OF NEWFOUNDLAND
AND LABRADOR

DEPARTMENT OF ENVIRONMENT AND LANDS
WATER RESOURCES DIVISION

GOVERNMENT OF
NEWFOUNDLAND AND LABRADOR
Department of Environment and Lands

COTTAGE DEVELOPMENT PLANNING IN NEWFOUNDLAND



Water Resources Management Division
Surface Water Section

May 1994

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

APPENDICES

LIST OF FIGURES

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

ACKNOWLEDGEMENTS

This study was initiated on the advice of Dr. Wasi Ullah, Director of the Water Resources Management Division. The completion of the study was made possible by the contribution of several individuals working for provincial and federal governments. Mr. Peter Beck, a temporary employee with the Water Resources Management Division, collected and compiled input data for cottage carrying capacity methods. Mrs. Anna Buffinga and staff of the Land Use Management Division provided basic data and other information related to cottage planning in Newfoundland. The staff of the Department of Fisheries and Oceans provided bathometric data and technical reports on several water bodies in the study area. Ms. Cathy Carroll used her word processing expertise in the typing and printing of this report.

The Water Resources Management Division would like to express its gratitude to all the above mentioned members who contributed directly or indirectly towards the completion of this study.

EXECUTIVE SUMMARY

The Island of Newfoundland has an innumerable number of freshwater lakes and ponds, some of which are attractive recreational areas and under intense pressure for development. Unguided development of these recreationally important areas will result in social and environmental problems and it is, therefore, important to address this issue during the recreational (cottage development) planning of such areas. This was the main focal point of this study and, accordingly, 20 water bodies with intense pressure for cottage development were selected for this study. The information relating to morphology, shoreline, drainage pattern, land uses and soil conditions of these water bodies were compiled and used to assess the natural carrying capacity of these water bodies. Six cottage carrying capacity assessment methods available in the literature were reviewed and five of these for which input data was readily available were used to determine the natural carrying capacity of 20 water bodies selected for this study. The methods selected for application were: (1) Lake Trophic State, (2) Natural Shoreline Reserve, (3) Shoreline Capability, (4) Boat Density, and (5) High and Low Energy Recreation Cottage Pond Capacity. The Sports Fisheries Approach could not be tested due to the lack of required input data. The applicability of the five methods for cottage planning in Newfoundland was assessed and modifications made where necessary to adopt the methods to suit local conditions.

Section 1 of the report provides information on objectives, scope, study area and various carrying capacity methods. The geographical information on lakes and ponds selected for this study is also presented. Section 2 of the report deals with lake trophic state methodology, its application to the study area and discussion of results. The focal point of the approach is to assess the effects of the cottage development on water quality, considering the physical, biological, morphological and hydrological characteristics of a water body and its watershed. The methodology was applied to 20 selected water bodies in the study area to determine their flushing rate, vulnerability index and maximum additional level of development. The results of the analysis indicate that ponds such as Garnish, Junction, Tors Cove, Cape Broyle and Peak have very high flushing rates compared to other ponds in the study area and, therefore, would be least sensitive to cottage development and unit increase in total phosphorus supply. The surface area and volume of all these ponds are very high compared to other ponds selected for the study. The vulnerability index matrix, which is based on drainage-lake area relationship, shoreline configuration, mean depth, shoalness and water transport, indicates that ponds such as Cape Broyle, Thorburn, Georges, Lady and Freshwater have very low vulnerability index compared to other ponds and would be least sensitive to development on their shorelines or watersheds. Phosphorous, chlorophyll a and secchi disc values were the main parameters used to assess the algal biomass and eutrophication level of selected ponds and lakes. The results of these estimates indicate that most of the selected water bodies fall in the oligotrophic state according to the general trophic classification of lakes and reservoirs. However, the accuracy of these estimates could not be verified since no or very limited data was available to compare the estimated values of phosphorous, chlorophyll a and secchi disc with the observed values. Limited data on observed phosphorous levels was available for a few of the lakes and ponds selected for this study. These results are far off from the estimated values and their analysis in terms of trophic classification indicates that most of these lakes/ponds are in the eutrophic state, which is contrary to the earlier trophic classification, based on estimated values of phosphorous, chlorophyll a and secchi disc. This advocates the need for field work to collect data on observed springtime phosphorous, chlorophyll a and secchi disc which would be useful in comparing estimated values with observed values as well as in the model parameter calibration. The accuracy of estimates is highly dependent on the accuracy of model parameters. A preliminary model sensitivity analysis indicates that the model is very sensitive to runoff, rainfall, phosphorous export and retention coefficients.

The analysis of the results indicates that most of the lakes/ponds selected for this study except Georges Pond, Shoal Harbour Pond, Freshwater and Garnish Ponds, have no room for additional development and it is recommended that these water bodies be frozen for future development in order to maintain the present water quality levels. The water bodies for which analysis indicated room for additional development, should be assessed for shoreline conditions, drainage pattern, slopes, soils, normal, low and high water marks prior to the onset of future development. This assessment is important because of the fact that most of the cottage developments take place within 200 metres from the shoreline while the trophic state approach assumes that development will be distributed over the entire watershed. Another consideration for the above mentioned investigation is to assess the physical features of the existing cottages, as some of the cottages may be located within the high water mark of the water body and may pose safety and water quality related problems. If this is the case, future development should not be approved until the corrective measures have been adopted to rectify such problems. A recent visit to Garnish Pond during high flow conditions revealed that some of the existing cottages and their sewage disposal systems are within the high water mark of the pond and could be a source of water quality impairment. A similar type of situation may be existing in other recreational areas for which no information is available. For effective and successful planning, it is recommended that a site survey should be conducted and cottage numbers obtained by the trophic state approach should be prorated by an appropriate factor to account for shoreline development.

Section 3 of the report deals with the Natural Shoreline Reserve Method of cottage carrying capacity. The method recommends that 25% of the natural shoreline linear length should be reserved in its natural state to preserve the natural and aesthetic beauty of a water body. In order to apply this approach in Newfoundland, it was concluded that 60% of the suitable shoreline linear length should be considered for planning purposes and 40% of this suitable linear length should be reserved for public spaces such as beaches, public access, etc. This recommendation is based on the fact that in Newfoundland much of the shoreline is covered with wetlands and the terrain is rough with mineral soils being mostly shallow and stony, which is not a favourable situation for satisfactory operation of sewage facilities. The application of this modified approach to the study area indicates that all water bodies except Tors Cove Pond, Cape Broyle Pond and Nine Island Pond can sustain additional cottages. This may not be true in a few cases since this method does not take into consideration other factors such as size of water body, shoreline conditions, pre-development water quality and shoreline land use. Freshwater Pond is a good example of this case where 45% of the natural shoreline is under Provincial Parks jurisdiction and will not be available for development which implies that actual cottage development at Freshwater Pond will be much lower than the estimated numbers.

Shoreline capability is another approach which has been used in Ontario and Saskatchewan for cottage planning. The approach is based on the topography and drainage characteristics of the shoreline and the desirable number of cottages is based on slope of the shoreline and soil types within a distance of 100 metres from the shoreline. As discussed in Section 4, this approach was modified by introducing a 100 metre buffer along the shoreline to account for high flow conditions and 40% of the suitable shoreline reserved for public access, open space and future development. The application of this modified approach to selected water bodies indicates that all ponds and lakes except Tors Cove can sustain additional development. These numbers may be questionable in a few cases especially when shorelines are used for some other purposes as well. Freshwater Pond is a good example of this case where potential carrying capacity of 166 cabins cannot be implemented since approximately 45% of the linear shoreline is owned by a Provincial Park. The approach does not take into consideration pre-development water quality of a water body and water area available for recreational activities.

In the Boat Density Method, which is outlined in Section 5, the size of a water body and area available for boating are the main planning criteria. Once the area available for boating has been determined, then boating capacity of the water body is determined using a recommended boat space standard. The determined boating capacity is apportioned between the private cottagers and non-cottagers at a ratio of 60% and 40% respectively. The private cottagers boating capacity is translated into actual number of cottages assuming that only 10% of the boats will be on a water body at any peak time. This assumption was not found to be practical for Newfoundland conditions and carrying capacity was estimated with 25% of the boats on a water body at any peak time. The carrying capacity results obtained using this method indicates that 11 water bodies (Tors Cove, Cape Broyle, Old Mans, Nine Island, Goulds, Hawcos, Grand, Ocean, Dennys, Peak, Junction Ponds) are over developed and the remaining nine are under developed. The approach considers the size of water body only. Shoreline conditions, other existing land uses and pre-development water quality are not considered in the planning. A shoreline survey is recommended to implement the numbers obtained using this approach.

The existing and potential angling pressure on a water body has also been used for cottage development planning purposes. The methodology is based on fish yield and morophometry of a water body and the fact that cottage development can affect the fish habitat. As discussed in Section 6, the approach provides the planner with the options of determining (1) whether a proposed number of new cottages is likely to generate too much angling pressure on the fishery to sustain, or (2) how many cottages might be put on the lake without giving rise to excessive angling pressure. A complete step-by-step procedure along with required input data is discussed in Section 6. The method could not be tested because of lack of data on total dissolved solids, angling pressure, percentage of sports fisheries, etc. However, it is strongly recommended that at some point in time, the Lands Management Division, in cooperation with the Depart-ment of

Fisheries and Oceans, should collect the required information and test the applicability of this approach.

Section 7 provides an overview of the present cottage planning guidelines outlined in a report *"Recreational Cottage Planning in Newfoundland"*, proposed by the Land Use Management Division in 1978. The document is well written and provides useful information for recreational cottage planning in Newfoundland. However, considering the research development of the 1980's dealing with carrying capacity of lakes, the capability analysis approach (known as High Energy-Low Energy Recreation Cottage Carrying Capacity) presented in the manual seems to be inadequate. The application of this approach to ponds and lakes selected for this study indicate that all water bodies can sustain additional development which is contrary to the fact that many water bodies are experiencing over development and water quality related problems.

For effective and successful cottage planning, it is essential that all constraints to development be considered in determining the carrying capacity of a water body. This can best be accomplished through a spectrum analysis approach. A spectrum analysis approach uses all of the cottage carrying capacity methods or at least one method from each of the three categories discussed in the foregoing sections. The carrying capacity results obtained by each of the three categories are reviewed to provide a range of development level choices or a spectrum of alternatives for planning. A single constraint or a combination of constraints most sensitive to cottage development are used as a basis in selecting the level of development. The results of spectrum analysis approach for each water body are presented in Section 8. The assumptions adopted in the application of each method and recommendations for application of these methods are outlined. The results indicate that eight of the water bodies are under developed (Hell Hill Pond, Middle Gull Pond, Thorburn Lake, Goulds Ponds, Lady Pond, Shoal Harbour Pond, Freshwater Pond and Garnish Pond). Three were at carrying capacity or very close to it (Dennys Pond, Peak Pond and Salmonier Pond) and nine over developed (Tors Cove Pond, Cape Broyle Pond, Old Mans Pond, Nine Island Pond, Goulds Pond, Hawcos Pond, Grand Pond, Ocean Pond and Junction Pond). Of the eight water bodies that were determined as being underdeveloped not all of them will be able to sustain additional level of cottage development for reasons not considered by the spectrum analysis. To overcome spectrum analysis limitations and environmental problems, it is recommended that spectrum analysis results be analyzed along with other site specific information on topography, soil characteristics, access to the area, and other stakeholders in the area before a final decision is made regarding the exact number of cottages on a water body.

Finally, Section 9 of this report outlines guidelines for future cottage planning in this province. The guidelines deals with the types of data to be collected and its utility in cottage planning. The section also provides information on various constraints to cottage development and guidelines to chose appropriate cottage carrying capacity method for single as well as multiple constraints to cottage development. The guidelines outlined in this section will prove to be useful to all for successful cottage planning in this province. The main conclusions drawn from this study and recommendations to improve the cottage development planning in this province are outlined in Section 10.

1.0 INTRODUCTION

1.1 Background

The Island of Newfoundland is richly endowed with many freshwater lakes and ponds, some of which have recreational values for people and are under intense pressure for development. In recent years, demand for outdoor recreation has also increased and most of it has been focused on water bodies. Water based recreational activities are generally grouped into two categories. The first category deals with on and in water activities such as fishing, swimming, boating, water skiing, etc., while the second category deals with on land recreation around water bodies such as cottage industry, which is usually associated with the first category of activities. Both on water and land based recreation developments are related to each other and may deteriorate the environment of lakes/ponds if development exceeds the recuperative capacity of the ecosystem. Also, each water body, depending on its size, location, hydrological and ecological characteristics will vary in its ability to provide for water-based recreation without any impairment to the environment. Accordingly, there is a need to establish a standard methodology to determine the limits to which an area of land, or water, may be used or developed. This limit has been defined as *"use capacity"* or *"development capacity"*, *"lake carrying capacity"* or *"cottage carrying capacity"*. According to *"Guidelines for Land Use Planning"* (MNR, LUCB, Draft 1978), capacity is defined as the upper limits to which an area of land, or water, may be used or developed without an undesirable change taking place in the environment. This capacity is called *"use capacity"* or *"development capacity"*. The other commonly known carrying capacities are: ecological capacity, visitor capacity and institutional capacity. The detailed definitions of these capacities are presented in Appendix A.

Cottage development in Newfoundland is planned by the Land Use Management Division of the Department of Environment and Lands. At present, this planning is based on a manual *"Recreational Cottage Planning in Newfoundland"* prepared by the staff of the Land Use Management Division. The planning manual recommends the use of high and low energy recreation pond capacity approach for cottage carrying capacity determination which is one of the main components of cottage planning. This approach is based on the size of the water body and length of the shoreline and does not take into consideration other important factors such as morphology, drainage pattern, land uses, soil conditions, biological and ecological components. The present study is an effort towards the establishment of a method in which all the above factors are integrated.

1.2 Objectives

The main objective is to recommend guidelines for cottage carrying capacity assessment in this province. Other specific objectives of the study are as follows:

1. *To review the cottage carrying capacity methods and to assess their applicability in Newfoundland;*

2. *To determine the optimum number of cottages to be sustained by each selected lake/pond using various available methodologies;*

3. *To assess the level of the existing development for lakes and ponds in the study area;*

4. *To develop the carrying capacity spectrum for selected lakes and ponds; and*

5. *To make recommendations to determine the carrying capacity of lakes/ponds and cottage development planning in Newfoundland.*

1.3 Scope

This study is based on summarization, analysis and interpretation of data obtained from various provincial and federal departments, reports, scientific publications and telephone contacts with cottage owners. The only new data generated relates to the areas which were digitized for each lake and its watershed. Staff of the Land Use Management Division provided useful information on maps of the area, existing levels of development, and present planning procedure.

The study began with the identification of lakes and ponds with significant recreational activities in the eastern region of the Island. Cottage carrying capacity methods were reviewed and input variables were identified. Data for input variables such as rainfall, runoff, soil conditions, topography, shoreline conditions, existing development, drainage pattern, water quality, etc. were collected from different sources and analyzed to meet the requirements of carrying capacity methods. Carrying capacity of selected lakes was analyzed using the available data. Carrying capacity spectrum was developed for each lake and pond selected for the study. The results of the study were used to classify the lakes as overdeveloped or underdeveloped in terms of their carrying capacity. Finally, the results of the study were summarized and recommendations were made for cottage development planning in Newfoundland.

The report describes the methods and their limitations to determine cottage carrying capacities on the basis of lake trophic state, natural shoreline reserve, shoreline development, boat density and high and low energy recreation. The report also includes examples on how the methods are applied to specific lakes. Results of the study, summarized in a tabular form, reveal the extent to which additional cottages can be permitted on each lake. The detailed procedure for each method is presented in the Appendices at the end of the report.

In view of the limited available data on lakes and ponds and their watershed systems, the methods identified and the results generated through this study should not be viewed as the ultimate solution. Efforts should continue for the refinement of the recommended methodologies based on additional field data. The carrying capacity estimates presented in this report do not offer the right or wrong answers but provide a basis for a rational judgement about the use intensity of the land and water body. These estimates can be used by planners as guidelines in deciding which lakes can sustain additional development and what measures need to be taken to ensure that acceptable levels of development are not exceeded.

1.4 Study Area

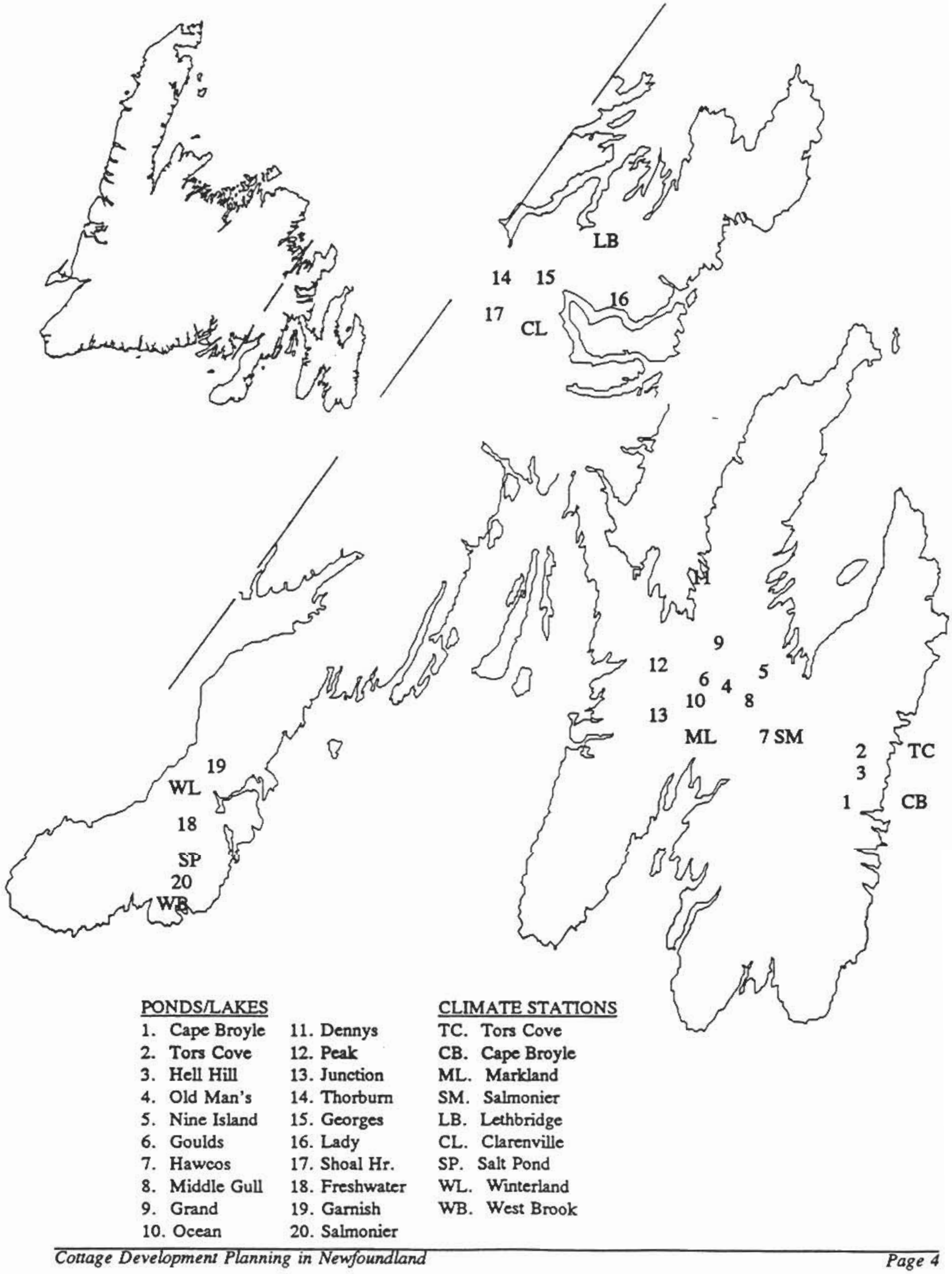
This study of cottage carrying capacity for selected ponds and lakes in Newfoundland was carried out on the eastern part of the Island. The 20 lakes and ponds selected for this study have high recreational values and are under intense pressure for cottage development. The location of selected ponds and lakes is shown in Figure 1.1 and the latitude and longitude of water bodies are given in Table 1.1. Thirteen of the selected water bodies are located on the Avalon Peninsula, three on the Burin Peninsula, and four on the eastern half of the Island near the Town of Clarenville. Much of the study area is characterized by barren, irregular and rough topography with numerous rock outcrops. The soil cover is generally thin, and the proximity of bedrock has led to the formation of many bogs and ponds.

The population of the area is about 320,000 (1986 census), 56% of the total population of the Island, with the major concentration along the coast. Fishing and fish processing is the main economic base of the area. Some peat operations and minor agricultural activities also take place in the southern part of the region. The surface waters of the study area are themselves an important resource, contributing socio-economic benefits through hydropower, tourism, recreation, fisheries and wildlife. Many residents of the study area use surface water for recreation and go to their summer cabins on numerous ponds and brooks. For both tourism and recreation, the benefits are dependent on water quality as well as quantity. To ensure these benefits, it is essential to maintain good water quality, and equally important, the quality of the surroundings.

The climate of the eastern part of the Island is strongly influenced by the cold Labrador current and by onshore winds. The modifying influence of the ocean generally results in cooler summer temperatures and mild winter temperatures. The south flowing cold Labrador current prevents summer temperatures from rising above 20°C. In the winter, the moderating effect of the ocean generally keeps winter temperatures above -10°C. The warmest month is July and the coldest is February, with mean maximum and minimum temperatures of 15.5°C and -4.5°C respectively.

The region receives the highest precipitation in Newfoundland which is distributed fairly evenly throughout the year. Because of the moderate winter temperatures, winter precipitation can fall as either rain or snow. The average annual rainfall varies from approximately 1000 mm to greater than 1300 mm while average annual snowfall equivalent to water depth varies from approximately 150 mm to 400 mm. The wettest time of the year occurs from November to March and the driest period occurs from April to June. Snow cover is often times discontinuous during the winter months.

FIGURE 1.1 MAP SHOWING THE LOCATION OF STUDY LAKES/PONDS AND CLIMATIC STATIONS



PONDS/LAKES

1. Cape Broyle
2. Tors Cove
3. Hell Hill
4. Old Man's
5. Nine Island
6. Goulds
7. Hawcos
8. Middle Gull
9. Grand
10. Ocean
11. Dennys
12. Peak
13. Junction
14. Thorburn
15. Georges
16. Lady
17. Shoal Hr.
18. Freshwater
19. Garnish
20. Salmonier

CLIMATE STATIONS

TC. Tors Cove
CB. Cape Broyle
ML. Markland
SM. Salmonier
LB. Lethbridge
CL. Clarenville
SP. Salt Pond
WL. Winterland
WB. West Brook

TABLE 1.1 LOCATION OF TWENTY SELECTED LAKES/PONDS

Water Body	NTS Map No.	Latitude (N)	Longitude (W)
Cape Broyle Pond	1N/2	47°07'	52°56'
Tors Cove Pond	1N/2	47°13'	52°53'
Hell Hill Pond	1N/2	47°09'	52°55'
Old Mans Pond	1N/6	47°26'	53°20'
Nine Island Pond	1N/6	47°26'	53°17'
Goulds Pond	1N/6	47°25'	53°23'
Hawcos Pond	1N/6	47°18'	53°18'
Middle Gull Pond	1N/6	47°22'	53°18'
Grand Pond	1N/6	47°27'	53°22'
Ocean Pond	1N/6	47°25'	53°27'
Dennys Pond	1N/11	47°34'	53°29'
Peak Pond	1N/5	47°27'	53°37'
Junction Pond	1N/5	47°22'	53°40'
Thorburn Lake	2D/8	48°16'	54°09'
Georges Pond	2D/8	48°16'	54°04'
Lady Pond	2C/4	48°14'	53°43'
Shoal Harbour Pond	2D/1	48°11'	53°59'
Freshwater Pond	1M/3	47°06'	55°16'
Garnish Pond	1M/3	47°12'	55°13'
Salmonier Pond	1M/3	47°32'	55°34'

1.5 Lake Carrying Capacity Methods

Lake carrying capacity can be defined as the ability of a lake to sustain particular types of development within defined levels of water quality standards. Every lake has two carrying capacities known as ecological and social. The ecological capacity deals with the maximum level of nutrients loading that a lake will tolerate while social capacity deals with the level of recreational use that people will tolerate. In both cases, the use or development limits are defined on the basis of predefined objectives i.e. the objective is to maintain a particular water quality level, types of fish population, characteristics of the shore land and safety. This suggests the need to define the objectives and then analyze the current state of a lake in light of these objectives.

There is no single method that describes the amount of development or use a lake can accommodate. Much depends on the objectives, type of lake, morphology of lake and the nature of the present development. In general, all the above factors play an important role in defining the development level of a lake. Since each lake has its own development capacity, standard development for one lake cannot be applied to other lakes and, therefore, each lake has to be examined separately. Excessive lake development has negative impacts on the economy of the region which results in a decline in visitors and depression in property value.

In the past, the following methods have been developed and tested to evaluate the development limit of a lake or pond: Lake Trophic State, Natural Shoreline Reserve, Shoreline Capability, Boat Density, and Sport Fisheries. These methods can be applied to both developed and under developed lakes. Some of these methods have been adopted for the planning of cottage development in Ontario and Saskatchewan. This study deals with the review of all these methods and their application to selected lakes and ponds in Newfoundland. Model formulation, data requirement, assumptions, limitations and other details of these methods are discussed in subsequent sections of this report.

1.6 Outline of Report

This report is comprised of ten chapters. Chapters 2, 3, 4, 5 and 6 present the formulation, basic assumptions, application and results (if applicable) of the lake trophic state, natural shoreline reserve, shoreline capability, boat density and sport fisheries carrying capacity method respectively. The limitations associated with each method are also summarized.

In Chapter 7, an overview of present recreational cottage planning in Newfoundland is presented. The results on carrying capacity of lakes and ponds selected for the study are also summarized.

In Chapter 8, the results of the carrying capacity spectrum are presented. The results provides the user with a number of scenarios for cottage development.

The findings of the study and recommendations for future cottage carrying capacity planning are presented in Chapters 9 and 10.

2.0 LAKE TROPHIC STATE

2.1 Introduction

Lake water quality assessment can be carried out in two parts: (1) the determination of lake trophic status, and (2) the evaluation of the relationship between water quality and watershed land use. The trophic status of a lake is usually assessed by measurement of specific water quality parameters including total phosphorus concentrations, average summer time chlorophyll a levels (a measurement for phytoplankton biomass), water clarity (often known as secchi disc depth), total dissolved solids, total alkalinity, dissolved oxygen deficit, standing crops of plankton and bottom fauna, and morphology of the water body. This basic information along with additional data on watersheds and its land uses can be used as input to trophic status models to estimate development limits.

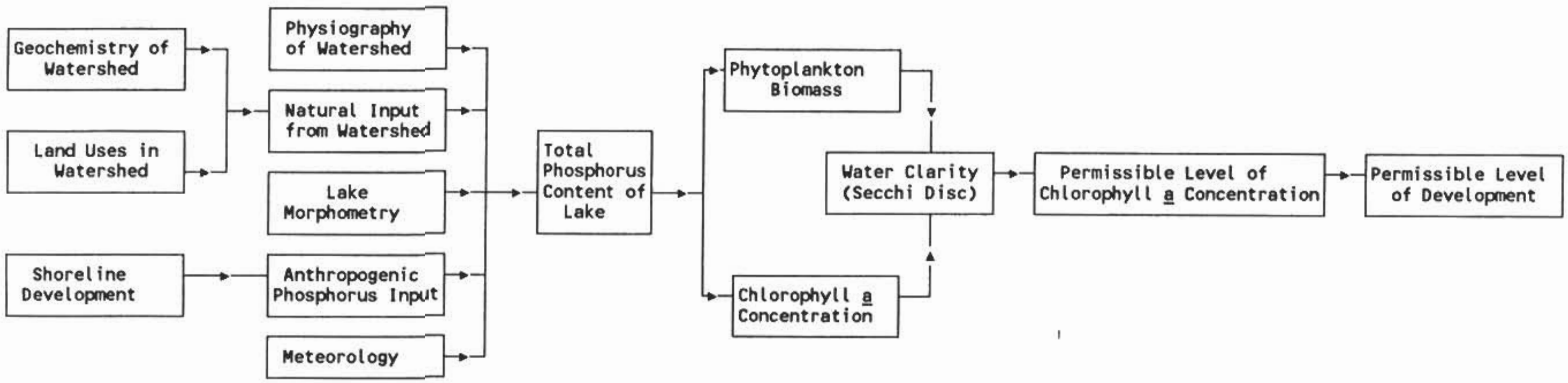
The *"trophy"* of a lake is defined as the rate at which organic matter is supplied by or to the lake. The adjective trophic comes from the Greek word for food. The effects of chemical (phosphate, nitrates, lime and other chemicals) input on a water body are generally expressed on a scale from nutrient poor to nutrient rich. Nutrient poor lakes have low production of photosynthetic organisms and are classified as oligotrophic lakes, while nutrient rich lakes have high productions and are classified as eutrophic. Lakes in an intermediate state are classified as mesotrophic. Lakes located in the sparse soil and granitic rocks of the precambrian shield tend to be oligotrophic, whereas those in deep glacial overburden and limestone bedrock are usually mesotrophic or eutrophic.

Relationship between total phosphorus content and trophic status was the main basis for the conceptual model developed by Dillon and Rigler (1975) and Vollenweider (1973) for the assessment of the effects of lakeshore development on the trophic status of lakes. The conceptual model is outlined in Figure 2.1. The potential effects of shoreline development on trophic status were considered to result from the septic systems. Other man made activities in, on and around lakes were considered to have little impact on trophic status. The model can be used for determining the effects of shoreline development on variables which described the trophic status of a lake including the concentration of total phosphorus (TP), chlorophyll a concentration, water clarity, and aerial hypolimnetic oxygen deficit (AHOD). The model can also be used to determine the capacity of a specific lake for development if an acceptable level of trophic status is specified.

2.2 Methodology

The approach described below is based on the concepts advanced by Vollenweider (1973), and further defined by Dillon (1974) and Dillon and Rigler (1975). The method relates a lake's phosphorus balance to hydrologic budget and morphometry so that trophic state alternations resulting from land use changes can be predicted. The basic steps of the methodology include:

FIGURE 2.1 CONCEPTUAL MODEL DEFINING THE RELATIONSHIP BETWEEN TOTAL PHOSPHORUS AND THE TROPHIC STATUS OF A WATER BODY



A. An estimate of the total phosphorus exported to a lake from its watershed.

B. An estimate of the total phosphorus in precipitation falling directly on a lake.

C. An estimate of the total natural phosphorus load to the lake.

D. An estimate of the total man-made or artificial phosphorus loading to the lake.

E. A prediction of the spring time total phosphorus concentration.

F. A prediction of the average summer time chlorophyll a concentration.

G. A prediction of the summer secchi disc transparency.

The results obtained from the above are used to define the permissible level of phosphorus loading for a given water body, which in turn is used to calculate the permissible level of cottage development. The methodology, theoretical background and comments on each of the above steps are presented in the following sections.

2.2.1 Basic Morphometric, Meteorological and Land Use Data

The different type of data to be collected under this category is surface area of lake or pond (A_o) in m^2, volume of lake or pond (v) in m^3, average depth of lake or pond (Z) in metres, watershed area of lake or pond (A_d) in m^2, mean annual precipitation (P_r) in metres, mean annual evaporation (E_v) in metres, mean annual runoff (r) in metres and physiographic characteristics of the watershed.

2.2.2 Hydrological Characteristics

Information on various hydrological parameters such as total outflow volume, flushing rate, areal water load, and retention coefficient of lakes or ponds is required as input to the model. The details of these variables are discussed in the following section.

Total outflow volume (Q):

The computation of the total outflow volume from a lake or pond will depend on the surface area of a lake or pond and its watershed area. If the watershed area is greater than ten times the surface area of the lake, then the total outflow volume from a lake or pond is calculated using the following equation:

$$Q = A_d \times r \qquad 2.1$$

where Q = total outflow volume in m^3/year
A_d = the watershed area in m^2
r = the mean annual runoff (m/year)

If the watershed area is less than ten times the lake or pond surface area, then the following equation

$$Q = A_d \times r + A_o (P_r - E_v) \qquad 2.2$$

where A_o = the lake surface area in m^2
P_r = the mean annual precipitation in m/year
E_v = the mean annual evaporation in m/year

Flushing rate (ρ):

Flushing rate or water replenishment rate of a lake or pond is calculated using the following equation:

$$\rho = \frac{Q}{V} \qquad 2.3$$

where ρ = the flushing rate and
V = the volume of the lake in m^3

Long-term variations of a lake or water quality are associated with the flushing rate or hydraulic detention (residence time) of the water body. Hydraulic residence time of a reservoir is defined as

$$T_R = \frac{V}{Q}$$

$$\text{or} \quad T_R = \frac{1}{\rho} \qquad 2.4$$

where T_R = residence time

Areal water load (q_s):

The areal water load (q_s) of a lake or pond is defined as the lake outlet discharge divided by the lake surface area and is expressed as

$$q_s = \frac{Q}{A_o} \qquad 2.5$$

where q_s = areal water load in m/year

Flushing rate, hydraulic residence time and areal water load are interrelated by the lake morphometry and either can be used in the model.

Retention coefficient (R):

Phosphorus is lost from the water column of lakes by two major processes - outflow and sedimentation. Unfortunately, sedimentation is more important for total phosphorous (TP) than is loss by outflow. A number of approaches have been used to account for loss of TP through sedimentation. According to mass balance models used to predict chemical content of lakes, the retention coefficient of phosphorus through sedimentation can be expressed as

$$R = \frac{V}{V + q_s} \qquad 2.6$$

where V = settling velocity in m/sec
q_s = areal water load in m/year $\frac{(Q)}{A_o}$

Empirical calibration of Equation 2.6 with data collected for a limited number of lakes (Dillon and Kirchner 1975) indicates that settling velocity averaged 13.2 m/year. Reckhow (1977) proposed that different mass balance models are required for oxic and anoxic lakes. Empirical calibration of Equation 2.6 by optimizing the settling velocity (v) such that the predicted and observed TP concentrations agree, indicated that for anoxic lakes, the optimum settling velocity is 7.2 m/year while for oxic lakes the volume is 12.4 m/year.

2.2.3 Total Phosphorus Supply

There are two main sources of phosphorus supply to any water body i.e. watershed area, phosphorus supply from natural sources (precipitation and drainage area) and phosphorus supply from artificial sources (shoreline development). Total phosphorus supply to a lake or pond from the above two sources can be predicted according to the following approaches.

Total Phosphorus Supply From Natural Sources (J_N):

Precipitation and overland drainage are the main natural sources of phosphorus supply. Phosphorus contribution through precipitation (J_{pr}) can be predicted using the following equation:

$$J_{pr} = L_{pr} \times A_o \qquad 2.7$$

where L_{pr} = the phosphorus loading value for precipitation
A_o = the lake surface area in m^2

According to Dillon et. al. (1978), L_{pr} has been reported to range between 30 - 70 $mg/m^2/year$ and a value of 50 $mg/m^2/year$ has been recommended as a reasonable value. Some published values for bulk phosphorus loading via precipitation are 77.2 $mg/m^2/year$ (Dillon, 1974), 37 $mg/m^2/year$ (Cromolka, 1975), 74.4 $mg/m^2/year$ (Nicholls and Cox, 1977), 24-53 $mg/m^2/year$ (Schindler et al., 1978) and 15-60 $mg/m^2/year$ (Rechhow and Simpson, 1980).

Phosphorus is also transported from watersheds to lakes via streamflow. Phosphorus supplied through the watershed (J_D) can be calculated using the following equation:

$$J_D = A_d \times E \qquad 2.8$$

where A_d = the total area for each land use within the watershed in m^2
E = the phosphorus export value which corresponds to each of the land use categories ($mg/m^2/year$)

The earliest attempt to classify watersheds on the basis of the total phosphorus export was made by Vollenweider (1968). According to the results of his study, the watersheds on oligotrophic soils usually had a total phosphorus export of <20 $mg/m^2/year$ while more fertile watersheds which are often used for agriculture, had TP export of >20 $mg/m^2/year$. Dillon and Kitchner (1975) categorized all watersheds for which TP export was reported according to land use and bedrock geology. The TP export values for watersheds with various land uses and geological classifications are presented in Table 2.1.

TABLE 2.1 RANGES AND MEAN VALUES FOR EXPORT OF TOTAL PHOSPHORUS

Land Use	**GEOLOGICAL CLASSIFICATION**			
	Igneous		**Sedimentary**	
	Range	Mean	Range	Mean
	$mg/m^2/year$		$mg/m^2/year$	
Forest	0.7-12.2	5.5	6.7-14.5	10.3
Forest Pasture*	0.7-16.0	9.8	5.8-37.0	19.8

* 15% or more of watershed was cleared

Export coefficients for various land uses according to Reckhow and Simpson (1980) are as presented in Table 2.2. These coefficients are based on land use only and bedrock geology was not considered.

Table 2.2 PHOSPHORUS EXPORT COEFFICIENTS

Land Use	Export Coefficient - mg/m²/year		
	High	Medium	Low
Urban	500	80-300	50
Rural/Agriculture	300	40-170	10
Forest	45	14-30	2
Pasture	60	20-50	15

Total phosphorus supply to a lake or pond from natural sources can be estimated as

$$J_N = J_{pr} + J_D \qquad 2.9$$

Total Phosphorus Supply From Artificial Sources (J_A):

Human activities may contribute (TP) to a lake in many ways. Phosphorus input from waste disposal systems was considered to be the most important potential source of anthropogenic TP. Several factors such as input of TP to sewage disposal systems and removal of TP by sewage disposal systems, will influence the supply of TP to lakes from waste disposal systems. The current artificial phosphorus supply from the sewage disposal systems associated with the development of cottages and cabins at the shoreline of lakes or ponds can be calculated as

$$J_A = S \times N_{cy} (1 - R_s) \times N \qquad 2.10$$

where S = the amount of phosphorus contributed per capita year of use (kg/capita year)
N_{cy} = the number of capita years/year/unit
R_s = the retention coefficient of the existing sewage treatment facilities
N = the number of cottage and resort units

On the basis of past studies, the value of S has been recommended as 0.8 kg/capita year. According to Reckhow and Simpson (1980), this value could be as low as 0.3 kg/capita year and as high as 1.8 kg/capita year. The retention coefficient of sewage disposal system varies with the type of system and soil conditions in the area. If the septic system is in a satisfactory condition and the information on soil type is available, then a retention factor may be adopted from values recommended by Brandes, Chowdry and Cherry (1974) and outlined in Table 2.3.

TABLE 2.3 RETENTION COEFFICIENT OF TP FOR SEPTIC FILTER BED OF DIFFERENT CHARACTERISTICS

	Filter Bed	R_s
1	22 in. sand (D_{10} = 0.24 mm) 8 in. mixture 4% red mud, 96% sand	0.76
2	30 in. sand (D_{10} = 0.30 mm)	0.34
3	30 in. sand (D_{10} = 0.60 mm)	0.22
4	30 in. sand (D_{10} = 0.24 mm)	0.48
5	30 in. sand (D_{10} = 1.0 mm)	0.01
6	30 in. sand (D_{10} = 2.5 mm)	0.04
7	15 in. sand (D_{10} = 0.24 mm) 15 in. mixture 10% red mud, 90% sand	0.88
8	15 in. sand (D_{10} = 0.24 mm) 15 in. mixture 50% limestone, 50% sand	0.73
9	30 in. silty sand	0.63
10	15 in. sand (D_{10} = 0.24 mm) 15 in. mixture 50% clay-silt, 50% sand	0.74

Total phosphorus supply (J_T) in kg/year to a lake from natural and artificial sources can be expressed as

$$J_T = J_N + J_A \qquad 2.11$$

where J_N = total phosphorus supplied from natural sources in kg/year
J_A = total phosphorus supplied from artificial sources in kg/year

For the assessment of trophic state changes in a water body, all approved and proposed lots must be considered in estimating artificial phosphorus loading. However, proposed lots should not be considered if the objective is to predict present total phosphorus concentration, chlorophyll a concentration and secchi disc depths.

2.2.4 Existing Spring Total Phosphorus Concentrations, Average Summer Chlorophyll a Levels and Secchi Disc Transparencies

Existing Spring Total Phosphorus Concentrations

The springtime total phosphorus concentration, average summer chlorophyll a level, and secchi disc depth are considered as baseline parameters in defining the trophic status of a water body. All impoundments (lakes, ponds, reservoirs), whether natural or artificial, undergo eutrophication, which is caused by the natural or artificial addition of nutrients. Initially an impoundment is characterized by low nutrient concentrations and low biological productivity, which is termed as the oligotrophic stage. As the mass of nutrients, present in the impoundment, increases the biological productivity increases and impoundment passes into the mesotrophic stage. When nutrient concentrations and biological productivity become high, the impoundment is termed as eutrophic. Eutrophication is a natural process, but the rate of progression from an oligotrophic to a eutrophic state is directly related to the shoreline development and man-made activities. At present, there is no precise numerical definition for determining the trophic status of a water body.

The factors that determine the TP concentrations in lakes include lake morphometry, the hydrologic budget, the TP input and TP loss rate. Over the past years, numerous models (Vollenweider 1969, Dillon and Rigler 1974, Vollenweider 1978, Reckhow 1977, Walker 1977 and others) have been employed to interrelate these parameters. All these developments are based on mass balance of a nutrient between its source and its losses. The general equation takes the following form:

> Nutrient gain or loss = external nutrient load -loss by lake outflow - loss to the lake sediment + nutrient reloading from lake sediment.

As discussed earlier, sedimentation from the water column is the major mechanism for the loss of TP and must be considered in model formulation. Accordingly, Dillon and Kitchner, 1975, developed a model to predict TP through the use of a retention coefficient. In mathematical format at steady - state, the model can be expressed as

$$P = \frac{J_T (1 - R)}{Q} \tag{2.12}$$

where P = the existing spring phosphorus concentration in kg/m^3
J_T = the total phosphorus supply in kg/year
R = the retention coefficient of the lake
Q = the total outflow volume in m^3/year

Many alterations have been proposed to this simple mass balance model and several improvements have been made. The simplest version of the total phosphorous mass balance model was later modified to:

$$P = \frac{L (1 - R)}{0.956\, q_s} \tag{2.13}$$

where $L = \frac{J_T}{A_o}$ and $q_s = \frac{Q}{A_o}$

A factor of 0.956 was incorporated to update the basic assumption of the model that TP concentration in lake and outlet is equal. Once the prediction has been made, the results are compared with measured values. Depending on the accuracy of observed and predicted results, judgement is made whether the estimated J_T and the adopted value of R are correct or not.

Vollenweider (1968) investigated the phosphorus loading versus mean depth relationship. According to him, when the areal total phosphorus loading was plotted against mean depth on a log - log scale (Figure 2.2), straight lines or bands could be arbitrarily drawn separating lakes into three standard lake types - in terms of degree of eutrophication i.e. oligotrophic, mesotrophic, or eutrotrophic lakes. Flushing rate of lakes were not incorporated in this model. The data of this figure has been translated into a table and is presented in Table 2.4 which provides approximate phosphorus loading rates required to maintain lakes in a steady state.

TABLE 2.4 PROVISIONAL LOADING LEVELS FOR TOTAL PHOSPHORUS IN GRAMS/M^2/YEAR

Mean Depth (m)	Permissible Loading	Dangerous Loading
5	0.07	0.13
10	0.10	0.20
50	0.25	0.50
100	0.40	0.80
150	0.50	1.00
200	0.60	1.20

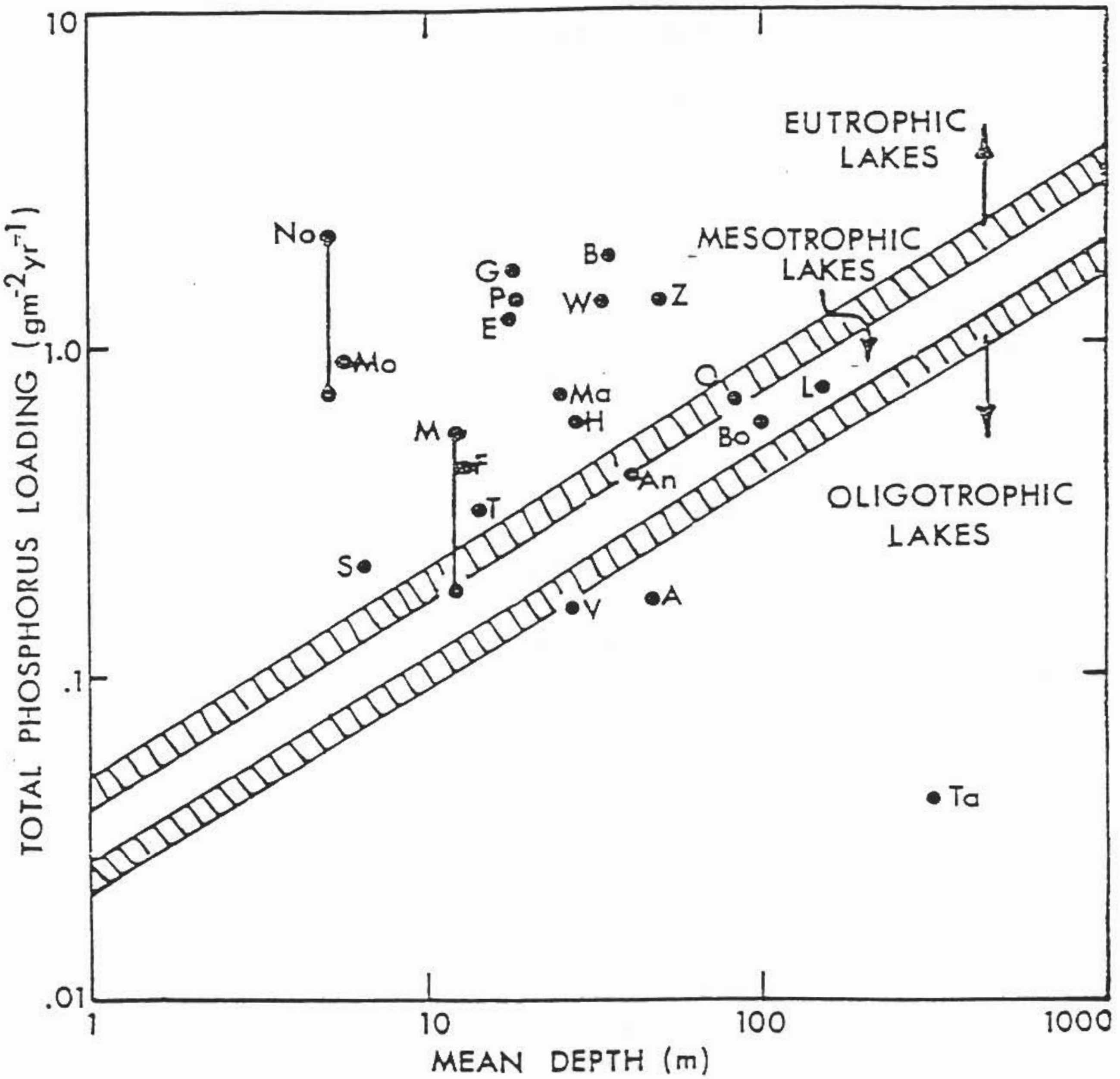
Average Summer Chlorophyll a Levels

Recognizing that the nutrient loading to a reservoir directly affects biomass production/growth, a number of investigators have developed regression model for the estimation of concentration of chlorophyll a in a reservoir as a function of the nutrient loading. Dillon and Rigler (1974) utilized data from 19 lakes in Southern Ontario and developed a relationship between chlorophyll a and phosphorous concentration.

$$\log [\text{chl } \underline{a}] = 1.45 \log [P] - 1.14 \qquad 2.14$$

where chl a = mean summer chlorophyll a concentration in mg/l
and P = total phosphorous concentration at spring overturn in mg/l

FIGURE 2.2 TOTAL PHOSPHORUS LOADING VERSUS MEAN DEPTH RELATIONSHIP (After Vollenweider, 1968)



The above relationship was based on the observation made by Sakamoto (1966) that TP and chlorophyll concentrations were highly related with TN:TP > 12. Sakamoto also noted that lakes with low TN:TP (< 10) demonstrated better relationship between chlorophyll and TN than TP. In view of this, Dillon and Rigler (1974) specified that the predictive relationship be used only in these cases where TN:TP > 12. In the subsequent decade, several other predictive relationships relating chlorophyll a̲ and nutrients have been developed but to date, the equation developed by Dillon and Rigler is commonly used. Sawyer (1947) and Dillon (1974) have also related phosphorus concentration to chlorophyll levels as shown in Figure 2.3 which reflects trophic status of lake. This relationship has been recommended as a convenient means of predicting the average summer time chlorophyll concentration in a lake from a single measurement or prediction of the phosphorus concentration at spring overturn.

Secchi Disc Depth or Water Clarity

Water clarity in lakes is governed by the amount of a particulate material, the amount and colour of dissolved organic matter and by the inherent absorption of light by pure water (Brezonik 1978). The secchi disc depth and chlorophyll a̲ concentration have been found to be highly correlated with each other. Accordingly, Dillon and Rigler (1975) demonstrated that the relationship between chlorophyll a̲ and secchi disc depth can be written as

$$SD_{ss} = \frac{5.21}{(\text{chlorophyll } \underline{a})^{0.41}} \qquad 2.15$$

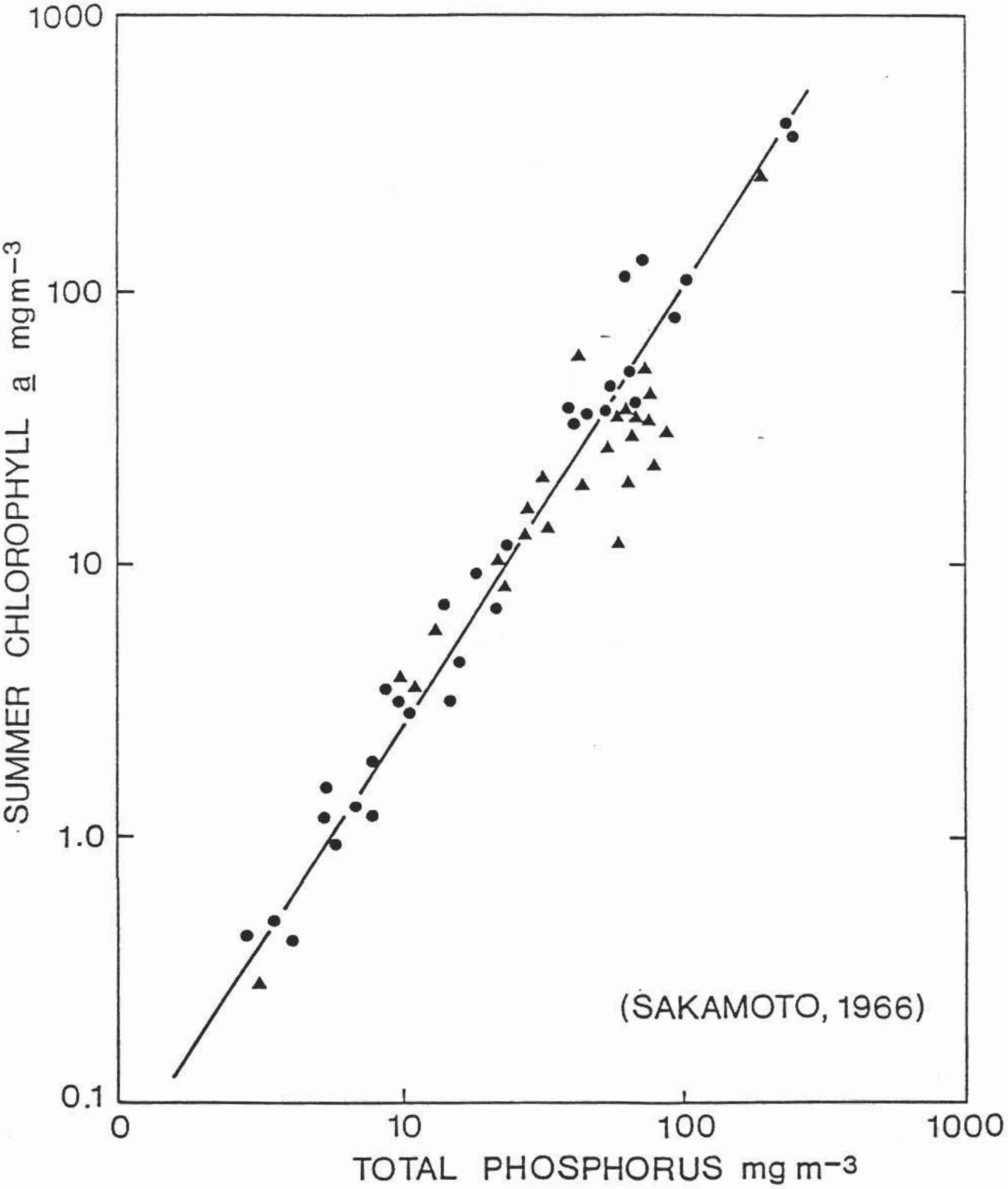
where SD_{ss} = the mean secchi disc depth in metres during summer stratification

However, predictive capability of this equation for lakes with high concentrations of dissolved organic matter was poor. Dillon and Rigler (1974) presented another relationship (Equation 2.16) to predict the secchi disc depth.

$$SD_{ss} = \frac{1}{(0.1138 + 0.0386 \, (\text{chlor } \underline{a}))}$$

The three parameters discussed above are considered as baseline parameters to assess the trophic status of a water body. Phosphorus is considered to be the nutrient most frequently in limiting supply to algal and aquatic plant growth, while chlorophyll a̲ is the green photosynthetic pigment in algae and provides a rough indication of the degree of biological activity at the time of sampling. The secchi disc depth is the depth at which a small (20 cm diameter) disc having black and white alternating quadrants disappears from view when lowered into a lake. The depth at which the disc can be seen is a measure of water transparency and is influenced mainly by algal population.

FIGURE 2.3 TOTAL PHOSPHORUS AND SUMMER CHLOROPHYLL RELATIONSHIP (After Sakamato 1966)



Trophic-State Indices

The trophic-state index (TSI) is a summary statistics which is intended to allow the trophic state of an impoundment to be estimated on the basis of a numerical value. A number of attempts have been made to establish a TSI which is based on commonly available water quality parameters. For example, Sakamoto and Dobson et al. (1966) have developed TSI based on the concentration of chlorophyll a (Table 2.5). The U.S. Environmental Protection Agency has suggested a TSI based on the concentration of chlorophyll a, the total phosphorus concentration, and the secchi disc depth (Table 2.6). However, all these classifications are based on subjective judgements and geographically limited database and may not be applicable to other regions.

TABLE 2.5 TROPHIC STATE AS A FUNCTION OF CHLOROPHYLL a (After Sakamato and Dobson et al. 1966)

Trophic State	Concentration of Chlorophyll a (μg/l)		
	Sakamota	Dobson	National Academy
Oligotrophic	0.3 - 2.5	0 - 4.3	0 - 4
Mesotrophic	1 - 15	4.3 - 8.8	4 - 10
Eutrophic	5 - 140	>8.8	>10

TABLE 2.6 TROPHIC STATE AS A FUNCTION OF CHLOROPHYLL a, TOTAL PHOSPHORUS, AND SECCHI DISC DEPTH (USEPA)

Trophic State	Chlorophyll a (μg/l)	Total Phosphorus (μg/l)	Secchi Disc Depth (m)
Oligotrophic	<7	<10	>3.7
Mesotrophic	7 - 12	10 - 20	2.0 - 3.7
Eutrophic	>12	>20	<2.0

Tables 2.7 and 2.8 illustrate values for secchi disc, total phosphorus (TP), and chlorophyll a and their relationship to trophic state based on the work of Reckher (1978). Table 2.7 expresses the traditional classification ranging from oligotrophic to hypereutrophic while Table 2.8 allows for 100 TSI, providing a clearer resolution for rating lakes in relation to each other. Trophic state index (TSI) values reported in Table 2.8 are calculated using the following relationships:

$$TSI_{(TP)} = 4.14 + 14.43 \ln (TP) \quad 2.17$$

$$TSI_{(CHL)} = 30.56 + 9.81 \ln (CHL) \quad 2.18$$

$$TSI_{(SD)} = 60 - 14.43 \ln (SD) \quad 2.19$$

where TP(μg/l), CHL(μg/l), and SD(m) are the measured average values for the lake.

TABLE 2.7 GENERAL TROPHIC CLASSIFICATION OF LAKES AND RESERVOIRS (After Reckher, 1978)

Parameter	Oligotrophic	Mesotrophic	Eutrophic	Hypereutrophic
Trophic state index	≤40	41 - 50	51 - 70	>70
Total phosphorus (μg/l)	≤12	13 - 25	26 - 99	≥100
Chlorophyll a (μg/l)	<3	3 - 7	8 - 54	≥55
Secchi transparency depth (m)	>13	13 - 6.5	6.5 - 1.5	<1.5

TABLE 2.8 CARLSON'S TROPHIC STATE INDEX (After Reckher, 1978)

TSI	Secchi disc (m)	Surface phosphorus (μg/l)	Surface chlorophyll (μg/l)
0	64	0.75	0.04
10	32	1.5	0.12
20	16	3	0.34
30	8	6	0.94
40	4	12	2.6
50	2	24	6.4
60	1	48	20
70	0.5	96	56
80	0.25	192	154
90	0.12	384	427
100	0.062	768	1183

2.2.5 Maximum Permissible Development

Calculation for maximum permissible development of a lake will depend on maximum acceptable chlorophyll value related to the lake's biological, physical, and morphometric characteristics and desired uses. Maximum permissible average summer chlorophyll a concentrations for various desired uses of lakes are given in Table 2.9. Lake phosphorus concentration can also be expressed in terms of trophic status or related to intended lake use. Table 2.10 shows these relationships.

TABLE 2.9 MAXIMUM PERMISSIBLE AVERAGE SUMMER CHLOROPHYLL a CONCENTRATION (After Dillon, 1975)

Lake Level	Chlorophyll Concentration mg/m^3	Use of Lake	Remark
Level 1	2.00	1. Primarily for body contact and water recreation	1. Lake will be unproductive
		2. To maintain hypolimnetic concentration of oxygen in excess of 5 mg/l to preserve cold water fisheries	2. Lake will be extremely clear with secchi disc depth >5 m
Level 2	5.00	1. Primarily for body contact and water recreation	1. Lake will be moderately productive
		2. Preservation of cold water fisheries is not a criteria	2. Secchi disc depth will range 2 - 5 m
Level 3	20.00	1. No body contact and recreation	1. Development of algae and rooted aquatic problems
		2. No fisheries	2. Secchi disc depth <2 m
Level 4	25.00	1. No recreation	1. Extensive algae bloom
		2. Hypolimnetic depletion will occur in summer	

TABLE 2.10 PROPOSED RELATIONSHIPS AMONG PHOSPHORUS CONCENTRATION, TROPHIC STATE AND LAKE USE (After Dillon, 1975)

Phosphorus Conc. (μg/l)	Trophic State	Lake Use
<10	Oligotrophic	Suitable for water based recreation and propagation of cold water fisheries such as trout. Very high clarity and aesthetically pleasing.
10 - 20	Mesotrophic	Suitable for water based recreation but not for cold water fisheries. Clarity less than for oligotrophic lakes.
20 - 50	Eutrophic	Limited total body contact suitability, based upon either loss of aesthetic properties or possible health hazards. Generally very productive for warm water fisheries.
>50	Hypereutrophic	A typical *"old aged"* lake in advanced succession. Some fisheries, but high levels of sedimentation and algae or macrophyte growth, may be diminishing open water surface area.

Maximum allowable development for any water body will also depend on maximum permissible spring total phosphorus concentration.

According to Equation 2.14

$$\log [\text{chl } \underline{a}] = 1.45 \log [P] - 1.14 \qquad 2.20$$

or

$$\log [P]_{Perm} = \frac{\log [\text{chl a}]_{Perm} + 1.14}{1.45}$$

where $[\text{chl } \underline{a}]_{Perm}$ = maximum acceptable chlorophyll $\underline{a}$ concentration from Table 2.9

Once permissible levels of phosphorus have been calculated, then calculate the maximum permissible phosphorus supply using Equation 2.12

$$P = \frac{J_T (1 - R)}{Q}$$

or

$$J_{Perm} = \frac{P_{Perm} \times Q}{(1 - R)} \qquad 2.21$$

P_{Perm} will be calculated in mg/l using Equation 2.20. Q and R are the same as discussed before.

At this stage, it should be ensured that total phosphorus supply J_T should not exceed the maximum permissible phosphorus supply J_{Perm}. In case it does exceed, any additional development should not be allowed. If $J_T < J_{Perm}$, then maximum additional development should be calculated using the following equation:

$$N_{Perm} = \frac{J_{Perm} - J_T}{S \times N_{cy} (1 - R_s)} \qquad 2.22$$

where J_{Perm} = the maximum permissible phosphorus supply in kg/year

J_T = the total existing phosphorus supply in kg/year

S, N_{cy} and R_s are the same as discussed in Equation 2.10

For planning purposes, the total development capacity of a water body can be estimated by the following equation:

$$N_{Perm} = \frac{J_{Perm} - J_N}{N_{cy} \times S(1 - R_s)} \qquad 2.23$$

Complete step by step procedure to calculate cottage development of a water body is presented in Appendix B.

2.3 Application of the Methodology to Selected Lakes

The methodology described in previous sections was used to carry out cottage capacity assessments of the 20 lakes and ponds selected for the study. The approach, criteria and assumption adopted in selecting various parameters are discussed in the following section.

2.3.1 Morphometry and Meteorology

2.3.1.1 Morphometry

Parameters related to morphometry of lakes/ponds and meteorology of the study area were adopted from various government published reports.

Surface area of the lakes (A_o) was determined by digitizing the boundaries using aerial photographs and/or 1:50,000 scale topographic maps. This data was also verified with the data digitized by Federal Fisheries. Average depth (Z) and maximum depth (Z_{max}) of lakes and ponds under study were obtained from bathometric survey reports prepared by Federal Fisheries (Wiseman and Whelan, 1973, 74, 76, 77).

Lakes and ponds for which bathometric survey was not conducted, depth data was obtained by telephone contact with various individuals and government officials in the area. Drainage boundaries of each lake were outlined on 1:50,000 scale topographic maps by following the high points of land. The resulting boundaries were also compared with the aerial photographs. Finally, these boundaries were digitized to determine drainage area (A_d) for each lake. A summary of selected morphometric information is presented in Table 2.11.

The lakes selected for this study vary in area from 24.8 to 962.0 hectares, in mean depth from 1.3 to 25.0 metres, in drainage area from 87 to 19243 hectares, and in volume from 0.62×10^6 to 158.0×10^6 m^3. The ratio of $(A_d + A_o)/V$, a good indicator of lake productivity, ranges from 0.42 to 16.62. All lakes and ponds except Cape Broyle Pond, Junction Pond, Freshwater Pond, and Garnish Pond are headwater lakes with many small and permanent brooks draining into and out of these lakes and ponds. Few ponds have several small impoundments in their watersheds. All ponds have a single, well developed outflow. Main inflow and outflow sources for each pond are listed in Table 2.12. Water bodies with well defined outflow are considered to be less sensitive to development.

TABLE 2.11 SUMMARY OF SELECTED MORPHOMETRIC ATTRIBUTES FOR STUDY LAKES/PONDS

Water Body	Drainage Area of Lake Watershed (A_d) in $m^2 \times 10^6$	Lake Gross Area in $m^2 \times 10^4$	Island Area in $m^2 \times 10^4$	Lake Net Area in m^2 (A_o) x 10^6	Average Depth of Lake in Metres Z	Maximum Depth of Lake in Metres Z_{max}	Volume of Lake in $m^3 \times 10^6$ ($V = A_o \times Z$)	$\frac{A_d + A_o}{V}$
1. Tors Cove Pond	190.37	238.9	4.5	2.344	9.1	31.4	21.3	9.03
2. Hell Hill Pond	7.51	114.3		1.143	4.4	17.7	5.0	1.72
3. Cape Broyle Pond	135.98	273.0	2.9	2.701	6.6	25.3	17.8	7.78
4. Old Mans Pond	0.87	24.8		0.248	2.5	-	0.6	1.80
5. Nine Island Pond	5.70	165.2	3.1	1.621	6.2	16.2	10.1	0.73
6. Goulds Pond	1.74	63.6	0.2	0.624	3.1	-	1.9	1.22
7. Hawco's Pond	12.95	263.1	6.3	2.568	3.4	11.4	8.7	1.78
8. Middle Gull Pond	11.14	314.4	7.8	2.066	10.3	32.6	31.6	0.45
9. Grand Pond	12.43	187.2	5.1	1.821	3.9	14.6	7.1	2.01
10. Ocean Pond	21.50	439.5	35.1	4.044	4.5	9.8	18.2	1.40
11. Denny's Pond	21.95	94.0	1.2	0.928	4.6	-	4.3	5.36
12. Peak Pond	3.37	56.4	1.7	0.547	1.3	2.4	0.7	5.51
13. Junction Pond	25.12	61.9		0.619	3.1	12.0	1.9	13.41
14. Thorburn Lake	25.23	289.3		2.893	12.3	-	35.6	0.79
15. Georges Pond	19.88	445.5	0.1	4.456	6.1	-	27.2	0.90
16. Lady Pond	68.68	475.8	5.6	4.702	25.0	-	118.0	0.62
17. Shoal Harbour	40.99	309.6	19.1	2.905	6.7	-	19.5	2.26
18. Freshwater Pond	148.87	962.0	1.4	9.606	16.5	-	158	1.00
19. Garnish Pond	192.43	401.8	22.2	3.796	3.1	-	11.8	16.68
20. Salmonier Pond	12.60	89.2		0.892	9.2	-	8.21	1.64

TABLE 2.12 SUMMARY OF MAIN INFLOW AND OUTFLOW CONDITIONS FOR SELECTED STUDY LAKES/PONDS

Water Body	Main Inflow	Main Outflow
1. Tors Cove	Headwater	Tors Cove River
2. Hell Hill Pond	Headwater	Freshwater River
3. Cape Broyle Pond	Horse Chops River	Horse Chops River
4. Old Man's Pond	Headwater	Goulds Brook
5. Nine Island Pond	Headwater	Colliers River
6. Goulds Pond	Headwater	Goulds Brook
7. Hawco's Pond	Headwater	Back River
8. Middle Gull Pond	Headwater	Colliers River
9. Grand Pond	Headwater	Hodge River
10. Ocean Pond	Headwater	Hodge River
11. Denny's Pond	Headwater	Hopeall River
12. Peak Pond	Headwater	Spreadeagle Brook
13. Junction Pond	Northeast River	Northeast River
14. Thorburn Lake	Headwater	Southwest River
15. Georges Pond	Headwater	Georges Brook
16. Lady Pond	Headwater	Hickmans Harbour Brook
17. Shoal Harbour	Headwater	Shoal Harbour River
18. Freshwater Pond	Main Brook	Tides Brook
19. Garnish Pond	Black River	Garnish River
20. Salmonier Pond	Headwater	Big Salmonier Brook

2.3.1.2 Meteorology

To determine the mean annual precipitation and runoff for each of the 20 selected watersheds, data was obtained from climate stations and gauged watersheds. The following criteria were used to estimate mean annual precipitation and runoff for the selected watersheds:

1. Climate or runoff station must be close to watershed.
2. In case of more than one station, the data was combined and averaged.
3. Stations with longer records were chosen over stations with shorter records.
4. Lakes or ponds located close to each other and influenced by the same geographic factors were assumed to have similar amounts of precipitation/runoff.

Precipitation

Precipitation data was obtained from Atmospheric Environment Service; Environment Canada; Canadian Climate Normals, Volume 3, 1951-80, and from provincial climate stations. The mean annual precipitation and climate stations used to determine precipitation for each of the 20 selected lakes/ponds are presented in Table 2.13. The length of record for each climate station is also presented.

TABLE 2.13 CLIMATIC STATIONS, PERIOD OF RECORD AND MEAN ANNUAL PRECIPITATION

Station	Date	Precipitation (mm)
Tors Cove	October 1955 to present	1390
Cape Broyle	June 1957 to present	1521
Markland	1981 - 1986	1697
Salmonier	April 1983 to present	1424
Lethbridge	1954 - 55, 1982 - 84, 1986 - 88	1201
Clarenville	1982 - 1988	1098
Salt Pond	1974 - 85, 1988	1728
Winterland	1981 - 85, 1988	1388
West Brook	June 1961 - present	1437

Runoff

Runoff for each of the 20 selected lakes/ponds was determined using surface water data obtained from the Water Survey of Canada and Provincial hydrometric networks. A total of 13 hydrometric stations were used. These were Southern Bay River, Shoal Harbour River, Garnish River, Tides Brook, Salmonier River, Northwest River, Little Barasway, Little Salmonier, Shearstown Brook, South River, Rocky River, Seal Cove Brook and Northwest Brook.

Runoff values for the selected water bodies are presented in Table 2.14.

Evaporation

Along the south coast of the Island, annual amount of lake evaporation is reported to be approximately 480 mm according to estimates made from the equations of Kohler, Nordensen and Fox (1955) and Christiansen (1966) (Canada, Department of Transport, Meteorological Branch, 1969). The amount of evaporation used in the study was derived using the relationship (Mean Annual Precipitation - Mean Annual Runoff = Evaporation) and is presented in Table 2.14.

As will appear from Table 2.14, the estimated values of evaporation are substantially lower than the reported value of 480 mm. It is primarily due to errors in estimating precipitation values because of the inadequate number and locations of precipitation gauges. Also, the recorded precipitation values may be less than actual amounts due to strong winds at the exposed coastal locations (Banfield, 1981). There may also be some error in the estimation of runoff. There are only two locations in the Province, Gander and St. John's, where evaporation data is collected.

There are other methods of estimating evaporation which could be used.

2.3.2 Hydrologic Characteristics

Parameters related to hydrology of ponds were calculated according to the methodology outlined in Section 2.2.2 of this report.

A summary of hydrologic characteristics - outflow volume (Q), flushing rate (ρ), hydraulic residence time (T_R), areal water load (q_s) and retention coefficient (R) for the study ponds is provided in Table 2.15. Retention coefficient of phosphorus through sedimentation was calculated using a settling velocity as 13.2 m/s, i.e. assuming all ponds are in oxic conditions.

Hydrologic parameters vary in outflow volume from 0.014 x 10^8 to 2.67 x 10^8 m^3/year, in flushing rate from 0.56 to 22.24 times/year, in hydraulic residence time from 0.045 to 1.79 years, and in areal water load from 3.85 to 114.1 metres/year. Lakes and ponds with high flushing rate are less sensitive to nutrient loadings and shoreline development.

TABLE 2.14 PRECIPITATION, EVAPORATION AND RUNOFF VALUES FOR SELECTED PONDS AND LAKES

Water Body	PPT (mm)	Evap. (mm)	Runoff (mm)	Climate Stations
Tors Cove Pond	1455	50	1405	TC & CB
Hell Hill Pond	1455	50	1405	TC & CB
Cape Broyle Pond	1455	50	1405	TC & CB
Old Mans Pond	1560	320	1240	ML & SM
Nine Island Pond	1560	275	1285	ML & SM
Goulds Pond	1560	320	1240	ML & SM
Hawcos Pond	1560	320	1240	ML & SM
Middle Gull Pond	1560	320	1240	ML & SM
Grand Pond	1560	320	1240	ML & SM
Ocean Pond	1560	320	1240	ML & SM
Dennys Pond	1560	320	1240	ML & SM
Peak Pond	1560	320	1240	ML & SM
Junction Pond	1560	160	1400	ML & SM
Thorburn Lake	1201	496	705	Lethbridge
Georges Pond	1201	496	705	Lethbridge
Lady Pond	1201	246	955	Lethbridge
Shoal Harbour Pond	1098	393	705	Clarenville
Freshwater Pond	1518	118	1400	SP & WL & WB
Garnish Pond	1518	158	1360	SP & WL & WB
Salmonier Pond	1518	158	1360	SP & WL & WB

Tors Cove (TC) & Cape Broyle (CB) = 1455 mm
Markland (ML) & Salmonier (SM) = 1560
Lethbridge = 1201 mm; Clarenville = 1098 mm
Salt Pond (SP) & Winterland (WL) & West Brook (WB) = 1518 mm

TABLE 2.15 SUMMARY OF HYDROLOGIC ATTRIBUTES FOR SELECTED PONDS AND LAKES

Water Body	Ratio of A_d/A_o	Total Outflow Volume (Q) in m^3/year x 10^8	Flushing Rate (ρ) x/year	Hydraulic Residence Time in Years (T_R)	Areal Water Load (q_s) in m/year	Retention Coefficient (R)
1. Tors Cove Pond	81.22	2.675	12.54	0.086	114.108	0.104
2. Hell Hill Pond	6.57	0.122	2.42	0.414	10.636	0.554
3. Cape Broyle Pond	50.34	1.917	10.72	0.093	70.734	0.157
4. Old Mans Pond	3.51	0.014	2.24	0.447	5.590	0.703
5. Nine Island Pond	3.52	0.094	0.94	1.068	5.804	0.695
6. Goulds Pond	2.79	0.029	1.52	0.660	4.698	0.738
7. Hawcos Pond	5.04	0.192	2.20	0.454	7.493	0.638
8. Middle Gull Pond	3.63	0.176	0.56	1.793	5.745	0.697
9. Grand Pond	6.83	0.177	2.49	0.402	9.704	0.576
10. Ocean Pond	5.32	0.317	1.74	0.575	7.832	0.628
11. Dennys Pond	23.65	0.272	6.38	0.157	29.330	0.310
12. Peak Pond	6.16	0.049	6.83	0.146	8.879	0.598
13. Junction Pond	40.58	0.352	18.33	0.055	56.814	0.189
14. Thorburn Lake	8.72	0.198	0.56	0.795	6.853	0.658
15. Georges Pond	4.46	0.172	0.63	0.584	3.852	0.774
16. Lady Pond	14.61	0.656	0.56	0.792	13.949	0.486
17. Shoal Harbour	14.11	0.289	1.49	0.674	9.948	0.570
18. Freshwater Pond	15.50	2.084	1.32	0.760	21.697	0.378
19. Garnish Pond	50.69	2.617	22.24	0.045	68.942	0.161
20. Salmonier Pond	14.13	0.171	2.09	0.479	19.211	0.407

2.3.3 Total Phosphorus Supply

Total phosphorus supply to each of the selected lakes/ponds was calculated using the methodology outlined in Section 2.2.3. Geological characteristics and predominant land uses for watersheds of the study lakes/ponds are summarized in Table 2.16. These two parameters have been reported to influence the phosphorus export value to a lake. The phosphorus export (E) values for each watershed is summarized in Table 2.16. Using the results of Dillon et al. (1978), a value of 50 mg/m^2/year was used as our estimate of L_{Pr} since site specific information was not available. Phosphorus supply through precipitation and overland drainage for each lake/pond is presented in

Table 2.17. The data on phosphorus export via anthropogenic sources and total phosphorus export value are presented in Table 2.18. Total phosphorus export value varies from a minimum of 46.2 kg/year for Old Mans Pond to a maximum of 3122 kg/year for Tors Cove Pond.

The anthropogenic supply of phosphorus to a lake is highly influenced by cabin development in its watershed and the performance and types of sewage disposal system. Information on cabin development, sewage disposal system and its performance for each water body is summarized in Table 2.19. No data was available on phosphorus contribution and usage of cabins. According to the Tourism Branch of the Department of Tourism and Culture, seasonal cottage use in Newfoundland is approximately 0.35 capita-years/year/unit. A phosphorus contribution value of 0.8 kg per capita year was adopted from literature. The number of people using a cottage was assumed to be 3.6 people which is the average family size in Newfoundland (1991 census).

In addition to the major components of the phosphorus budget described above, there may be several other inputs and outputs of TP to and from lakes/ponds which are of less importance because of their insignificant contributions.

2.3.4 Total Phosphorus Concentration, Chlorophyll a Levels, and Secchi Disc Transparencies

Existing spring total phosphorus concentrations for selected lakes and ponds were calculated using Equation 2.12 of Section 2.2.4

$$P = \frac{J_T (1 - R)}{Q}$$

Values of J_T, R, and Q for each study lake and pond were obtained from Tables 2.15 and 2.18 respectively. Estimated and observed values of P for the study lakes and ponds are presented in Table 2.20. The estimated spring time phosphorus concentration varies from a minimum of 6.21 μg/l to a maximum of 10.46 μg/l. These estimated values were also compared against the observed values of phosphorous concentrations. The observed value of TP is based on a limited number of samples collected during the *months of July to September instead of April to June when spring runoff occurs.*

In most cases, observed values are much higher than estimated values. Discrepancy in observed and estimated values can be attributed to a number of factors such as sampling period, number of samples, modelling coefficients, and rainfall and runoff values. However, it is recommended that additional spring time samples should be collected to verify the estimated spring time phosphorus concentration of lakes.

TABLE 2.16 GEOLOGY, LAND USE AND ADOPTED PHOSPHORUS LOADING AND PHOSPHORUS EXPORT VALUES FOR SELECTED LAKES AND PONDS

Water Body	Geological Class	Land Use	Phosphorus Export Value (E) (mg/m^2/yr)	Phosphorus Loading Precipitation (L_{Pr}) (mg/m^2/yr)
Tors Cove Pond	Sedimentary	Forest	14.5	50
Hell Hill Pond	Sedimentary	Forest	14.5	50
Cape Broyle Pond	Sedimentary	Forest	14.5	50
Old Mans Pond	Sedimentary	Forest	14.5	50
Nine Island Pond	Sedimentary	Forest	14.5	50
Goulds Pond	Sedimentary	Forest	14.5	50
Hawcos Pond	Sedimentary	Forest	14.5	50
Middle Gull Pond	Sedimentary	Forest	14.5	50
Grand Pond	Sedimentary	Forest	14.5	50
Ocean Pond	Sedimentary	Forest	14.5	50
Dennys Pond	Sedimentary	Forest	14.5	50
Peak Pond	Sedimentary	Forest	14.5	50
Junction Pond	Sedimentary	Forest	14.5	50
Thorburn Lake	Sedimentary	Forest	14.5	50
Georges Pond	Igneous	Forest	12.2	50
Lady Pond	Sedimentary	Forest	14.5	50
Shoal Harbour Pond	Igneous	Forest	12.2	50
Freshwater Pond	Igneous	Forest	12.2	50
Garnish Pond	Igneous	Forest	12.2	50
Salmonier Pond	Igneous	Forest	12.2	50

TABLE 2.17 POTENTIAL NATURAL PHOSPHORUS SUPPLY

Water Body	Phosphorus Loading Through Precipitation (J_{Pr}) (kg/year)	Phosphorus Export via Overland Drainage (kg/year)	Total Phosphorus Export to Lake via Natural Sources (J_N) (kg/year)	Remarks
Tors Cove Pond	117.2	2760.4	2887.6	1. Estimated annual amount of nutrients is based on E and L_{Pr}. 2. The user must be aware that these coefficients have been developed for specific geographic areas and may not accurately reflect land cover, precipitation and soil conditions in the study area. 3. Cape Broyle, Junction, Freshwater and Garnish Ponds have well defined upstream sources and may receive some phosphorus contribution from up-stream sources which is considered to be insignificant.
Hell Hill Pond	57.2	108.9	166.0	
Cape Broyle Pond	135.1	1971.9	2106.8	
Old Mans Pond	12.4	12.6	25.0	
Nine Island Pond	81.1	82.7	163.7	
Goulds Pond	31.2	25.2	56.4	
Hawcos Pond	128.4	187.8	316.2	
Middle Gull Pond	153.3	161.5	314.8	
Grand Pond	91.1	180.2	271.3	
Ocean Pond	202.2	311.8	514.0	
Dennys Pond	46.4	318.3	364.7	
Peak Pond	27.4	48.9	76.2	
Junction Pond	30.9	364.2	395.2	
Thorburn Lake	144.6	365.8	510.5	
Georges Pond	222.7	242.5	465.2	
Lady Pond	235.1	995.9	1231.0	
Shoal Harbour Pond	145.3	500.1	645.3	
Freshwater Pond	480.3	1816.2	2296.5	
Garnish Pond	189.8	2347.6	2537.4	
Salmonier Pond	44.6	153.7	198.3	

TABLE 2.18 POTENTIAL ANTHROPOGENIC AND TOTAL PHOSPHORUS SUPPLY

Water Body	Phosphorus Export via Natural Sources (J_N) (kg/year)	Phosphorus Export via Anthropogenic Sources (J_A) (kg/year)	Total Phosphorus Export (J_T) (kg/year)	Remarks
Tors Cove Pond	2877.6	244.9	3122.5	1. Direct measurement of nutrient concentration and hydraulic loading will provide a more accurate picture about the lake's dynamics than modelling estimates. 2. Data collection task for such measurement will be very time consuming and expensive.
Hell Hill Pond	166.0	9.1	175.1	
Cape Broyle Pond	2106.8	221.8	2328.5	
Old Mans Pond	25.0	21.2	46.2	
Nine Island Pond	163.7	121.0	284.7	
Goulds Pond	56.4	47.4	103.8	
Hawcos Pond	316.2	152.2	468.4	
Middle Gull Pond	314.8	115.9	430.8	
Grand Pond	271.3	152.2	423.5	
Ocean Pond	514.0	258.0	772.0	
Dennys Pond	364.7	43.3	408.0	
Peak Pond	76.2	32.3	108.5	
Junction Pond	395.2	42.3	437.5	
Thorburn lake	510.5	28.2	538.7	
Georges Pond	465.2	6.0	471.3	
Lady Pond	1231.0	26.2	1257.2	
Shoal Harbour Pond	645.3	13.1	658.4	
Freshwater Pond	2296.5	58.5	2355.0	
Garnish Pond	2537.4	54.4	2591.9	
Salmonier Pond	198.3	36.3	234.6	

TABLE 2.19 EXISTING NUMBER OF CABINS, SEWAGE DISPOSAL SYSTEMS, AND RETENTION COEFFICIENT OF SEWAGE DISPOSAL SYSTEMS

Water Body	Number of Cabins	Sewage Disposal System	Retention Coefficient of Sewage Disposal System
Tors Cove Pond	243	Information on type of sewage disposal systems was not available.	1. As indicated by Public Health Inspectors, the majority of cottage owners in Newfoundland do not have an appropriate sewage disposal system and there is no site specific information available on soils in the cottaging areas. 2. Since no specific data was available, the retention coefficient of the sewage disposal system was assumed zero.
Hell Hill Pond	9		
Cape Broyle Pond	220		
Old Mans Pond	21		
Nine Island Pond	120		
Goulds Pond	47		
Hawcos Pond	151		
Middle Gull Pond	115		
Grand Pond	151		
Ocean Pond	256		
Dennys Pond	43		
Peak Pond	32		
Junction Pond	42		
Thorburn lake	28		
Georges Pond	6		
Lady Pond	26		
Shoal Harbour Pond	13		
Freshwater Pond	58		
Garnish Pond	54		
Salmonier Pond	36		

TABLE 2.20 ESTIMATED AND OBSERVED TOTAL SPRING TIME PHOSPHORUS CONCENTRATIONS IN μg/l

Water Body	Estimated Spring Time Total Phosphorus Concentration μg/l	Observed Spring Time Total Phosphorus Concentration μg/l (May-Jun)	Observed Total Phosphorus Concentration μg/l (Jul-Sep)	Observed Ratio of Total Nitrogen/Total Phosphorus (Spring Time)	Remarks
Tors Cove Pond	10.46				1. The relationship used for the chlorophyll a concentration was based on the observation that TP and chlorophyll a concentrations were highly correlated with TN:TP>12. Lakes with low TN:TP<10 demonstrated a better relationship between chlorophyll and TN than TP. 2. Dillon and Rigler (1974) specified that predicted relations be used only if TN:TP>12. 3. Observed nutrient levels were available only for a few lakes/ ponds and these results are based on limited random samples.
Hell Hill Pond	6.43				
Cape Broyle Pond[1]	10.27		5		
Old Mans Pond	9.91				
Nine Island Pond	9.24				
Goulds Pond[2]	9.29	56.48	81	6.52	
Hawcos Pond[3]	8.81	28.6	69	11.91	
Middle Cove Pond	7.42			-	
Grand Pond[4]	10.15	24.8	34	13.31	
Ocean Pond	9.08				
Dennys Pond	10.34				
Peak Pond[5]	8.98		10		
Junction Pond	10.10				
Thorburn Lake	9.29				
Georges Pond	6.21				
Lady Pond	9.85				
Shoal H. Pond	9.79				
Freshwater Pond[6]	7.03	63.75	41	8.75	
Garnish Pond[7]	8.31	20.5	35	8.76	
Salmonier Pond	8.12				

1. Cape Broyle Pond - Samples collected September 1974.
2. Goulds Pond (1982-1985) - Results based on the mean of four sets of samples (May-June) 18 from July-September.
3. Hawcos Pond (1982-1985) - Results based on the mean of six sets of samples (May-June), 17 from July-September.
4. Grand Pond (1982-1984) - Results based on the mean of four sets of samples (May-June), 18 from July-September.
5. Peak Pond - Samples collect July, 1973.
6 Freshwater Pond (1989) - Results based on the mean of one set of samples (may-June), 3 from July-September.
7. Garnish Pond (1991) - Results based on the mean of four sets of samples (1989), 3 from July-September.

Average summer chlorophyll a concentration and Secchi disc depth for the selected lakes/ponds is calculated using the following equations:

$$\log [\text{Chl } \underline{a}] = 1.45 \log [P] - 1.14$$

$$SD = \frac{1}{(0.1138 + 0.0386 (\text{chlor } \underline{a})}$$

The computed chlorophyll a and SD values using the above equations are reported in Table 2.21. The estimated chlorophyll a value varies from a minimum of 1.02 μg/l to a maximum of 2.18 μg/l and Secchi disc transparency runs from a minimum of 5.05 metres to a maximum of 6.53 metres. The estimated values could not be compared with measured values because no data on chlorophyll a and Secchi disc transparency are available for the study area. Some data is available on observed total phosphorus concentration, which has been presented in Table 2.20 and compared with estimated values of total phosphorus. The chlorophyll a and SD values were also computed using observed phosphorus values and the results are listed in Tables 2.22 and 2.23.

There is no way to measure the accuracy of the above predictions unless these (total phosphorus, chlorophyll a and Secchi disc) values are compared with observed values. It is strongly recommended that for successful application of this approach, selected lakes in various regions of the province should be monitored to collect data on total phosphorus level, chlorophyll a level and Secchi disc value. Depending on how well the predicted and measured values compare, a decision is to be made as to whether the total estimated phosphorus value is correct or not. For this study, in the absence of observed data on chlorophyll a and Secchi disc depth, phosphorus data was used for comparative purposes. If the predicted and observed values of the above parameters show significant deviation, then alternative methods of determining J_T should be used. For many of the lakes, substantial variances existed in comparing predicted and measured phosphorus concentrations. This meant that either total phosphorus supply was underestimated or there could be some sampling errors in measured values.

2.3.5 Maximum Permissible Development

In order to calculate the maximum permissible development for a lake or pond, the planners or decision makers have to decide about the primary use (recreation, sport, preservation of cold water fisheries) of the lake or pond. Once the desired use of the water body has been determined, then a value has to be selected for permissible chlorophyll a concentration. Such values for various desired uses of water bodies are presented in Table 2.9.

TABLE 2.21 CHLOROPHYLL a CONCENTRATION AND SECCHI DISC TRANSPARENCIES USING ESTIMATED SPRING TIME PHOSPHORUS CONCENTRATION

Water Body	Chlorophyll a Concentration in μg/l	Secchi Disc Transparency in metres	Remarks
Tors Cove Pond	2.18	5.05	Oligotrophic
Hell Hill Pond	1.08	6.44	Oligotrophic
Cape Broyle Pond	2.12	5.11	Oligotrophic
Old Mans Pond	2.02	5.22	Oligotrophic
Nine Island Pond	1.82	5.43	Oligotrophic
Goulds Pond	1.84	5.42	Oligotrophic
Hawcos Pond	1.70	5.57	Oligotrophic
Middle Gull Pond	1.32	6.07	Oligotrophic
Grand Pond	2.09	5.15	Oligotrophic
Ocean Pond	1.77	5.49	Oligotrophic
Dennys Pond	2.14	5.09	Oligotrophic
Peak Pond	1.75	5.52	Oligotrophic
Junction Pond	2.07	5.16	Oligotrophic
Thorburn Lake	1.83	5.42	Oligotrophic
Georges Pond	1.02	6.53	Oligotrophic
Lady Pond	2.00	5.24	Oligotrophic
Shoal Harbour Pond	1.98	5.26	Oligotrophic
Freshwater Pond	1.22	6.21	Oligotrophic
Garnish Pond	1.56	5.74	Oligotrophic
Salmonier Pond	1.51	5.82	Oligotrophic

TABLE 2.22 CHLOROPHYLL a AND SECCHI DISC VALUES BASED ON OBSERVED VALUES OF PHOSPHORUS (MAY - JUNE)

Water Body	P in spring (μg/l)	Chlor a (μg/l)	SD (m)	Remarks* (1)	Remarks** (2)
Goulds Pond	56.48	25.133	0.923	hypereutrophic	eutrophic
Hawcos Pond	28.6	9.370	2.103	eutrophic	mesotrophic
Grand Pond	24.8	7.620	2.451	eutrophic	mesotrophic
Freshwater Pond	63.75	29.957	0.787	hypereutrophic	eutrophic
Garnish Pond	20.5	5.78	2.968	eutrophic	oligotrophic

* Based on Reckher's Classification Approach
** Based on USEPA's Classification Approach

TABLE 2.23 CHLOROPHYLL a AND SECCHI DISC VALUES BASED ON OBSERVED VALUES OF PHOSPHORUS (JULY - SEPTEMBER)

Water Body	P - Jul-Sept (μg/l)	Chlor a (μg/l)	SD (m)	Remarks (1)	Remarks (2)
Cape Broyle Pond	0.005	0.747	7.010	oligotrophic	oligotrophic
Goulds Pond	0.081	42.393	0.571	hypereutrophic	eutrophic
Hawcos Pond	0.069	33.599	0.709	hypereutrophic	eutrophic
Grand Pond	0.034	12.040	1.728	eutrophic	mesotropic
Peak Pond	0.01	2.041	5.192	mesotrophic	oligotrophic
Freshwater Pond	0.041	15.795	1.382	eutrophic	mesotrophic
Garnish Pond	0.035	12.557	1.671	eutrophic	mesotrophic

A maximum acceptable chlorophyll a concentration of 2.0 μg/l was selected for this study, assuming that lakes will primarily be used for water recreation and preservation of cold water fisheries will be a consideration. Once the lake use criteria and maximum acceptable chlorophyll a concentration has been decided, then Equation 2.20 is used to calculate the maximum acceptable phosphorus concentration. Finally, Equations 2.21, 2.22 and 2.23 are used to calculate maximum permissible phosphorus supply and maximum number of additional development units. The maximum permissible phosphorus supply in kg/year, total number of allowable development units and number of maximum additional development units for each lake are presented in Table 2.24. The number of maximum additional permissible units varies from a minimum of two (2) for Lady Pond to a maximum of 943 for Freshwater Pond. Five of the ponds, Tors Cove Pond, Cape Broyle Pond, Grand Pond, Dennys Pond and Junction Pond, however were classified as being overdeveloped. Development at Old Man's Pond has reached its cottage carrying capacity. It should be noted at this point that data presented in Table 2.24 deals with maximum permissible development under a given set of conditions and is based on an entire drainage basin of a given water body, not only on shoreline of a water body. In some cases, it may not be possible to allow the maximum permissible development because of various site conditions such as shoreline, soil type, steep and unstable slopes, wetlands, sensitive areas, etc.

The development units presented in Table 2.24 would all be seasonal in nature, since a seasonal value of annual use (i.e. 0.35 capita years/year) was used in the calculations. The permissible number of additional units would be much lower had the annual use value of permanent homes been employed.

Estimation of phosphorous loading to a water body is another simplified approach to determine the number of development units. This can be accomplished using the Equation 2.12.

$$J_{T(existing)} = \frac{P_{(observed)} \times Q}{(1-R)}$$

where $P_{(observed)}$ = springtime observed phosphorus concentration in a water body in kg/m^3

$J_{T(existing)}$ = existing springtime phosphorus supply to the water body in kg/year

Other terms are the same as explained earlier.

In order to use this approach, long-term springtime phosphorus values should be available for a lake/pond considered for carrying capacity determination. In this case, the need for selection of various model parameters and other field data is eliminated.

Once the existing phosphorus level for a water body is known, then Equation 2.22 can be used to determine the additional number of development units. J_{Perm} is calculated as explained earlier.

TABLE 2.24 MAXIMUM PERMISSIBLE PHOSPHORUS SUPPLY AND NUMBER OF DEVELOPMENT UNITS

Water Body	Permissible Phosphorus in kg/yr	Additional # of Development Units	Total # of Allowable Development Units	Existing Phosphorus Supply in kg/yr	Remarks
Tors Cove Pond	2942.33	-179	64	3122.51	Overdeveloped
Hell Hill Pond	268.64	93	102	175.12	Underdeveloped
Cape Broyle Pond	2235.31	-92	128	2328.52	Overdeveloped
Old Mans Pond	45.95	0	21	46.18	Underdeveloped
Nine Island Pond	303.71	19	139	284.66	Underdeveloped
Goulds Pond	110.12	6	53	103.81	Underdeveloped
Hawcos Pond	523.96	55	206	468.38	Underdeveloped
Middle Gull Pond	572.73	141	256	430.75	Underdeveloped
Grand Pond	411.25	-12	139	423.49	Overdeveloped
Ocean Pond	838.65	66	322	772.00	Underdeveloped
Dennys Pond	389.15	-19	24	408.02	Overdeveloped
Peak Pond	119.08	11	43	108.47	Underdeveloped
Junction Pond	427.32	-10	32	437.53	Overdeveloped
Thorburn Lake	572.02	33	61	538.71	Underdeveloped
Georges Pond	748.85	275	281	471.28	Underdeveloped
Lady Pond	1258.69	2	28	1257.17	Overdeveloped
Shoal H. Pond	663.03	5	18	658.43	Underdeveloped
Freshwater Pond	3305.24	942	1000	2354.98	Underdeveloped
Garnish Pond	3074.47	478	532	2591.88	Underdeveloped
Salmonier Pond	285.06	50	86	234.61	Underdeveloped

For illustration purposes, this simplified approach was applied to Goulds, Hawcos, Grand, Freshwater and Garnish Ponds for which limited springtime observed phosphorus data was available. Additional number of development units for these ponds along with existing and permissible phosphorus loadings are presented in Table 2.25. These numbers should not be considered for planning purposes, since observed phosphorus values are based on a very limited number of samples and cannot be considered as representative values for the ponds.

TABLE 2.25 NUMBER OF DEVELOPMENT UNITS BASED ON EXISTING PHOSPHORUS LOADING

Water Body	Mean P-Obs. May-June ($\mu g/l$)	Existing Phosphorus Loading $J_TEXT=QP/(1-R)$ (kg/year)	Permissible Phosphorus Loading J_{Perm} (kg/year)	Future Development
Goulds Pond	56.48	652.14	110.12	No
Hawcos Pond	28.6	1515.36	523.96	No
Grand Pond	24.8	1090.91	391.57	No
Freshwater Pd	63.75	20421.05	3305.24	Yes
Garnish Pond	20.5	6352.69	3074.47	No

* Since for all water bodies, except Freshwater Pond, existing phosphorous loading is more than permissible phosphorous loading, no development should be permitted.

2.4 Discussion of Results

The understanding of lake biological and chemical processes is very important to the management and development of that system. The carrying capacity of a lake or pond is generally determined by the physical and biological characteristics of the lake and the surrounding watershed. By identifying the relationships between development and water quality and recreational experiences, land use planners and decision makers will be in a better position to manage and preserve lake and shore land resources. This study is an attempt in this direction and carrying capacity of lakes and ponds has been analyzed using morphologic and hydrologic attributes, watershed land use and nutrient loading. The results of the analysis are summarized in Tables 2.11 and 2.25 and discussed in the following sections.

2.4.1 Morphologic and Hydrologic Data

The morphologic and hydrologic attributes of twenty study lakes and ponds are summarized in Tables 2.11 and 2.15. As indicated, the lakes vary considerably in size, ranging from 0.25 km^2 to 9.61 km^2 in area. Other parameters such as watershed area, lake volume, average depth, flushing rate, and residence time also vary considerably, reflecting the uniqueness spectrum of the study lakes. The results of the analysis indicate that ponds such as Garnish, Junction, Tors Cove, Cape Broyle and Peak have very high flushing rates compared to other ponds in the study area and these are the ponds which will be less sensitive to cottage development and to a unit increase in total phosphorus supply. The surface area and volume of all these ponds is very high compared to other ponds of the study area. The lakes and ponds with low flushing rates such as Middle

Gull, Lady, Thorburn and Georges will be highly vulnerable to cottage developments and land use changes.

2.4.2 Lake Vulnerability Index

Hydrologic and morphologic data along with Sargent (1976) Lake vulnerability index criteria were used to develop the lake vulnerability index for all 20 study lakes and ponds. This index can be used as an indicator of the lake's relative vulnerability to eutrophication. The methodology used for the calculation of the lake vulnerability index considers watershed effects as well as effects of the structure of the lake itself. Five characteristics considered in the calculation of the index are as follows:

1. ***The Ratio of Watershed Area to Lake Volume.*** The ratio will affect the vulnerability index of the lake; the larger ratio will indicate that the lake is more vulnerable since nutrient and sediment loadings into the lake vary with the size of the watershed. This ratio is very high for Tors Cove, Junction, Garnish and Cape Broyle Ponds indicating higher sediment and nutrient loadings into these ponds compared to other ponds in the study area.

2. ***Shoreline Configuration.*** This parameter is obtained by dividing the total shoreline length by the circumference of a circle with an area equal to the area of the lake. The higher value of this parameter will indicate higher productivity of the water body due to the higher number of bays retaining nutrients. Bays tend to be more shallow than the rest of the lake and, thus, more productive. Shoreline configuration ratio (s) can be defined by the following relationship

$$s = \frac{L}{2\pi\sqrt{A/\pi}}$$

where s = shoreline configuration
L = length of shoreline lake
A = area of lake from planimeter measurement
π = 3.14

3. ***Mean Depth.*** Deeper lakes have a greater capacity to assimilate nutrients and trap them in sediments where they are not available for growth. Georges Pond, Lady Pond, Thorburn Lake, Middle Cove Pond and Tors Cove Pond come under this category. Their average mean depth varies from 9.1 metres to 25.0 metres, which is much higher compared to the average depth of other ponds in the study area.

4. ***Shoalness Ratio.*** This is the percentage of lake bottom area with a depth of less than 4.5 metres, which is approximately the maximum area depth of light penetration and plant growth. A lake with a high percentage of bottom at depths greater than 4.5 metres is less likely to be vulnerable to human caused eutrophication. Old Man's, Goulds, Peak, Junction and Garnish Ponds are in this category.

5. *Water Transport.* Mean hydrologic residence time is the amount of time necessary for a volume of water equal to the volume of the lake to flow through the system. It indicates the rate at which a lake is flushed. A water body with a low hydrologic residence time will have a high flushing rate and vice versa. Nutrients are flushed more quickly through a lake with a short residence time and, therefore, /have less effect on lake processes. Related to residence time is the means available for water to enter and leave the lake. Lakes may be ranked on the basis of the manner that water and nutrients are removed from the lake.

Flowage Lake

A flowage lake, commonly a reservoir or part of a river system, may have a short residence time. Cape Broyle Pond, Junction Pond, Freshwater Pond, and Garnish Pond are examples of flowage lake. All these ponds are part of the well defined river systems. These ponds receive water from their watershed as well as river/brooks on the upstream side. All these ponds have well defined outlets and drains either into a river or into a brook. The hydraulic residence time for these ponds is low and varies from 0.04 to 0.76 years.

Drainage Lake

Tors Cove Pond, Hell Hill Pond, Old Mans Pond, Nine Island Pond, Goulds Pond, Hawcos Pond, Middle Cove Pond, Grand Pond, Ocean Pond, Dennys Pond, Peak Pond, Thorburn Lake, Georges Pond, Lady Pond, Shoal Harbour Pond and Salmonier Pond are examples of drainage lakes. All these ponds have well defined outlets and, therefore, may not be highly vulnerable from a flushing standpoint. Hydraulic residence time of these ponds varies from a minimum of 0.08 to a maximum of 2.0 years.

Inflow Lake

Lakes with inlets but no outlets receive water from their watershed but have no immediate means of release and are referred to as inflow lakes. These lakes have very long residence time and are critical for lakeshore activities. None of the study lakes falls in this category. In general, there are very few lakes and ponds in Newfoundland without any outlet.

Based on the above criteria, a vulnerability index matrix was developed for lakes selected for this study. The results are summarized in Table 2.27. An index number was assigned to each characteristic according to Sargent's criteria as presented in Table 2.26. The sum of the index numbers as presented in the last column of Table 2.27 is the total vulnerability index which can be interpreted on its own. Sargent has assigned 1 for lowest vulnerability, 2 for medium, and 3 for high vulnerability. The sensitivity index also expresses the vulnerability of a lake to a unit increase in phosphorus supply.

Most of the information necessary for the lake vulnerability index can be computed from topographic maps. However, it is advisable to collect data on other lakes in the region and use common judgement in the evaluation of the total vulnerability points. Generally, the results of Table 2.26 reveal that lakes least sensitive to cottage development are those with the highest flushing rates, greatest volume, and largest surface areas. On the other hand, the lakes most vulnerable to trophic state changes are those with the lowest flushing rates and volumes and smallest surface areas.

TABLE 2.26 SARGENT'S LAKE VULNERABILITY INDEX CRITERIA FOR RATING OF LAKES AND PONDS

Factor	Measurement Parameter	Index Points		
		1	2	3
1. Drainage lake area relationship	Ratio of watershed area to lake volume	<0.3	0.3-1.0	>1.0
2. Shoreline configuration	Ratio of shoreline length to circumference of a circle	<1.5	1.5-2.0	>2.0
3. Mean depth	Ratio of lake volume to lake area	<3	3-9	>9
4. Shoalness	Ratio of lake area with depth ≤4.5 metre to total area	0-40%	40-80%	80-100%
5. Water transport	Lake type based on structure	Flowage	Drainage	No outlet

2.4.3 Land Use and Nutrient Loading

Phosphorus concentration is directly related to the amount of chlorophyll a in the lake, which is a common algal pigment and serves as an estimate of algal biomass. This can be used to assess the eutrophication level of a lake or pond. Table 2.28 summarizes the results of our work on the nutrient loading and additional development. The listed data deals with current and maximum permissible phosphorus and chlorophyll a levels and total and additional development units. Total and additional permissible units reflect the ultimate development capacity of a lake or pond. Data presented in Tables 2.20 and 2.21 indicate that at present, most of the study lakes fall in the oligotrophic state according to general trophic classification of lakes and reservoirs. These lakes are aesthetically pleasant, have a high clarity of water and plant growth is very slow, considerable development capability for cottages exists on many of these lakes. However, other constraints such as the shoreline's physical constraints to development (e.g. steep slopes, cliffs, poor soil conditions, rocky outcrops, poor site drainage, etc.) are certainly to be considered for planning purposes.

Limited phosphorus levels were available for a few of the lakes/ponds selected for this study. Existing chlorophyll a and Secchi disc values for such lakes/ponds were calculated using the observed values. The computed results are presented in Tables 2.22 and 2.23. Comparison of these results with the general trophic classification of lakes and reservoirs indicate that most of these lakes are eutrophic state, which is contrary to the results presented in Tables 2.20 and 2.21. This advocates the need for additional field

TABLE 2.27 APPLICATION OF SARGENT'S VULNERABILITY INDEX TO SELECTED WATER BODIES

Water Body	Drainage Lake Area Relationship		Shoreline Configuration		Mean Depth		Shoalness		Water Transport		Total Vulnerability Index (15)
	Watershed Area/Lake Volume	Index Point	Shoreline Length/Circum. of a Circle	Index Point	Volume Area	Index Point	Lake Area with Depth <6 m Total Area	Index Point	Lake Type Based on Structure	Index Point	
Tors Cove Pond	8.94	3	2.97	3	9.04	3	32%	1	Drainage	2	12
Hell Hill Pond	1.50	3	2.57	3	4.39	2	55%	2	Drainage	2	12
Cape Broyle Pond	7.64	3	4.27	3	6.74	2	42%	2	Flowage	1	11
Old Mans Pond	1.45	3	3.57	3	2.5	1	Est.	3	Drainage	2	12
Nine Island Pond	0.56	2	3.15	3	6.15	2	41%	2	Drainage	2	11
Goulds Pond	0.92	2	3.98	3	3.09	2	Est.	3	Drainage	2	12
Hawcos Pond	1.49	3	7.90	3	3.50	2	70%	2	Drainage	2	12
Middle Gull Pond	0.35	2	5.63	3	11.09	3	18%	1	Drainage	2	11
Grand Pond	1.75	3	5.26	3	3.89	2	65%	2	Drainage	2	12
Ocean Pond	1.18	3	6.66	3	3.68	2	Est.	2	Drainage	2	12
Dennys Pond	5.1	3	3.38	3	4.60	2	Est.	2	Drainage	2	12
Peak Pond	4.81	3	3.20	3	1.27	1	Est.	3	Drainage	2	12
Junction Pond	13.22	3	3.32	3	3.12	2	Est.	3	Flowage	1	12
Thorburn Lake	0.71	2	3.64	3	12.31	3	Est.	1	Drainage	2	11
Georges Pond	0.73	2	2.66	3	6.11	2	Est.	2	Drainage	2	11
Lady Pond	0.58	2	3.55	3	25.10	3	Est.	1	Drainage	2	11
Shoal Hr Pond	2.10	3	2.31	3	6.71	2	Est.	2	Drainage	2	12
Freshwater Pond	0.94	2	1.89	2	16.45	3	Est.	1	Flowage	1	9
Garnish Pond	16.31	3	3.77	3	3.11	2	Est.	3	Flowage	1	12
Salmonier Pond	1.54	3	3.57	3	9.20	3	Est.	1	Drainage	2	12

work to collect data on observed springtime phosphorus, chlorophyll a and Secchi disc. This will also be useful in calibrating the model parameters. The application of the approach will require decision making regarding the selection of values for model parameters, especially when specific information is not available. The accuracy of estimates will depend on accuracy of values selected for model parameters. A preliminary model sensitivity analysis indicate that the model is very sensitive to runoff, rainfall, phosphorus export retention coefficients.

Data presented in Tables 2.24 and 2.28 indicate that most of the lakes/ponds except Georges Pond, Shoal Harbour Pond, Freshwater and Garnish Ponds have no room for additional development. These ponds should be frozen for future development in order to maintain the present water quality levels in these ponds and lakes. Ponds such as Georges, Shoal Harbour, Freshwater and Garnish, for which analysis has indicated room for additional development, should be assessed for shoreline conditions, drainage patterns, slopes, normal, low and high water marks prior to the onset of future development. Garnish Pond has been studied in detail under a separate study and results indicate a unique situation. Although this study indicates that there may be room for additional development, recent visits during high flow conditions to the pond indicated that most of the existing cottages are within the high water mark of the pond. This is of serious concern from a safety and water quality point of view. A similar type of situation may be existing in other areas for which no information is available.

TABLE 2.28 SUMMARY OF NUTRIENT LOADING AND ADDITIONAL DEVELOPMENT

Water Body	Total Current Phosphorus Loading in kg/year	Maximum Permissible Phosphorus Loading in kg/year	Estimate Phosphorus Concentration in μg/l	Existing Predicted Chlorophyll a in μg/l	Existing Predicted Secchi Disc Depth in m	Additional Permissible Development Units
Tors Cove Pond	3122.51	2942.33	10.46	2.18	5.05	
Hell Hill Pond	175.12	268.64	6.43	1.08	6.44	93
Cape Broyle Pond	2328.52	2235.31	10.27	2.12	5.11	
Old Mans Pond	46.18	45.95	9.91	2.02	5.22	
Nine Island Pond	284.66	303.73	9.24	1.82	5.43	19
Goulds Pond	103.81	110.12	9.29	1.84	5.42	6
Hawcos Pond	468.38	523.96	8.81	1.70	5.57	55
Middle Gull Pond	430.75	572.73	7.42	1.32	6.07	141
Grand Pond	423.49	411.25	10.15	2.09	5.15	
Ocean Pond	772.00	838.65	9.08	1.77	5.49	66
Dennys Pond	408.02	389.15	10.34	2.14	5.09	
Peak Pond	108.47	119.08	8.98	1.75	5.52	11
Junction Pond	437.53	427.32	10.10	2.07	5.16	
Thorburn Lake	538.71	572.02	9.29	1.83	5.42	33
Georges Pond	471.28	748.85	6.21	1.02	6.53	275
Lady Pond	1257.17	1258.69	9.85	2.00	5.24	2
Shoal H.Pond	658.43	663.03	9.79	1.98	5.26	5
Freshwater Pond	2354.98	3305.24	7.03	1.22	6.21	942
Garnish Pond	2591.88	3074.47	8.31	1.56	5.74	478
Salmonier Pond	234.61	285.06	8.12	1.51	5.81	50

2.4.4 Concluding Remarks

As discussed in the earlier sections of this chapter, this is the only approach of cottage carrying capacity estimates where hydrology and morphology of a water body, as well as land uses in its watershed and anticipated nutrients loading, are considered. The approach has some inherent weaknesses as well which are related to selection of appropriate values for various model parameters and availability of site specific data. The various other factors associated with the application of this approach are listed below:

1. Model formulation is based on steady state (i.e. concentration of TP in the study lakes is not changing) assumption. Effect of thermal stratification of lakes is not incorporated in the model.

2. Values for various model parameters such as L_{Pr}, E, R, S and N_{cy} were adopted from the literature since no site specific information was available for these variables.

3. Each water body is a unique system and therefore, empirical formulas may produce highly variable results especially when used under different settings.

4. Nutrient loading models appear to be the most comprehensive predictive tool for evaluating carrying capacity of water bodies provided site specific information on model parameters is available or can be collected. The application of the approach can be quite expensive where monitoring is required for basic model input.

5. Carrying capacity calculations are based on the entire drainage basin of the water body and it is assumed that development will take place in the entire watershed and not only on the shoreline of the water body. For planning purposes, the estimated carrying capacity number should be distributed over the entire drainage basin of the water body and not only on the shoreline.

6. It seems to be a very good approach for the initial assessment of a water body in terms of its vulnerability to cottage development, nutrient levels, flushing rate, etc. The approach can also be a good tool to determine cottage carrying capacity of a water body, provided site specific data on model parameters is available or can be collected.

3.0 NATURAL SHORELINE RESERVE METHOD

3.1 Introduction

The Natural Shoreline Reserve (NSR) is another method of cottage development planning. The method is based on reserving a portion of the shoreline of waterways in its natural state. The various reasons cited for this reservation are:

- *to preserve the visual and aesthetic beauty of lakes and ponds;*
- *to preserve the natural vegetative cover along the shoreline;*
- *to protect and enhance the livability and economic value of cottages or residences along the shorelines;*
- *to preserve ecological balance of lake or pond ecosystems;*
- *to protect water quality of the lake or pond; and*
- *to prevent development in sensitive areas such as floodplains, erodible slopes, etc.*

It has been recommended that at least 25% of the natural shoreline linear length should be reserved in its natural state for the above stated reasons. To date, this guideline has been commonly adopted by planners involved in cottage development planning. However, technical basis of this guideline is highly questionable. The NSR method was originally developed in the Province of Saskatchewan for the planning of the Emma and Christopher Lakes (1976). The method was later used by the Ontario Ministry of Natural Resources in the planning of the Muskoka Lakes (1980).

3.2 Methodology

In the natural shoreline reserve carrying capacity method, the length of existing natural shoreline is compared with the desirable shoreline length that should be conserved in order to preserve the ecological balance of a lake or pond. The guideline used in the Emma and Christopher Lakes study and by the Ontario Ministry of Natural Resources is that a minimum of 25% of the natural shoreline linear length of a water body must be preserved. Shoreline development should therefore be limited to only 75% of the natural shoreline. Accordingly, lakes and ponds with less than 25% of their natural shoreline preserved are considered as overdeveloped; lakes and ponds with greater than 25% of their natural shoreline preserved are considered as underdeveloped.

The advantages of using the natural shoreline reserve method are as follows:

1. *The natural shoreline reserve method is easy to apply. There is little background information required to apply this method to the selected lakes or ponds.*

2. *This method will determine the maximum number of cabins a water body will be able to support based on a given lot size.*

3. *25% of the shoreline is preserved in its original state.*

The disadvantages of using the natural shoreline reserve method are:

1. *The length of shoreline is the primary factor considered in the planning. Other factors such as size of the water body, topography, soil conditions, and shoreline conditions are not considered.*

2. *Reserving 25% of the natural shoreline of a lake or pond may not be enough to preserve the ecological balance and it may not be appropriate to many water bodies with irregular and sensitive shorelines.*

3. *There is no provision for public places, open spaces and buffer zones.*

3.3 Application of Methodology to the Study Area

The following criteria were adopted to apply the natural shoreline reserve method to lakes and ponds in the present study:

Shoreline Reserve

- *A minimum of 25% of the natural shoreline was left undeveloped;*
- *Development was allowed on 75% of the natural shoreline of a lake or pond;*
- *Lakes and ponds with less than 25% of their natural shoreline preserved are considered as overdeveloped; and*
- *Lakes and ponds with greater than 25% of their natural shoreline preserved are considered as underdeveloped.*

Cottage Lot Width

- *The minimum cottage building lot width is 30 metres and the maximum is 45 metres as recommended by the Lands Branch of the Department of Environment and Lands.*

The classification of water bodies as being underdeveloped or overdeveloped was determined in the following way:

1. *The cottage carrying capacity was determined based on development on 75% of the shoreline of the water body and 30 metre and 45 metre lot width sizes.*

2. *The existing number of cabins around the shoreline of the lake or pond were compared with the cottage carrying capacity of the water body.*

A full description of the natural shoreline reserve method is provided in Appendix C. The cottage carrying capacity was calculated using the following relationship:

$$\text{cottage carrying capacity} = \frac{\text{total shoreline length (m)} \times 0.75}{\text{cottage lot width}} \qquad 3.1$$

3.4 Discussion of Results

Tables 3.1 and 3.2 present the results of cottage carrying capacity for selected lakes/ponds using 30 metres and 45 metres lot width size respectively. The shoreline parameter for each lake/pond was digitized using 1:50,000 NTS maps. The data on the existing number of cabins was obtained from different sources (Crown Lands, aerial photographs and personal contacts) while data on potential number of cabins was calculated using Equation 3.1. The ratio of existing number of cabins to potential number of cabins was used to determine the development status of a water body. Lakes or ponds with ratio less than 1.0 are considered as underdeveloped and greater than 1.0 as overdeveloped. The data presented in Tables 3.1 and 3.2 indicate that this ratio is less than 1.0 for all lakes/ponds and, therefore, all these lakes/ponds are underdeveloped. However, this conclusion is not supported by field observations which indicate that some of the ponds have already reached their potential development capacities and have started experiencing water quality and other environmental problems. This shows the weakness of the methodology.

The data presented in Tables 3.1 and 3.2 indicate that there is enough room for future development on all 20 lakes and ponds selected for this study. However, this may not be true in a few cases. Range of additional number of cabins based on minimum 30 m width lot sizes varies from a minimum of 136 for Old Mans Pond to a maximum of 971 for Hawcos Pond (Table 3.1). A 15 m increase in 30 m minimum lot size width resulted in an entirely different scenario and the range of additional number of cabins varies from a minimum of 25 for Tors Cove Pond to a maximum of 597 for Hawcos Pond.

The planners should be careful in adopting this method for planning purposes, since the methodology does not take into account the conditions of the shoreline, ecological balance of the lake or pond, size of the water body, water quality impairment potential of shoreline development, etc. The 25% reservation criteria is based on subjective judgement and has no technical basis. The results obtained using this method will overestimate the cottage carrying capacity of the water bodies under consideration. This method will only provide the maximum theoretical number of cabins that you could fit along a water body and should thus serve only as a maximum theoretical value for cottage carrying capacity consideration. In some cases, for reasons such as unfavourable shoreline conditions, soils, topography, etc., more than 25% of the natural shoreline may not be suitable for development which will make this approach impractical and unrealistic. It is felt that for this method to be of some use, the guideline dealing with 25% reservation of natural shoreline should be changed to 25% - 40% depending on the shoreline conditions. Accordingly, if this method is to be adopted for planning purposes, then a natural shoreline length suitable for development should be determined and 25% - 40% of suitable shoreline length should be reserved for public access, future development, etc.

The 25% reservation criterion may be applicable in Ontario or other provinces where suitable land base (good soils, mild terrain) is available. In Newfoundland, much of the area is covered with forest and wetland and land terrain is rough with mineral soil being mostly shallow and stony, which is not a favourable situation for satisfactory operation of sewage disposal facilities. In order to use this method for Newfoundland, it is important to determine the shoreline perimeter suitable for development. According to shoreline capability analysis (Section 4.0) of selected ponds and lakes in Newfoundland, it was observed that, on an average, 60% of the actual shoreline perimeter may be suitable for cottage development. Based on this assessment and reserving 40% of suitable shoreline for public access and open spaces, two cottage carrying capacity scenarios, one with 30 m lot width and another with 45 m lot width, were generated for lakes and ponds selected for this study. The results are presented in Tables 3.3 and 3.4. Based on 30 m lot width, all ponds except Tors Cove can sustain varying degree of additional cottage development. If the width is increased to 45 m, then Tors Cove Pond, Cape Broyle Pond and Nine Island Pond cannot sustain additional cottage development. As discussed in the limitations, there is no provision for other existing land uses and thus carrying capacity determined by this method could give an unrealistically high number. This has been observed in the case of Freshwater Pond where significant portions of the shoreline is owned by a Provincial Park and will not be available for any type of development. This implies that actual possible cottage development along Freshwater Pond will be much lower than estimated cottage carrying capacity.

TABLE 3.1 COTTAGE CARRYING CAPACITY USING 30 M LOT WIDTH

Water Body	Perimeter Shoreline (m)	75% Maximum Allowable for Development	Existing # of Cabins	Total # of Cabins	Existing/Total # of Cabins	Existing - Total # of Cabins
Tors Cove Pond	16103	12077	243	402	0.603	-160
Hell Hill Pond	9728	7296	9	243	0.037	-234
Cape Broyle Pond	24870	18652	220	621	0.353	-402
Old Man's Pond	6295	4721	21	157	0.133	-136
Nine Island Pond	14228	10671	120	355	0.337	-235
Goulds Pond	11152	8364	47	278	0.168	-231
Hawcos Pond	44860	33645	151	1121	0.134	-971
Middle Gull Pond	34952	26214	115	873	0.131	-758
Grand Pond	25141	18855	151	628	0.240	-478
Ocean Pond	47440	35580	256	1186	0.215	-930
Dennys Pond	11552	8664	43	288	0.148	-246
Peak Pond	8287	6290	32	209	0.152	-178
Junction Pond	9267	6950	42	231	0.181	-190
Thorburn Lake	21941	16455	28	548	0.051	-521
Georges Pond	19921	14940	6	498	0.012	-492
Lady Pond	27307	20480	26	682	0.038	-657
Shoal Hr. Pond	13938	10453	13	348	0.037	-335
Freshwater Pond	20765	15573	58	519	0.111	-461
Garnish Pond	26053	19539	54	651	0.082	-597
Salmonier Pond	11934	8950	36	298	0.121	-262

* minus (-) indicates that the water body is *underdeveloped by x number of cabins*

TABLE 3.2 COTTAGE CARRYING CAPACITY USING 45 M LOT WIDTH

Water Body	Perimeter Shoreline (m)	75% Maximum Allowable for Development	Existing # of Cabins	Total # of Cabins	Existing/ Total of Cabins	Existing - Total # of Cabins
Tors Cove Pond	16103	12077	243	268	0.905	- 25
Hell Hill Pond	9728	7296	9	162	0.055	-153
Cape Broyle Pond	24870	18653	220	415	0.530	-195
Old Man's Pond	6295	4721	21	105	0.200	- 84
Nine Island Pond	14228	10671	120	237	0.506	-117
Goulds Pond	11152	8364	47	186	0.253	-139
Hawcos Pond	44860	33645	151	748	0.201	-597
Middle Gull Pond	34952	26214	115	583	0.197	-468
Grand Pond	25141	18856	151	419	0.360	-268
Ocean Pond	47440	35580	256	791	0.323	-535
Dennys Pond	11552	8664	43	193	0.223	-150
Peak Pond	8387	6290	32	140	0.228	-108
Junction Pond	9267	6950	42	155	0.271	-112
Thorburn Lake	21941	16456	28	366	0.076	-338
Georges Pond	19921	14941	6	332	0.018	-326
Lady Pond	27307	20480	26	455	0.057	-429
Shoal H. Pond	13938	10454	13	232	0.055	-219
Freshwater Pond	20765	15574	58	346	0.167	-288
Garnish Pond	26053	19540	54	434	0.124	-380
Salmonier Pond	11934	8951	36	199	0.180	-163

* minus (-) indicates that the water body is underdeveloped by x number of cabins

TABLE 3.3 COTTAGE CARRYING CAPACITY USING 30 M LOT WIDTH BASED ON SHORELINE SUITABLE FOR DEVELOPMENT

Water Body	Actual Perimeter Shoreline (m)*	Shoreline Suitable for Development	Shoreline for Public Access*	Shoreline Available for Cottage Dev. (m)	Potential # of Cabins	Existing # of Cabins	Additional # of Cabins**
Tors Cove Pond	16103	9662	3865	5797	193	243	-50
Hell Hill Pond	9728	5837	2335	3502	117	9	108
Cape Broyle Pond	24870	14922	5969	8953	298	220	78
Old Man's Pond	6295	3777	1511	2266	75	21	54
Nine Island Pond	14228	8537	3415	5122	171	120	51
Goulds Pond	11152	6691	2676	4015	134	47	87
Hawcos Pond	44860	26916	10766	16150	538	151	387
Middle Gull Pond	34952	20971	8388	12583	419	115	304
Grand Pond	25141	15085	6034	9051	302	151	151
Ocean Pond	47440	28464	11386	17078	569	256	313
Dennys Pond	11552	6931	2772	4159	139	43	96
Peak Pond	8387	4972	1989	2983	99	32	67
Junction Pond	9267	5560	2224	3336	111	42	69
Thorburn Lake	21941	13165	5266	7899	263	28	235
Georges Pond	19921	11953	4781	7172	239	6	233
Lady Pond	27307	16384	6554	9830	328	26	302
Shoal Harbour Pond	13938	8363	3345	5018	167	13	154
Freshwater Pond	20765	12459	4984	7475	249	58	191
Garnish Pond	26053	15632	6253	9379	313	54	259
Salmonier Pond	11934	7160	2864	4296	143	36	107

* based on 40% reservation

** negative sign indicates that the water body is overdeveloped by x number of cabins

TABLE 3.4 COTTAGE CARRYING CAPACITY USING 45 M LOT WIDTH BASED ON SHORELINE SUITABLE FOR DEVELOPMENT

Water Body	Actual Perimeter Shoreline (m)	Shoreline Suitable for Development (m)	Shoreline for Public Access (m)*	Shoreline Available for Cottage Dev. (m)	Potential # of Cabins	Existing # of Cabins	Additional # of Cabins**
Tors Cove Pond	16103	9662	3865	5797	128	243	-115
Hell Hill Pond	9728	5837	2335	3502	78	9	69
Cape Broyle Pond	24870	14922	5969	8953	199	220	-21
Old Man's Pond	6295	3777	1511	2266	50	21	29
Nine Island Pond	14228	8537	3415	5122	114	120	-6
Goulds Pond	11152	6691	2676	4015	89	47	42
Hawcos Pond	44860	26916	10766	16150	359	151	208
Middle Gull Pond	34952	20971	8388	12583	280	115	165
Grand Pond	25141	15085	6034	9051	201	151	50
Ocean Pond	47440	28464	11386	17078	380	256	124
Dennys Pond	11552	6931	2772	4159	92	43	49
Peak Pond	8387	4972	1989	2983	66	32	34
Junction Pond	9267	5560	2224	3336	74	42	32
Thorburn Lake	21941	13165	5266	7899	176	28	148
Georges Pond	19921	11953	4781	7172	159	6	153
Lady Pond	27307	16384	6554	9830	218	26	192
Shoal Harbour Pond	13938	8363	3345	5018	112	13	99
Freshwater Pond	20765	12459	4984	7475	166	58	108
Garnish Pond	26053	15632	6253	9379	208	54	154
Salmonier Pond	11934	7160	2864	4296	95	36	59

* based on 40% reservation

** negative sign indicates that the water body is overdeveloped by x number of cabins

4.0 SHORELINE CAPABILITY METHOD

4.1 Basic Approach

The shoreline development carrying capacity method (or capability of shoreline to sustain development) was introduced by the Ontario Ministry of Natural Resources to be used in lake-cottage planning in that Province. This approach was also applied in the Emma and Christopher Lake Study in Saskatchewan but the method was substantially modified to suit the local conditions of the study area. Local conditions and cultural aspects of cottaging should be the main consideration in evaluating the carrying capacity of ponds or lakes. Therefore, a method developed for a particular region may not be directly applicable elsewhere, however, these can be modified if the various cultural, hydrological, morphological and environmental factors are taken into consideration.

The shoreline capability method compares the existing number of cottages, around a lake or pond, with the number of cottages that are desirable for development. The desirable number of cottages is based on (1) the slope of the shoreline, and (2) soil types within a distance of 100 metres from the shoreline. It is, therefore, obvious that a shoreline with poor physical conditions for development would support fewer cottages than a shoreline with good topography and soil conditions.

4.2 Application to Study Area

As discussed in the previous section, the desirable number of cottages is dependent on shoreline slope and soil types. Therefore, topographic maps and land use inventory maps were acquired for lakes and ponds selected for this study. The shore lands of selected ponds and lakes were analyzed for slopes and soil conditions within the recommended distance and ranked on a scale of four categories according to their suitability for development. The ranking scales used to determine slope and drainage conditions are presented in Table 4.1. The shorelines with less than 5% slope were defined as Class 1, 5 - 10% slopes as Class 2, 10 - 15% slopes as Class 3, and 15 - 20% slopes as Class 4. Shorelines were also classified according to soil conditions. Shorelines dominated by sand and gravel were classified as well drained Class 1, dominated with gravel as moderately well drained Class 2, dominated with gravel, rock and boulder as imperfectly drained Class 3 and others dominated by rock and boulder as poorly drained Class 4. Topographic capability class and soil drainage capability class were combined together to derive the cottage capability class. Table 4.2 presents the data on shoreline classification according to cottage capability class.

TABLE 4.1 SHORELINE CLASSIFICATION CRITERIA

TOPOGRAPHY		SOIL DRAINAGE			
Shoreline Condition	**Classification**	**Drainage Condition**	**Soil Type**	**Classification**	**Capability Class**
Less than 5% slope	Class 1	Well drained	Sand & gravel	Class 1	High
5 to 10% slope	Class 2	Moderately well drained	Gravel	Class 2	Moderate
10 to 15% slope	Class 3	Imperfectly drained	Gravel, rock & boulder	Class 3	Poor
15 to 20% slope	Class 4	Poorly drained	Rock & boulders	Class 4	Very poor

TABLE 4.2 SHORELINE CLASSIFICATION - COTTAGE CAPABILITY CLASS

Topography	Capability Class	Soil Drainage	Capability Class	Derived-Cottage Capability Class
Less than 5% slope	1	well drained	1	1
"	1	moderately well drained	2	2
"	1	imperfectly drained	3	3
"	1	poorly drained	4	4
5-10% slope	2	well drained	1	1
"	2	moderately well drained	2	2
"	2	imperfectly drained	3	3
"	2	poorly drained	4	4
10-15% slope	3	well drained	1	2
"	3	moderately well drained	2	2
"	3	imperfectly drained	3	3
"	3	poor drained	4	4
15-20% slope	4	well drained	1	2
"	4	moderately well drained	2	3
"	4	imperfectly drained	3	3
"	4	poorly drained	4	4

With each class of shoreline capability, there are desirable standards for the density of development, expressed either in terms of desirable cottage lot widths, or in terms of cottages per shoreline km. The lot widths standard employed in this study are presented in Table 4.3 and were developed in consultation with the Land Use Management Division. According to present policy, the width of Crown Land lots varies from a minimum of 30 metres to a maximum of 45 metres. Under-capacity situation would exist if the total number of existing cottages is lower than the maximum allowable number of cottages for all capability ranks. Over-capacity situation would exist if there are more cottages than the shoreline physiography is able to accommodate.

TABLE 4.3 DESIRABLE COTTAGE LOT SIZE BASED ON COTTAGE CAPABILITY

Cottage Capability Class	Desirable Lot Widths (m)	Desirable # of Cottages per km of Shoreline	Remarks
1	30	33/km	
2	45	22/km	-
3	0	0/km	should not be considered for development
4	0	0/km	unsuitable for development

Table 4.4 shows the results of the shoreline development carrying capacity method. Shoreline length according to cottage capability class was calculated using topographic and land use inventory maps for all lakes and ponds considered for the study. This data along with map scale is presented in Columns 1 to 5 of the table. Shore lands were analyzed up to a distance of 100 metres from the shoreline. A 100 m buffer zone was reserved to account for high flow conditions and shoreline protection. Shorelines, ranked as Class 1 and 2, were considered for cottage development and those ranked as Class 3 and 4 were considered unfit for development. Shorelines suitable for development for each water body are presented in Column 6. Column 7 presents shoreline reserved for public access and open space, which is 40% of the shoreline suitable for development. It should be noted that in the original approach no reservation was made for public access and open space. This was necessary to bring cottage development practices in other provinces and the capability method more in line with local conditions and cultural practices of cottaging in Newfoundland. Based on lot size criteria given in Table 4.3 and 40% reservation criterion, the potential number of cottages was determined for all the lakes/ponds in the study area (Column 8) using information in Columns 1 and 2. Column 9 shows the existing number of cottages for each water body. Data on future development potential is presented in Column 10. A detailed step by step procedure to calculate the carrying capacity of a water body is presented in Appendix D. The results of the analysis indicate that all ponds and lakes except Tors Cove Pond can sustain additional cottage development. However, it may not always be possible to proceed with recommended levels of development due to limitations

(public access, existing land uses, etc.) associated with this method. For example, a potential carrying capacity of 166 for Freshwater Pond can never be implemented since approximately 40% of the linear shoreline is owned by a Provincial Park which will not be available for cottage development.

4.3 Limitations

The carrying capacity approach presented in this section has the following limitations:

1. *Only foreshore cottage lots are considered, and that back-tier type lots and cluster development are not considered in the formulation.*

2. *The entire shore land suitable for development is included in the carrying capacity calculation and no provision is made for shore land protection, public access, numerous bays and irregularities in the shoreline and natural landscape.*

3. *Development is based on shoreline suitability only and no consideration is made for size of water body and other land uses in the watershed.*

TABLE 4.4 COTTAGE CAPABILITY FOR SELECTED PONDS AND LAKES - SHORELINE CAPABILITY APPROACH

Water Body	Shoreline Length According to Cottage Capability Class (km)				Map Scale	Shoreline Perimeter Suitable for Dev. (km)	Shoreline Reserved for Public Access (km)	Potential # of Cottages	Existing # of Cottages	Additional # of Cottages*
	1	2	3	4	5	6	7	8	9	10
Tors Cove Pond	1.8	8.2	2.7	0	1:12500	10.0	4.0	145	243	-98
Hell Hill Pond	0.2	34.5	0.5	3.9	1:50000	4.7	1.88	64	9	55
Cape Broyle Pond	2.2	16.2	2.2	0	1:50000	18.4	7.36	260	220	40
Old Man's Pond	2.6	3.7	0	0	1:12500	6.3	2.52	101	21	80
Nine Island Pond	2.7	6.9	1.7	0.7	1:12500	9.6	3.84	146	120	26
Goulds Pond	2.4	8.7	0	0	1:12500	11.2	4.48	166	47	119
Hawcos Pond	16.3	18.4	2.6	6.9	1:12500	34.7	13.88	571	151	420
Middle Gull Pond	5.9	10.9	10.2	7.8	1:12500	16.9	6.76	157	115	42
Grand Pond	4.7	20.4	0	0	1:12500	25.2	10.08	377	151	226
Ocean Pond	11.1	25.1	6.3	4.0	1:12500	36.2	14.48	557	256	301
Dennys Pond	1.4	7.2	0	0	1:12500	8.6	3.44	124	43	81
Peak Pond	0.7	1.9	0.1	0	1:12500	2.7	1.08	40	32	8
Junction Pond	3.1	4.4	1.7	0	1:12500	7.6	3.04	122	42	80
Thorburn Lake	2.2	15.1	4.6	0	1:50000	17.3	6.92	245	28	217
Georges Pond	3.4	14.4	0.7	0	1:50000	17.8	7.12	260	6	254
Lady Pond	5.1	5.9	9.2	7.1	1:50000	11.0	4.4	181	26	155
Shoal Harbour Pond	3.7	6.4	0.6	0	1:50000	10.1	4.1	159	13	146
Freshwater Pond	4.1	6.3	1.7	8.6	1:50000	10.4	4.2	166	58	108
Garnish Pond	3.2	22.4	0.4	0	1:50000	25.6	10.24	362	54	308
Salmonier Pond	2.3	5.5	0	0	1:50000	7.8	3.12	119	36	83

* negative sign indicates that a water body is overdeveloped by x number of cabins and no future development should be permitted

5.0 BOAT DENSITY METHOD

5.1 Introduction

Boating has been identified as a primary recreational activity associated with cottage use. Boats can be used for many activities by cabin owners including fishing, sailing, skiing and power boating. Depending on boat types and uses, boats require a certain amount of space to operate safely and to their full potential. The surface area of a water body, however, has a limited ability to sustain boating use and the recreational value of boating will decline if too many boats are operating in a small area. Thus, the number of boats that can safely operate on a water body can be considered a limiting factor to the number of people who can share the lake or pond.

The boat limit system approach uses space standards to determine the safe boating capacity of a lake. As each lake activity requires a certain amount of space to occur safely and avoid conflict with other activities, researchers have tried to standardize the average amount of space required for boating which is used as a guideline in estimating the carrying capacity of a water body. This method was used along with three other methods at Emma and Christopher Lakes in Saskatchewan and Muskoka Lakes in Ontario to assess the recreational capacity of these water bodies.

5.2 Methodology

The boat limit system is designed to provide an estimate of the capacity of a water body to handle boating use. If used in conjunction with other capacity methods, a more accurate estimate of the capacity of a water body is possible. There are two basic approaches to calculate the boating capacity of a water body known as: (1) Theoretical Boat-Density Calculation; and (2) Observed Boat-Density Calculation. The theoretical boat-density calculation compares the number of boats a water body could support with the number of boats that actually may be expected on water from shoreline development, while the observed boat-density approach compares the area of water surface required by actual boats and the area available on the lake for boating. Only the theoretical boat-density approach was used in this study since the information on actual boat counts was not available.

In the boat density method, the size (surface area and shape) of a water body is the limiting factor for the number of boats that can use a lake or pond at the same time. The spatial requirement of a boat to operate on a water body varies with the use of the boat. Table 5.1 presents the summary of boating standards for various boat uses. Some of these standards were developed from recorded observations of actual use while others are estimated or are adopted from other studies. The boating standards presented in Table 5.1 indicates that depending on the type of water oriented activities, boating standards vary from one boat per acre to one boat per fifty acres. A single standard of ten acres per boat is the most commonly used value. The central idea of this method is to determine the usable surface area of the lake by a space standard which can be determined according to one of the following two methods.

TABLE 5.1 BOATING STANDARDS FOR WATER BASED RECREATION (Barstad & Karasor, 1987)

Reference	Single Standard	Anchored Fishing	Trolling Fishing	Non-Power	10 hp or less	Sailing Boating	Water Skiing
	Acres per Boat						
Arm Corps of Engrs.	1						
Calif. Recr. Comm.	1						
Soil Conserv. Serv.		.2	.3		3	3	5
Ohio Dept. Nat. Resour.		5.5	5.5	5.5	5.5	5.5	5.5
Park Plng. Guidelines		.2	1	.3	1	.4	
Allegh. Res. Mgmt. Plan (1972)		1	1	1	5	1	20
Eberwein		2	2.2	2.4	3	2.6	
Sirles (1968)	.8-1.78						
Tichacek (1975)		8	8	1	10-20	2	40
Bur. Outdr. Recr. (1970)		3.6-8	3.6-8				20-40
Wisc. Dept. Nat. Resour.	20						
MB. Dept. Nat. Resour. (1979)	10						
Ontario Min. Hsg.	10						
Manitoba	50						

The first method requires no field work and provides a conservative low net acreage value. The value is determined by subtracting the total acreage of the following segments of a water body from the gross acreage of the water body.

1. *A 60 metre band around the shore and all subdivided islands for reasons of human safety, reduction of user conflicts and shoreline protection.*

2. *A 20 metre band around all marinas, public beaches and access points for the reasons as given above.*

3. *A 30 metre band around all non subdivided islands.*

4. *The central area of large water bodies at a distance more than 1.6 km from the shore, since it is rarely used for boating.*

The main purpose in reserving the above areas as non-boating areas is to account for those segments of the water body which are unsuitable for boating.

The second method is based on field inspection and subtracts water segments for Items 1 to 3 (listed above) from the gross acreage of the water body as they are needed. This method provides a higher net acreage than method number one. The maximum acreage will not be subtracted from the waters surface as is the case in method number one, in places where it does not have to be. Once the net area of the water body has been determined using one of the above methods, then boating capacity of the water body can be determined using the following relationship:

$$\text{Number of Boats (Boating Capacity)} = \frac{\text{Net area of water body (ha)}}{4} \qquad 5.1$$

The above relationship is based on the assumption that 4 hectares or 10 acres of space is required for each boat (Table 5.1). The above boating capacity must be apportioned between the two users: (1) Use by private cottagers and (2) use by non-cottagers. Non-cottager's or public share of the water bodies' boating potential is generally determined by multiplying the number of available parking spaces with average number of boats per parking space. Review of published data indicate that public share is generally 35 to 40% of the water bodies' boating potential. For this study, no data was available on the actual number of available parking spaces and average number of boats per parking space, therefore, it was assumed that 40% of the boating capacity will be used by non-cottagers. In this case, cottager's share of boating capacity will be equal to the water bodies' boating capacity minus the non cottager's share, which can be expressed as

$$\text{Cottager's share} = \text{Boating capacity - non cottager's share} \qquad 5.2$$

Cottage carrying capacity studies for Emma and Christopher Lakes and the Eastern Ontario Region have indicated that 10% - 25% of the boats owned by cottagers are on a water body at any peak time. Therefore, assuming that 10% of boats are on water bodies at any peak time, total permissible cottage boats will be:

$$\text{Total permissible cottage boats} = \text{cottager's share of capacity} \times \frac{100}{10} \qquad 5.3$$

From the total permissable number of cottage boats, planners can determine the maximum number of cottages the water body can support using equation 5.4 provided the information is available on the average number of boats per cottage:

$$\begin{array}{l} \text{Total cottages} \\ \text{(by boating} \\ \text{space standards)} \end{array} = \frac{\text{Total permissible cottager's boats}}{\text{Average number of boats per cottage}} \qquad 5.4$$

If the information on existing development is available, then development potential for cottages can be expressed as:

$$\text{Development Potential} = \text{Total cottages} - \text{Existing development} \qquad 5.5$$

A detailed step-by-step procedure for this approach is presented in Appendix E.

5.3 Application of Theoretical Boat-Density Approach

The theoretical boat density approach was applied to 20 lakes and ponds selected for this study. The following assumptions were made:

1. *The net acreage of water surface suitable for boating is 75% of the gross acreage of the water body. This takes into consideration the buffers for shoreline protection and public safety.*
2. *Average space requirement for each boat is 10 acres (4 hectares).*
3. *40% of the total boating capacity will be reserved for non-cottagers.*
4. *10% to 25% of the total boats may be on the water at any time.*
5. *Average number of boats per cottage is one.*

Table 5.2 presents information on boating capacity, total permissible cottage boats and development potential for lakes and ponds selected for the study. All these parameters are calculated using the above assumptions and approach described in Section 5.2.

TABLE 5.2 COTTAGE CARRYING CAPACITY - BOAT DENSITY APPROACH

Water Body	Lake Gross Area (Ha)	Net Acreage (Ha) NA*75%	Boating Standard (Ha)	Boating Capacity NA/4	Non-cottagers share 40%	Cottagers Share 60%	Total Cottages (10% in use at peak)	Total Cottages (25% in use at peak)	Existing Cottages	Develop. Potential (10%)	Develop. Potential (25%)
Tors Cove Pond	234	176	4	44	18	26	264	105	243	21	-138
Hell Hill Pond	114	86	4	21	9	13	129	51	9	120	42
Cape Broyle Pond	270	203	4	51	20	30	304	122	220	84	-98
Old Mans Pond	25	19	4	5	2	3	28	11	21	7	-10
Nine Island Pond	162	122	4	30	12	18	182	73	120	62	-47
Goulds Pond	52	47	4	12	5	7	70	28	47	23	-19
Hawcos Pond	257	193	4	48	19	29	289	116	151	138	-35
Middle Gull Pond	307	230	4	57	23	35	345	138	115	230	23
Grand Pond	182	137	4	34	14	20	205	82	151	54	-69
Ocean Pond	404	303	4	76	30	45	455	182	256	199	-74
Dennys Pond	93	70	4	17	7	10	104	42	43	61	-1
Peak Pond	55	41	4	10	4	6	62	25	32	30	-7
Junction Pond	62	46	4	12	5	7	70	28	42	28	-14
Thorburn Lake	289	217	4	54	22	33	325	130	28	297	102
Georges Pond	445	334	4	84	33	50	501	200	6	495	194
Lady Pond	470	353	4	88	35	53	529	212	26	503	186
Shoal H Pond	291	218	4	54	22	33	327	131	13	314	118
Freshwater Pond	961	720	4	180	72	108	1081	432	58	1023	374
Garnish Pond	380	285	4	71	28	43	427	171	54	373	117
Salmonier Pond	89	67	4	17	7	10	100	40	36	64	4

* negative sign indicates that a water body is overdeveloped by x number of cottages and no future development is to be permitted

As can be seen from Table 5.2, there is a large variation in cottage development potential which is based on the assumption that 10% and 25% of the total boats will be using a water body at any one time. Assuming 10% of boats are used on a water body at peak times, all 20 of the selected lakes and ponds are underdeveloped, and if the assumption is changed to 25%, nine of the water bodies would be considered underdeveloped with maximum cottage development to occur at Freshwater Pond (374 cabins) and 11 would be overdeveloped with Tors Cove Pond being overdeveloped by the largest number of cabins (138). However, it should be noted that it may not be possible to proceed with recommended levels of development as many factors (e.g. existing land uses, parks and recreational areas) are not considered in the formulation of this method which would result in an additional number of boats not originally anticipated. It is recommended that a shoreline survey should be conducted in order to implement the numbers obtained using this approach.

5.4 Limitations and Constraints

The boat density approach presented in this section possesses a number of short comings and requires users to be extremely cautious in its application for planning purposes. Users of this approach should make note of the following:

1. *The method is of very limited use in areas where soil conditions in shore land areas are limiting factors for future development.*

2. *The planners should evaluate both components (water and shore land) of the water body and adopt the one which will yield lower capacity. However, in this case only size of water body is considered.*

3. *The boat limit approach may be useful for lakes and ponds with small surface water areas. However, it may not be applicable for lakes and ponds with large surface water areas and in such cases shoreline characteristics should be evaluated.*

4. *The translation of boating capacity into development capacity does not take into account the public access, shoreline condition (numerous bogs, rock outcrops, erodible slopes, etc.) and other existing land uses.*

5. *It is recommended that efforts should be made to verify the assumptions of this approach through field data collection on lakes and ponds used for recreational purposes.*

6.0 SPORTS FISHERIES APPROACH

6.1 Literature Review

Development of cottages which attracts people to a lake can affect the fish habitat by:

- *changing the water chemistry and trophic status;*
- *altering or disturbing spawning, nursery and feeding grounds; and*
- *increasing fishing pressure.*

The first two effects are described in the section on the trophic state approach and the third effect related to increased fishing pressure is discussed below.

The yield of fish is a function of physical and chemical characteristics of the watershed, as well as the biotic potential of the fish and the fishing pressure. Rawson (1952, 1955) was probably the first to give a clear demonstration of the relation between fish production and lake morphometry. According to him

$$Y = 30.255(Z)^{-0.7029} + 0.5 \qquad 6.1$$

where Y = annual commercial fish landing in lb/acre
and Z = average lake depth in feet

Ryder (1964, 1965, 1978) found that commercial fish yield was positively correlated with the total phosphorus, total nitrogen and total alkalinity of lake waters, and these factors were related to the geology of the watershed and existing land uses. According to Ryder

$$Y = 1.4 \left(\frac{TDS}{Z}\right)^{0.45} = 1.4\ (MEI)^{0.45} \qquad 6.2$$

$$MEI = \text{Morphoedaphic index} \qquad \frac{(TDS)}{Z}$$

where Y = yield of fish in kg/hectare/year
TDS = total dissolved solids concentration in mg/l
Z = average lake depth in metres.

TDS is related to the edaphic factor (related to soil) while Z to morphometric factor. The relation of the two terms was defined as morphoedaphic index (MEI).

According to Jenkins and Morais (1971)

$$\log_{10}Y = 0.620\ (\log_{10}MEI) - 0.118\ (\log_{10} MEI)^2 + 0.115 \qquad 6.3$$

where Y = catch of sport fish in kg/hectare/year

Fish yield was found to be strongly correlated with the fishing pressure. The angling effort and yield statistics were related as:

$$Y = 0.134\ (E_s)^{0.862} \qquad 6.4$$

where Y = total summer angling yield in kg/hectare/year
and E_s = total summer effort in angler - hour/hectare of cottages and non cottages.

A multiple regression analysis of summer yield by all anglers, the MEI and the summer effort by all anglers gave the following relationship:

$$\log_{10}Y = 0.458\ (\log_{10} \mathrm{MEI}) + 0.126\ (\log_{10} \mathrm{MEI})^2 + 0.728\ (\log_{10} E_s) - 0.834 \qquad 6.5$$

Effort by anglers has been found to be related to the size of the lake as follows:

$$\log_{10} \frac{E_{sc}}{N} = 1.576 - 0.000148\ (A) \qquad 6.6$$

where $\frac{E_{sc}}{N}$ is the angler hours per cottage/summer

where E_{sc} = summer angler hours
N = total number of cottages
A = lake surface area in hectares

During the summer, non cottagers also come for fishing and their angling effort has been expressed as:

$$E_n = 0.518\ (E_c)^{1.204} \qquad 6.7$$

where E_n = angler - hours/hectares/summer by non cottagers and
where E_c = angler - hours/hectares/summer by cottagers

$$\text{where } E_s = E_n + E_c \qquad 6.8$$

Winter angling effort has been expressed as: $E_w = 0.365\ (E_s)^{1.315}$ 6.9

where E_w = total angler - hours/hectares/winter

The net productivity model has been tested by Lake Shore Study Groups (1983) on a number of lakes where MEI ranges from 0.6 to 82 mg/l/m, cottage numbers from 16 to 4,800, and areas of lakes from 90 to 10,500 hectares. Figure 6.1 summarizes the results of this application. This approach can be used as a guideline to predict allowable number of cottages for selected MEI and given lake area. However, the accuracy of such predictions would be questionable without adequate field data since these equations are based on data collected through extensive field work in regions with varied geological, hydrological and morphologic conditions.

6.2 Application of the Model in a Planning Context

To apply the net productivity model in a lake shore planning situation, one needs to know the area and mean depth of the lake; the midsummer total dissolved solids concentration, the existing number of cottages on the lake, the proposed number of new cottages, public access, and winter angling.

With the above information in hand, the planner has the option of determining:

1. *whether the proposed number of new cottages is likely to generate too much angling pressure for the fishery to sustain, or*
2. *what total number of cottages might be put on the lake without giving rise to excessive angling pressure.*

For Option 1, proceed as follows:

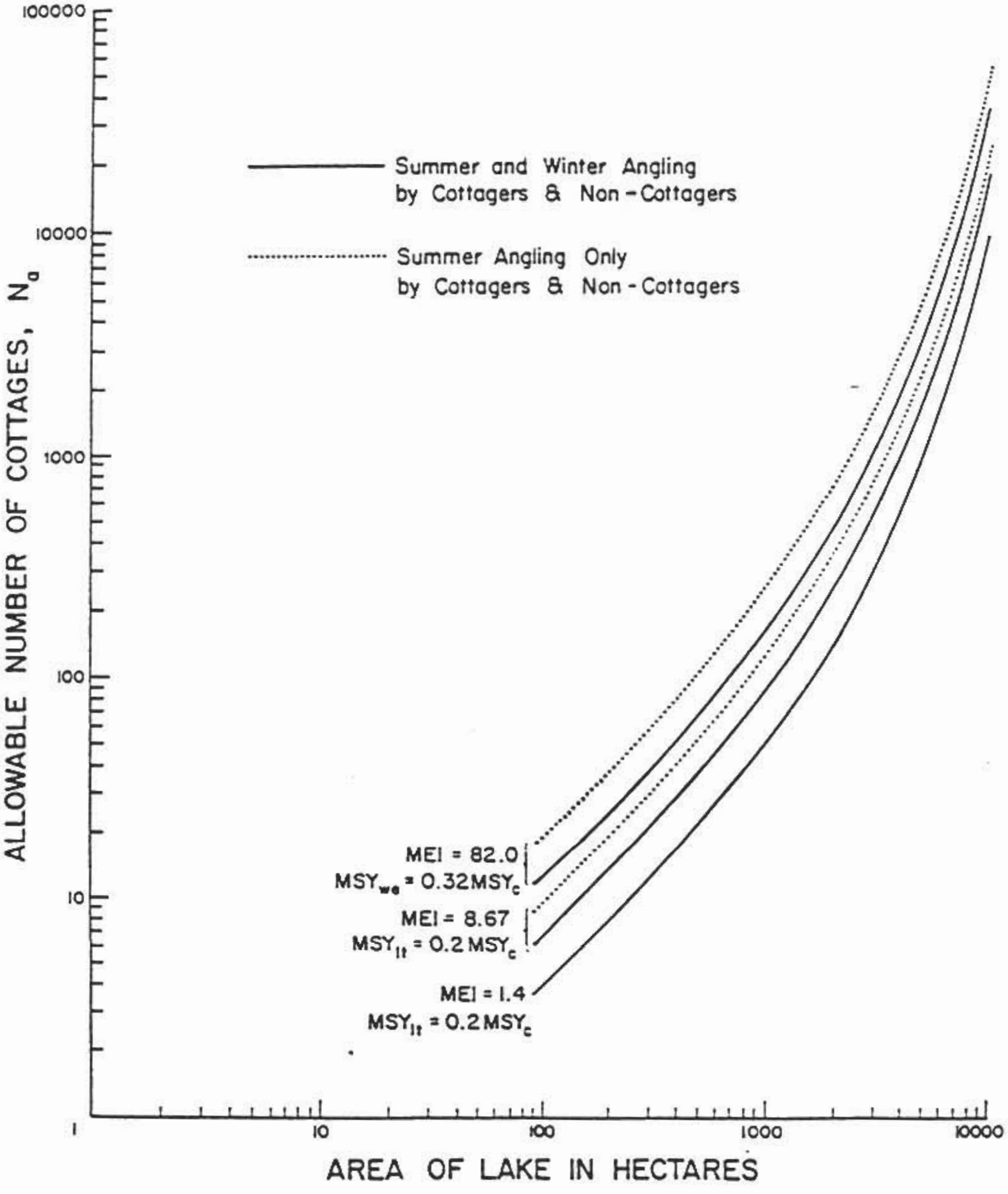
Step 1: Divide the total dissolved solids by the mean depth, insert the resulting MEI into Equation 6.2 ($Y = 1.4\ (MEI)^{0.45}$) and solve for the Y maximum sustainable yield for a fish community in kg/ha/year (MSY_c).

Step 2: To estimate the summer angling effort by cottagers in angler - hours ha^{-1}, solve Equation ($\log_{10} E_{tc}/N = 1.576 - 0.000148(A)$), multiply the result by the total number of cottages on the lake (existing + proposed) and divide by the area of the lake. If there is little or no public access to the lake, negligible angling by non-cottagers, and no winter fishery, skip to Step 5a.

Step 3: If there is public access and significant angling by non-cottagers, insert the summer effort by cottagers obtained in Step 2 into Equation ($E_n = 0.518\ (E_c)^{1.204}$) and solve for the angler - hours ha^{-1} $summer^{-1}$ spent by non-cottagers. Add the result to that obtained from Step 2 to get the total summer effort by cottagers and non-cottagers combined. If there is no winter angling, skip to Step 5b.

Step 4: If there is a winter fishery, insert the total summer effort calculated in Step 3 into Equation ($E_w = 0.365\ (E_s)^{1.315}$) and solve for the total angler - hours ha^{-1} $winter^{-1}$ by cottagers and non-cottagers combined. Add the result to the total summer effort obtained in Step 3 to get the total angler - hours ha^{-1} yr^{-1} by all anglers. Then go to Step 5c.

FIGURE 6.1 ALLOWABLE NUMBER OF COTTAGES BASED ON LAKE AREA AND FISH SPECIES (After Lakeshore Study, 1983)



Step 5a: Insert the summer effort by cottagers obtained in Step 2 into Equation ($\log_{10}Y = 0.458 (\log_{10} MEI) + 0.126 (\log_{10} MEI)^2 + 0.728 \log_{10} (E) - 0.834$), together with the MEI for the lake in question, and solve for the summer yield for cottagers.

Step 5b: Insert the total summer effort by cottagers and non-cottagers together with the MEI for the lake in question, and solve for the summer yield for cottagers and non-cottagers combined.

Step 5c: Insert the total angler - hours ha^{-1} yr^{-1} derived in Step 4 into Equation of Step 5a and solve for the annual yield for cottagers and non-cottagers combined.

Step 5d: For the remote possibility of a combined summer and winter fishery by cottagers only, insert the summer effort by cottagers obtained in Step 2 into Equation ($E_w = 0.365 (E_s)^{1.315}$) and solve for the winter effort by cottagers. The result would then be added to the summer effort to get the total angler - hours ha^{-1} yr^{-1} by cottagers. This in turn would be inserted into Equation of Step 5a, together with the MEI, to obtain the annual yield for cottagers only. However, this may be an overestimate, since the cottagers in our study area expressed relatively little interest in winter angling. This model is not designed to deal with the case where the angling is entirely by non-cottagers.

Step 6: Compare the estimated yield from Step 5a, b, c or d with the allowable yield selected in Step 1. If it is greater than the allowable yield, the proposed number of new cottages is likely to generate too much angling pressure. Notice that by carrying out Steps 1 through 5a, b, c or d for the conditions zero new cottages, one could determine whether the existing number of cottages posed a threat to the fishery. This information might be used by fisheries managers in regulating season lengths and catch quotas.

For Option 2, the procedure is:

Select the allowable yield as in Step 1 of option 1 and then repeat Steps 2 through 5 (or 6) for the existing number of cottages, half the existing number and twice the existing number in order to obtain three estimated yields.

6.3 Limitations and Constraints of the Approach

Two constraints are placed on the application of the sports fisheries approach in determining allowable number of cottages for a lake or pond:

- *Information required for the model should be collected within the planning area; and*

- *Data required to use the model be available in the existing record or easily obtainable with a minimum field work.*

The predicted value of fish yield using this approach is a theoretical limit and a number of factors, such as spawning area, and harvesting pressure, may affect this estimated value. There are a number of other factors such as winter kill, migration of fish from one lake to the next lake, which are not considered in the model formula. These factors will have significant impact on the estimated fish yield. However, from fisheries point of view, this is the only approach available at present and, if applied cautiously, will provide planners with some reasonable indication on the status of lake fishery in relation to harvesting stresses.

Our initial contacts with Federal Fisheries, Provincial Fisheries and the Department of Tourism and Culture indicated that no information is available on total dissolved solid concentrations, percentage of sport fisheries and angling pressure for the lakes selected for this study. In view of this, it was decided to not pursue the application of this method. However, we strongly feel that at some point of time, the Land Use Management Division, in cooperation with Fisheries, should collect the required information and test the applicability of this approach.

7.0 RECREATION COTTAGE PLANNING IN NEWFOUNDLAND

7.1 Review of Recreation Cottage Planning Guidelines

The Land Use Management Division in 1978, then under the Department of Forestry and Agriculture, compiled a manual for recreational cottage planning in Newfoundland. The main purpose of this manual was to outline the procedure for the processing of a recreation cottage lease application. In addition to this, the manual is used:

1. *as a reference guide for Regional Staff involved in recreation cottage planning;*
2. *as an information package on how and why certain methods and procedures are carried out in planning recreation cottage development; and*
3. *as an avenue to evaluate existing policy, procedure and specifications for recreation cottage developments.*

The guidelines outlined in this manual refer specifically to recreation cottages that are accessible by road.

The manual is divided into five sections followed by a number of appendices. Section one of the manual provides general information on land management approach and the need for the manual. Section two outlines the approach to be adopted for land capability analysis. This section has also provided a good review of various factors (present land use, feasibility for development, analysis of physical conditions of the site and shore land, sensitive areas) to be considered for planning purposes. An approach similar to the theoretical-boat-density approach has been presented to determine the recreational capacity of the pond which can be translated into cottage development potential of the pond. Section three reviews the referral system dealing with cottage development and suggests a new system to improve the existing referral system and, therefore, reduce the time taken to process recreational cottage applications. Section four of the manual presents detail procedures for survey and disposition of lots and other site improvements. Section five provides details on legislation, policy and procedures dealing with illegal occupancy of Crown land for recreational cottages. Design guidelines for cottage subdivisions and sewage disposal systems are presented in various appendices of the report.

As discussed earlier, the document is well written and provides useful information for recreation cottage planning in Newfoundland. For quite sometime, the Land Use Management Division has been using this document as a reference for recreational cottage planning in Newfoundland. The document seems to be satisfactory as a planning guideline but considering the research development of the 1980's dealing with carrying capacity of lakes, the capability analysis approach presented in the manual seems to be inadequate and deficient. This has been stated by the authors of the manual as well. The capability analysis approach outlined in the manual does not take into account the ecological and biological aspect of the water body. Capability analysis must consider all components which might be affected as a result of cottage development. As stated in the beginning of the report, the methods (high and low energy) are similar to those discussed in Sections 3 and 5 of this report and limitation associated with those methods applied to these as well.

7.2 Recreation Cottage Development Capacity

The main purpose in calculating the capacity of a pond or lake is to:

- *minimize conflict of recreation use between such activities as motor boating, swimming, water skiing and fishing;*
- *preserve the ecological balance of the water body;*
- *preserve non-developed public reserves adjacent to the water body; and*
- *preserve hydrologic (steep slopes, erodible soils, wetlands) and ecological (fish spawning areas, salmon rivers) sensitive areas from development.*

The cottage planning guidelines prepared by the Land Use Management Division include two methods of calculating the potential pond capacity for recreation cottage development. The methods refer specifically to:

1. *Ponds, which because of water surface area, shape and depth, are suitable for motor boat activity, designated here as high energy recreation ponds.*

2. *Ponds, which because of water surface area, shape and depth, are not suitable for motor boat activity, designated here as low energy recreation ponds.*

The cottage capacity for the first category of ponds is calculated using Reiner Jaakson (1970) formula which is more or less similar to the boat density approach. According to this method, the cottage capacity of a pond is directly proportional to its water surface area. For the second category of ponds, the natural shoreline is compared with the desirable shoreline length that theoretically should be conserved in order to preserve the ecological balance of any lake or pond. The method used is similar to the natural shoreline reserve method. A full description of the approach is presented in the following section.

7.2.1 High Energy Recreation Cottage Pond Capacity

Jaakson (1970) presented a formula to determine the largest number of cottages possible at a lake or pond, without deteriorating the environment. According to this method, the cottage capacity of a high energy recreation pond is calculated as outlined below:

This approach is based on the following assumptions:

1. *Four hectares of pond surface area is allocated to each boat.*
2. *Maximum use of only 10% of the total boats on the pond at any one time.*
3. *Each cottage owner owns two boats.*

4. *40% of the pond capacity for boats is reserved for future non-cottagers and development.*

- *calculate pond area in hectares (G)*
- *calculate the pond capacity for boating by dividing pond area by the boat space requirement* $(H = \frac{G}{4})$
- *calculate the pond capacity for boating by non-cottagers* $(I = H \times 0.4)$
- *calculate maximum number of boats to be accommodated from cottage use (J)* $(J = H - I)$
- *calculate the total allowable cottage boat by multiplying J with 10 which assumes that only 10% of the total boats will use the pond at any given time* $(K = J \times 10)$
- *calculate the cottage capacity by dividing total allowable cottage boat with the number of boats per cottage* $(L = \frac{K}{2})$

7.2.2 Low Energy Recreation Cottage Pond Capacity

According to this approach, the allowable development should be limited to 75% of the natural shoreline. The method of estimating cottage pond capacity is as follows:

- *Measure the shoreline length (A) in metres*
- *Calculate the development length of the shoreline* $(B = 0.75A)$ *by reserving 25% of the shoreline as a natural habitat*
- *Reserve a further 25% for future development and calculate the shoreline length for cottage development* $(D = B - 0.25B)$
- *Assuming a single tier of development and 45 metres, cottage lot frontage, calculate the allowable number of cottages by dividing D with 45* $(L = \frac{D}{45})$

7.3 Application of High and Low Energy Recreation Cottage Pond Capacity Estimation Methods or Approaches

Both these approaches were applied to 20 lakes (or ponds) selected for this study. Depending on size and depth, the ponds were classified into two categories: (1) high energy recreation ponds; and (2) low energy recreation ponds. The water bodies with depth >2.5 metres and adequate surface area were generally considered as high energy capacity and with depth ≤ 2.5 metres and small surface area were considered as low energy capacity. Cottage Development Capacity of each pond was calculated according to its classification. Tors Cove, Hell Hill, Cape Broyle, Nine Island, Hawcos, Middle Gull, Grand, Ocean, Thorburn, Georges, Lady, Shoal Harbour, Freshwater, Garnish and Salmonier were classified as high energy recreation lakes (or ponds) while Old Mans, Goulds, Dennys, Peak and Junction Ponds were classified as low energy development recreation ponds. Results on cottage capacity development potential of the water bodies using the high and low energy recreation methods are presented in Tables 7.1 and 7.2 respectively.

The results of high energy recreation cottage capability were based on the assumptions stated in Section 7.2.1 and also on each cottage having only one boat. Based on local knowledge and in consultation with the staff of the Land Use Management Division, one boat per cottage is more representative of Newfoundland conditions than two boats per cottage.

In Table 7.1, Columns 1, 2 and 3 show the name of the water body, mean depth and lake net area respectively. The pond boating capacity, Column 4, is the lake net area divided by the space required per boat (4 ha). The maximum number of boats a pond can accommodate while reserving 40% of the area for other activities is shown in Column 5 (maximum number of boats = pond boat capacity x 0.60). Cottage boat use, Column 6, is the maximum number of boats the water body can accommodate x 10 (10% is the maximum number of boats using the pond at peak times). The cottage carrying capacity, Column 7, is equal to the cottage boat use divided by two (based on two boats per cottage owner). The existing number of cottages is shown in Column 8. The cottage development capacity based on two boats and one boat is shown in Columns 9 and 10 respectively. The cottage development capacity based on two boats per cottage was found by subtracting the cottage capacity (Column 7) from the existing number of cottages. The cottage development capacity based on one boat per cottage was found by subtracting the cottage boat use, Column 6 (total number of boats/cottages on the water body) from the existing number of cottages.

Analysis of the development capacity data summarized in Table 7.1 indicates that based on two boats per cabin, Tors Cove Pond, Cape Broyle Pond and Grand Pond are over developed (negative values indicate the number of cottages the development capacity is exceeded by). Assuming one boat per cottage, the high energy recreation method will allow future development to continue on all of the lakes and ponds listed in Table 7.1.

The low energy recreation cottage pond capability method was used on five water bodies and the results are presented in Table 7.2. The name of the water body, mean depth, water bodies net area and perimeter of shoreline is given in Columns 1 to 4 respectively. Column 5 was developed by conserving 25% of the perimeter of the shoreline and Column 6 by reserving an additional 25% of the remaining shoreline for future development. Approximately 44% of the perimeter of the natural shoreline is to be reserved in total. The cottage carrying capacity equals the remaining perimeter of shoreline (Column 6) divided by 45 m (the maximum cottage lot frontage size). The present existing number of cottages are shown in Column 8. Cottage development potential (column 9) is equal to the cottage capacity (Column 7) minus the existing number of cottages (column 8).

Based on the results of Table 7.2, it will appear that there is room for future cottage development on all five ponds.

It may be noted that the approach employed to calculate the development capacity did not take into consideration factors such as shoreline conditions, existing land uses and the impacts of future development on aquatic life of the pond. Though development capacity data presented in Tables 7.1 and 7.2 indicate there is room for future recreational cottage development, shoreline conditions and other existing land uses may not permit this level of development.

TABLE 7.1 COTTAGE CAPACITY AND DEVELOPMENT POTENTIAL FOR HIGH ENERGY RECREATION AREAS

Water Body	Mean Depth (m)	Lake Net Area (Ha)	Pond Boat Capacity	Max. # of Boats Accommodating for Cottages	Cottage Boat Use	Cottage Capacity	Existing Cottages	Development Capacity*	Development Capacity**
1	2	3	4	5	6	7	8	9	10
Tors Cove Pond	9	234	59	35	352	176	243	109	-67
Hell Hill Pond	4	114	29	17	172	86	9	163	77
Cape Broyle Pond	6	270	68	41	405	203	220	185	-17
Nine Island Pond	6	162	41	24	243	122	120	113	2
Hawco's Pond	3	257	64	39	385	193	151	234	42
Middle Gull Pond	10	307	77	46	460	230	115	345	115
Grand Pond	4	182	46	27	273	137	151	122	-14
Ocean Pond	5	404	101	61	607	303	256	351	49
Thorburn Lake	12	289	72	43	434	217	28	406	189
Georges Pond	6	445	111	67	668	334	6	662	328
Lady Pond	25	470	118	71	705	353	26	679	327
Shoal H Pond	6	291	73	44	436	218	13	423	205
Freshwater Pond	16	961	240	144	1441	721	58	1383	663
Garnish Pond	3	380	95	56	569	285	54	515	231
Salmonier Pond	9	89	22	13	134	67	36	98	31

* based on one boat per cottage
** based on two boats per cottage

TABLE 7.2 COTTAGE CAPACITY AND DEVELOPMENT POTENTIAL FOR LOW ENERGY RECREATION AREAS

Water Body	Mean Depth (m)	Lake Net Area (Ha)	Perimeter in (m)	Conservation 25%	Future Dev. 25%	Cottage Capacity with 45m Lot Frontage	Existing Cottage	Cottage Dev. Potential
1	2	3	4	5	6	7	8	9
Old Mans Pond	2.5	24.8	6295	4721	3541	78	21	57
Goulds Pond	3.1	62.4	11152	8364	6273	139	47	92
Denny's Pond	4.6	92.8	11552	8664	6498	144	43	101
Peak Pond	1.3	54.7	8387	6290	4717	105	32	73
Junction Pond	3.1	61.9	9267	6950	5212	115	42	73

8.0 SPECTRUM ANALYSIS

8.1 Introduction

The cottage carrying capacity methods, discussed in Chapters two through seven, each focus on only one parameter (i.e. shoreline conditions, shoreline length, water body size, fisheries or nutrient loading) to determine sustainable levels of cottage development. The methods (excluding the sports fisheries approach) can be grouped into three categories: (1) The Natural Shoreline Reserve, Shoreline Capability, and Low Energy Recreation methods are based on shoreline or shoreline conditions which include slope, soil type and perimeter of shoreline; (2) The Boat Density and High Energy Recreation methods are based on the surface area of a water body; and (3) The Lake Trophic State method is based on the predicted level of nutrients input to a water body from various sources (i.e. rainfall, runoff, and cottage development) and the capacity of a lake or pond to sustain an acceptable nutrient level. As stated above, each of the methods consider only one constraint to cottage development and, therefore, sustaining carrying capacity of a water body is based on a single constraint rather than multiple constraints. The latter is the most common situation encountered by cottage planners. For effective and successful management, it is essential that all constraints to development be considered in determining the carrying capacity of a water body. This can best be accomplished through a spectrum analysis approach.

A spectrum analysis approach, developed by the Saskatchewan Department of Environment, uses all of the cottage carrying capacity methods or at least one method from each of the three categories mentioned above (i.e. shoreline length/condition, water body size, and nutrient loading). The carrying capacity results obtained by each of the three categories are reviewed to provide a range of development level choices or a spectrum of alternatives for planning. The advantages to using a spectrum approach are: (1) more than one development constraints would be used to determine the carrying capacity; (2) a range of development level choices would be available to the planner to decide the potential of a water body for cottage development; and (3) the method would be useful in identifying the extent of limiting factors.

At present, the Land Use Management Division uses a simplified version of the spectrum approach. One of two cottage carrying capacity methods is used based on whether motorboat activity can or cannot be sustained on a lake or pond. If motor boat activity can be sustained on a water body, then the high energy recreation method is used and, if it cannot be, the low energy recreation method is used. Size of the water body is the limiting factor for the High Energy Recreation method and length of shoreline for the Low Energy Recreation method. The High Energy method uses the assumption that each cottage owner has two boats and 10% of the total boats will be on the water body at any peak time. The results of this report indicate that one boat per cottage owner and 25% of total boats used at any peak time are more reasonable numbers and these values should be used unless either field observation or more extensive research prove otherwise. A similar type of impractical assumptions are used in the application of Low Energy Recreation method which have been discussed in detail in preceding sections of this report. The High and Low Energy Recreation methods do not consider the trophic status or shoreline conditions/capability of a lake or pond. It is, therefore, obvious that a method based on multiple parameters would provide a better estimate of the carrying capacity than a method based on one or two parameters.

8.2 Variability in Cottage Carrying Capacity Results

In each of the cottage carrying capacity methods, presented in this report, the predicted number of cottages a water body can support will depend on either one or more of the following: (1) percentage of area to be reserved as natural buffer zone; (2) percentage of area to be reserved as public space; (3) percentage of area to be reserved for future development; (4) background nutrient levels and trophic status of a water body; (5) morphological characteristics of a water body and its sensitivity to development pressure; (6) shoreline conditions and capability classification; (7) maximum lot frontage size and the spacing between lots; (8) development pattern (i.e. shoreline or cul-de-sac patterns); (9) sports fisheries and angling pressure; and (10) physiographic characteristics of the watershed and existing land and water use activities.

For the reasons mentioned above, cottage carrying capacity results are highly variable and there is a need for standards to be set for percentage of area to be reserved as natural buffer zone, public space, future development considerations and nutrient levels, etc. The standards should reflect the sensitivity of an area to environmental degradation as well aesthetic quality and space requirement for outdoor recreational use and enjoyment by both cottage owners and the general public. In highly sensitive areas, for example, waterfowl breeding grounds, fish spawning areas, nutrient rich water bodies or in areas with existing multiple demand and water use activities it may be desirable to limit or freeze cottage development. In such sensitive areas, it is recommended that more space should be reserved as natural buffer zones and less for cottage development. After the recreation potential or sensitivity of a lake has been defined, a spectrum approach can be used to determine the carrying capacity to meet a desired level of use and acceptable level of water quality.

8.3 Summary of Cottage Carrying Capacity Methods

8.3.1 Trophic State

Theory: The Lake Trophic State Method is based on the predicted level of phosphorus input to a water body from various sources (example rainfall and runoff) and the capacity of the lake or pond to support cottages at a desired level of phosphorus.

Adopted Approach: The amount of phosphorus entering a lake or pond through natural sources (example precipitation and overland drainage) and through artificial sources (example cottage development) was determined using empirical formulas. The concentration of phosphorus entering a water body is dependent on the geological characteristics and land uses within a watershed as well as the amount of phosphorus contributed by precipitation through direct phosphorus loading and runoff from overland drainage. The morphological characteristics of the water body (example depth, flushing rate, inflow and outflow pattern etc.) will also effect the concentration of phosphorus by controlling the amount of phosphorus lost through flushing or settled through sedimentation. To apply the empirical formulas, constants were used as reported in the literature. For many of the constants a range of values were given to suit various conditions. Where possible values were chosen to meet conditions affecting the study lakes. The amount of phosphorus entering a water body was compared against the desired level of phosphorus the water body should maintain. The capacity of the lake or pond to support either more or less cabins was then determined based on the difference between the estimated phosphorus input to the lake and the desired level of phosphorus the lake should maintain. The number of cabins above or below the carrying capacity was determined by estimating the amount of phosphorus input by one cabin and dividing this amount by the difference between the predicted minus the acceptable level of phosphorus.

Spring time phosphorus sample results were used where possible to characterise the trophic status of the water body (see Table 2.10) to determine if additional cottage development could be supported. In addition to water quality samples, the sensitivity of a water body to nutrient loading was also determined using a vulnerability index. The vulnerability index or Sargent's approach uses morphological characteristics of a water body as described in Table 2.26 to rate the sensitivity of a lake or pond to nutrient loading or shoreline development.

Assumptions:

1. The empirical formulas and parameters reported in the literature are applicable to all selected lakes and ponds for this study.

2. Model formulation is based on Steady-State (i.e. concentration of Total Phosphorus in the study lakes as remaining constant). The effect of thermal stratification of lakes is not incorporated in the model.

Limitations:

1. Each water body is a unique system and, therefore, empirical formulas may produce highly variable results especially when used under different settings.

2. There was no way of verifying the model parameters. Users must be aware that empirical formulas have been developed for specific geographic regions and may not accurately reflect land cover, precipitation or soil conditions of the study area. There was no comprehensive sampling of phosphorus on any of the study lakes.

3. The application of this approach can be quite expensive and requires long term testing where monitoring is required for basic model input.

4. The model is very sensitive to parameters such as phosphorus export coefficient, retention coefficient, rainfall and runoff values.

5. The trophic state method only looks at nutrient loading and not at other water quality parameters like pathogenic bacteria, etc.

Recommendations: The trophic state method is the only cottage carrying capacity method that addresses a component of water quality. There are, however, a few problems in applying this model to the selected lakes and ponds as mentioned above. The water quality of a lake or pond can become impaired in terms of other parameters, for example physical, microbiological as well as organic and inorganic parameters, other than phosphorous, can affect water quality.

To overcome some of the limitations of the Trophic State method, it is recommended that the following procedure be used to determine the trophic status of a water body: (1) Water quality data should be collected to characterise the spring time Total Phosphorus concentration, summer time Chlorophyll a and secci disc depth. The results of these parameters should meet the Canadian Water Quality Guidelines for the intended purpose (Tables 2.9, 2.10 and Figure 2.2, 2.3 will aid in the interpretation of the results). If the water quality of a lake or pond does not meet the standards, then the proposed/planned cottage development project should either be cancelled or revised, and (2) The vulnerability index of a water body should also be determined. The vulnerability index should be used along with the carrying capacity methods other than the Trophic State method that provides the most constraint to cottage development. If the vulnerability index of a water body is high then planned cottage development should be less than the number obtained by the most limiting carrying capacity method.

8.3.2 Natural Shoreline Reserve

Theory: Reserve part of the shoreline of a water body in its natural state for the preservation of its aesthetic quality and ecological balance.

Adopted Approach: The perimeter of the shoreline of a water body was measured. Forty percent of the shoreline was reserved to remain in its natural state. Of the remaining shoreline (60% of the actual shoreline) 40% was reserved for future planning, public access and open spaces and 60% was designated for cottage use. The shoreline designated for cottage use was divided by 30m and 45m lot width sizes to determine the maximum and minimum number of cottages respectively, a water body can support based on single tier development approach. Single tier development or shoreline frontage is commonly practised in Newfoundland.

Assumptions:

1. Reserve 40% of the shoreline as natural buffer zone to preserve both aesthetic quality and ecological balance.

2. Reserve 40% of the remaining shoreline for future planning purposes, public access, and open space.

3. Assume lot width sizes of 30m and 45m.

Note: The linear length of the shoreline excludes irregular bays and shoreline features. The remaining shoreline length can be considered for single tier development based on the given lot width sizes.

Limitations:

1. The length of shoreline is the only factor considered by this method, other factors such as water body size and shoreline conditions are not considered.

2. The ecological setting of every water body is different. Reserving a percentage of the buffer zone (40% in the Natural Shoreline Reserve methods case) may not be adequate to preserve the ecological balance of some sensitive water bodies.

3. Apart from reserving 40% of the shoreline, the water quality of the lake or pond is not addressed.

4. This method was designed for single tier development around a water body and the remainder of the watershed is not considered.

5. The conditions of the shoreline, or shoreline characteristics such as soil types, topography, and land use which are extremely important for determining acceptable level of development are not considered.

Recommendations: This method can be applied to determine the cottage carrying capacity of a lake or pond provided other parameters are not limiting to cottage development. If such parameters as water quality, shoreline conditions (slope and soil type), existing shoreline land uses or water body size are more limiting then this method may not be appropriate to determine the cottage carrying capacity of a water body.

8.3.3 Shoreline Capability

Theory: The number of cabins a water body can support is dependent on the shoreline's slope and soil conditions.

Adopted Approach: The perimeter of the shoreline of each water body was classified into one of four cottage capability classes. The cottage capability classes represent the number of cottages the shoreline can support based on the shoreline's slope and soil type. The length of shoreline in each capability class was determined by overlaying two maps, one prepared for topographic capability and the other for soil drainage capability to determine the desired cottage capability classification and actual number of cottages for each classification. Forty percent of the suitable shoreline was reserved either in its natural state or for public access.

Assumptions:

1. The number of cabins per km in each cottage capability class is based on soil type and slope obtained from the topographic maps.

2. Reserving 40% of the suitable shoreline from cottage development is considered enough to accommodate the general public access and to preserve ecological balance.

Limitations:

1. Only shoreline slope and soil drainage capability are taken into consideration. The watershed area and size of water body are not considered.

2. The soil conditions around every water body have not been mapped to a suitable scale to use this method throughout Newfoundland.

3. The irregular shape of many Newfoundland ponds and lakes and lack of data on soil characteristics make this method difficult to apply.

Recommendations: This is the only method that uses the shoreline's topography and soil conditions to determine the cottage carrying capacity of a water body. This method will help the land use planner to determine how suitable shoreline conditions are for cottage development. If the water quality, existing shoreline land uses and/or size of water body are more limiting parameters, then this method may not be appropriate to determine the cottage carrying capacity of a water body.

8.3.4 Boat Density

Theory: The number of boats that can operate on a water body will depend on the size of a water body and the space required for each boat to operate.

Adopted Approach: Twenty-five percent of the gross acreage of a water body was assumed to be unusable by boats. The remaining 75% of the water body was divided by 4 ha (the standard space for each boat to operate) to determine the boating capacity. Forty percent of the boating capacity of the water body was reserved for the public and 60% for cottagers. Assuming 25% of the boats owned by cottagers will be used at any peak time, then 4 times as many cottages as boats will be able to locate around the water body.

Assumptions:

1. 75% of the gross area of a water body is suitable for boating.

2. The standard boating space is 4 ha.

3. The general public's share of boating will not exceed 40% of use.

4. The number of boats in use at any peak time should not exceed 25%.

Limitations:

1. This method will not work on lakes or ponds that are virtually unusable by boats. Water bodies that are too shallow for boating or have excessive vegetation should be excluded from this method.

2. This method only deals with the size of the water body and its capacity to facilitate boating use. The water quality and shore land conditions are not addressed by this method.

Recommendations:

1. Some field work should be initiated to determine the number of boats in use at peak times on water bodies in Newfoundland. This will help to decide whether 25% of boats in use at peak times should be used or some other appropriate value.

2. Before this method is applied, preliminary field work should be completed to determine if the water body can sustain boat use. A water body with (1) shallow bottom or (2) excessive plant growth will not be able to sustain any boating activity and thus this method will not be applicable.

3. The boat capability method with 25% of cottager's boats in use at peak times can be used along with other methods that address shoreline conditions, shoreline length and water quality to determine the carrying capacity of a lake or pond. A strong point of this approach is that it considers the size of a water body and its capacity to handle on water recreational activities. If the water quality, shoreline conditions, shoreline length and morphological characteristics from a boating perspective are more limiting to cottage carrying capacity than the actual water body size then approaches incorporating these parameters should be given more weight over this approach.

8.4 Application of Selected Carrying Capacity Methods in Newfoundland

The results of the spectrum analysis for the 20 selected lakes and ponds are presented in Table 8.1. According to these results, eight of the water bodies are underdeveloped (Hell Hill Pond, Middle Gull Pond, Thorburn Lake, Georges Pond, Lady Pond, Shoal Harbour Pond, Freshwater Pond and Garnish Pond), three were at carrying capacity or very close to it (Dennys Pond, Peak Pond and Salmonier Pond) and nine overdeveloped (Tors Cove Pond, Cape Broyle Pond, Old Mans Pond, Nine Island Pond, Goulds Pond, Hawcos Pond, Grand Pond, Ocean Pond and Junction Pond). Of the eight water bodies that were determined as being underdeveloped not all of them will be able to sustain additional cottage development for reasons not considered by the carrying capacity methods. For example, (i) the water quality of the lakes or ponds may be impaired by microbiological or other chemical parameters or existing development could be too close to the shoreline and within high water mark of the water body, (ii) access to the site may be difficult or not permitted due to rough terrain or existing land use

TABLE 8.1 SUMMARY OF POTENTIAL COTTAGE CARRYING CAPACITY

Water Body	Existing Cabins	NSR (30m) 60%	NSR (45m) 60%	Shoreline Develop.	Boat Density 25%	Trophic State	Remark
Tors Cove Pond	243	193	128	145	105	64	OD
Hell Hill Pond	9	117	78	64	51	102	UD
Cape Broyle Pond	220	298	199	260	121	128	OD
Old Man Pond	21	75	50	101	11	21	OD
Nine Island Pond	120	171	114	146	73	139	OD
Goulds Pond	47	134	89	166	28	53	OD
Hawcos Pond	151	538	359	571	116	206	OD
Middle Gull Pond	115	419	280	157	138	256	UD
Grand Pond	151	302	201	377	82	139	OD
Ocean Pond	256	569	380	557	182	322	OD
Dennys Pond	43	139	92	124	42	24	At CC
Peak Pond	32	99	66	40	25	43	At CC
Junction Pond	42	111	74	122	28	32	OD
Thorburn Lake	28	263	176	245	130	61	UD
Georges Pond	6	239	159	260	200	281	UD
Lady Pond	26	328	218	181	212	28	UD
Shoal H. Pond	13	167	112	159	131	18	UD
Freshwater Pond	58	249	166	166	432	1001	UD
Garnish Pond	54	313	208	362	171	532	UD
Salmonier Pond	36	143	95	119	40	86	At CC

OD = Over Developed
UD = Under Developed
At CC = At Carrying Capacity

activities, (iii) functional septic systems may not be possible around the water bodies shoreline, and (iv) physical features like wetland and cliffs may not permit additional cottage development. Garnish and Freshwater Ponds are examples of water bodies that were determined as being underdeveloped, however, additional development may not be sustainable on either pond until some corrective measures are adopted. Both ponds were determined as having high levels of micro-biological parameters as documented in the 1989 report *"A Study on the Effects of Cabin Development on Surface Water Quality of Freshwater Pond and Garnish Pond"*. Freshwater Pond is also partly encompassed by a provincial park and Garnish Pond is an area where salmon migrate through to spawn upstream. These additional factors must also be considered in finalizing cottage development plans.

Cottage carrying capacity methods with assumptions that were deemed not suitable for cottage development in Newfoundland were omitted from Table 8.1 and not used in the spectrum analysis of the water bodies. The main reasons for there omissions were: (1) Results were not compatible with present cottage practices in Newfoundland (i.e. the Natural Shoreline Reserve method based on 25% natural buffer zone and Boat Density method based on 10% of boats in use at peak times predicted carrying capacities that would detract from the aesthetic beauty and space requirements for outdoor recreational enjoyment); (2) Methods could not be applied because of insufficient data (i.e. Sports Fisheries method); and (3) Few methods were similar to other methods in their approach and assumptions (example the High and Low Energy Recreation methods are just different versions of the Boat Density and Natural Shoreline Reserve methods respectively).

Data and information on morphology of each water body and physiographic features of its watershed were also used along with the spectrum approach. The flushing rate, shoreline configuration, and vulnerability index are important parameters that warrant special consideration in characterizing a water body for cottage carrying capacity or development. The results of these three parameters are listed in Table 8.2 and shown in Figures 8.1 to 8.3 respectively.

Flushing rate (which is inverse of hydraulic residence time) is an important parameter for the following reasons: (1) It can act as an indicator of the degree of fluctuation in the level of water of a lake or pond. Water bodies with high flushing rates can undergo significant changes from normal water levels to high water mark conditions and flood cottages or cause septic systems to fail. Cottage development planning around water bodies with high flushing rates should take appropriate measures to make certain that buffer zones are maintained between shore front property and high water mark; (2) Water bodies with high flushing rates will have a greater capacity to assimilate nutrients and other water quality parameters. The nutrients and other water pollutants entering the water body will have less effect on lake or pond processes.

Shoreline configuration is an important parameter for the following reasons: (1) It is an indicator of how productive the water body is in terms of nutrients. Lakes or ponds with high shoreline configuration are generally more sensitive to nutrient loading than water bodies with low shoreline configuration because of a higher number of

TABLE 8.2 FLUSHING RATE, SHORELINE CONFIGURATION AND VULNERABILITY INDEX

Water Body	Flushing Rate (times per year)	Shoreline Configuration Shoreline Length/ Circum. of a Circle	Vulnerability Index (Range 5-15)
Tors Cove Pond	12.5	2.97	12
Hell Hill Pond	2.4	2.57	12
Cape Broyle Pond	10.7	4.27	11
Old Mans Pond	2.2	3.57	12
Nine Island Pond	0.9	3.15	11
Goulds Pond	1.5	3.98	12
Hawcos Pond	2.2	7.90	12
Middle Gull Pond	0.6	5.63	11
Grand Pond	2.5	5.26	12
Ocean Pond	1.7	6.66	12
Dennys Pond	6.4	3.38	12
Peak Pond	6.8	3.20	12
Junction Pond	18.3	3.32	12
Thorburn Lake	0.6	3.64	11
Georges Pond	0.6	2.66	11
Lady Pond	0.6	3.55	11
Shoal H. Pond	1.5	2.31	12
Freshwater Pond	1.3	1.89	9
Garnish Pond	22.2	3.77	12
Salmonier Pond	2.1	3.57	12

FIGURE 8.1 FLUSHING RATE OF LAKES/PONDS

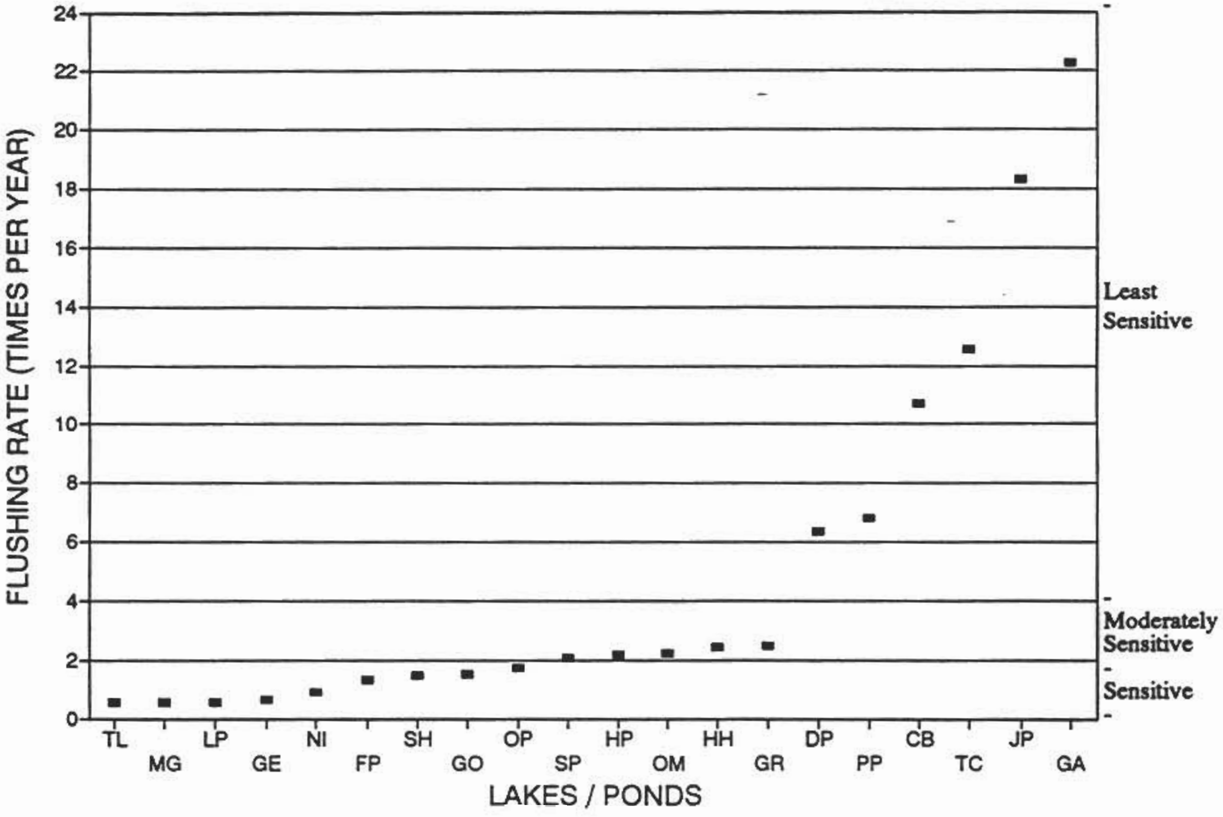


FIGURE 8.2 SHORELINE CONFIGURATION OF LAKES / PONDS

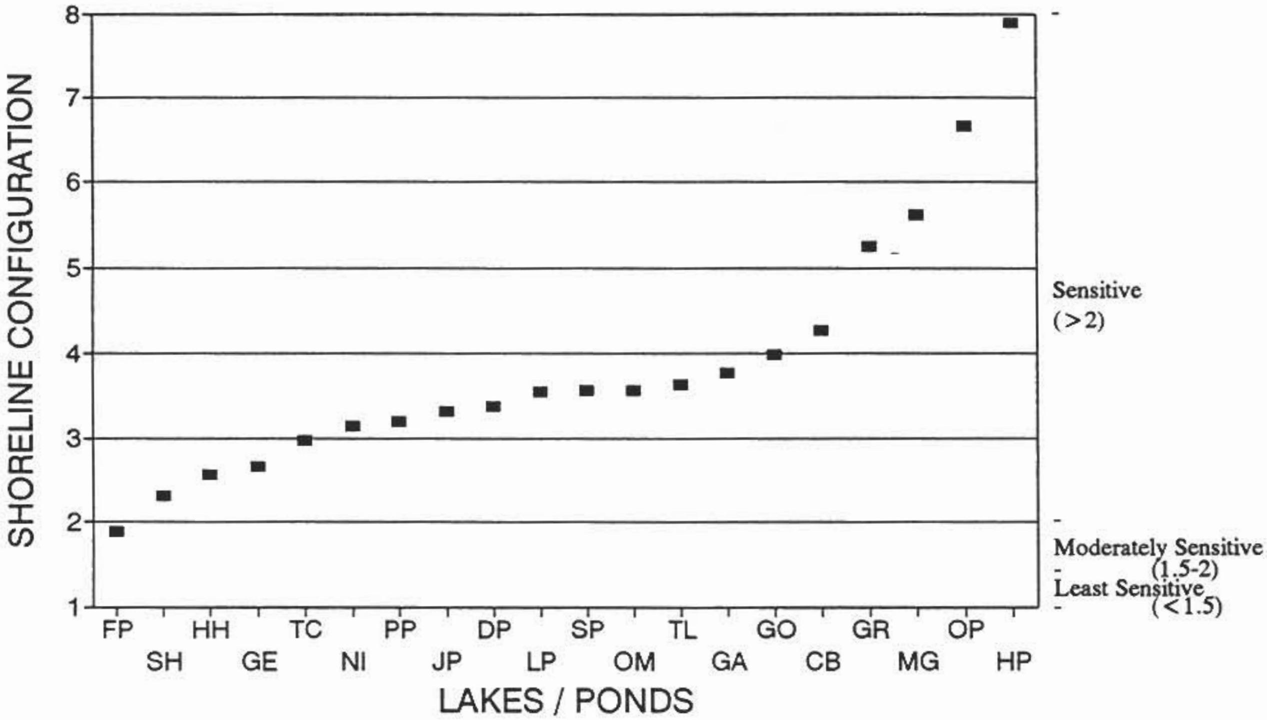
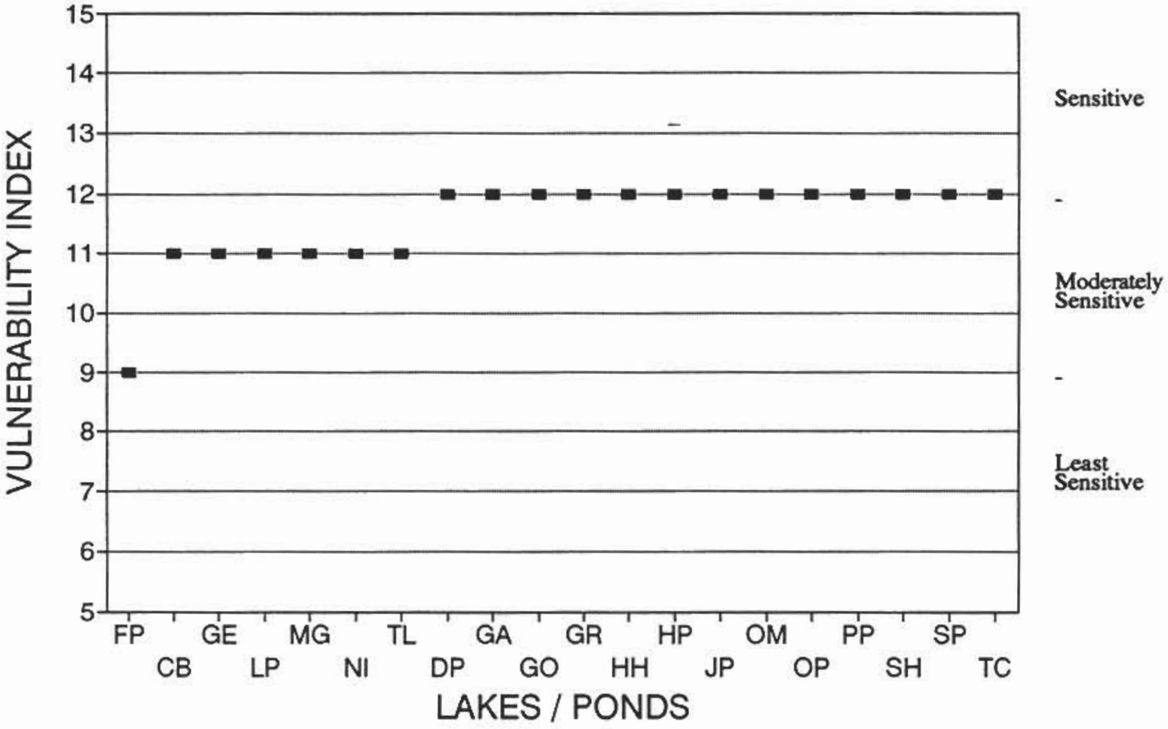


FIGURE 8.3 VULNERABILITY INDEX OF LAKES / PONDS



shallow bays. Shallow bays are more productive than open water areas and, therefore, more sensitive to development; and (2) Shorelines that are highly irregular can affect the predicted carrying capacity estimates based on the Natural Shoreline Reserve, Shoreline Capability, and Boat Density methods. The carrying capacity of a lake or pond determined by using these methods under irregular shoreline conditions will depend on the measurement of shoreline length for the Natural Shoreline Reserve and Shoreline Capability methods and water body area for the Boat Density method. Caution should be exercised and a lower carrying capacity value should be adopted in the above mentioned cases. The perimeter of shoreline is one of the main parameters for determining cottage carrying capacity using the Natural Shoreline Reserve and Shoreline Development methods. It is recommended that irregular shoreline features should be excluded from cottage lot planning in such cases. Another reason for this exclusion is the minimum required distance between shoreline frontage property and the high water mark of a water body is usually measured with straight lines and right angles not following irregular shoreline features. In the boat density method case under irregular shoreline conditions the actual boating space can be much less than 75% of the gross acreage of the water body. The area to be reserved as buffer zone for shoreline protection and public safety may not be sufficient to sustain the amount of boating pressure predicted by this method. It is, therefore, important to consider irregular features of a water body in determining the area available for boating.

The vulnerability index of a water body is another important consideration for determining sensitivity of a lake/pond to eutrophication. Sargent (1976) recommended a scale based on morphology and inflow and outflow patterns of a water body to define its vulnerability. Sargent's Lake Vulnerability index is described in Section 2.4.2. The Lake Vulnerability index ranges from 5 to 15 with the higher the index number indicating increasing sensitivity of a water body to eutrophication.

The data listed in Table 8.2 was plotted in ascending order in Figures 8.1 to 8.3 to show the flushing rate, shoreline configuration and vulnerability index respectively of the 20 selected water bodies. As shown in Figure 8.1, water bodies with flushing rates of less than one per year are sensitive to eutrophication and pollutants. Five water bodies are in this category including: Thorburn Lake, Middle Gull Pond, Lady Pond, Georges Pond and Nine Island Pond. Nine water bodies have flushing rates of between 1 and 4 times per year and are moderately sensitive to pollutants and eutrophication. Water bodies with flushing rates four times a year or greater are least sensitive to eutrophication and pollutants. Six water bodies had flushing rates greater than 4 times per year with Garnish Pond having the highest flushing rate of 22 times per year.

The shoreline configuration of the 20 water bodies as shown in Figure 8.2 is one of five components that make up the vulnerability index to eutrophication. As mentioned above, shoreline configuration is an important consideration when using the natural shoreline reserve, shoreline capability or boat density methods to determine cottage carrying capacity. The higher the shoreline configuration ratio is the more irregular the shoreline will be. With high shoreline configuration values, it is most likely that cottage carrying capacity will be overestimated by the above mentioned methods. Sargent classified lakes or ponds with shoreline configuration values of greater than 2.0 to be sensitive. Nineteen water bodies as shown in Figure 8.2 have shoreline configuration values greater than 2 and are considered sensitive. Only one water body (Freshwater Pond) was in the moderately sensitive range and had a shoreline configuration value of 1.89. There were no water bodies with a shoreline configuration value of less than 1.5 and classified as being least sensitive according to Sargent's vulnerability index.

The vulnerability index of the 20 selected water bodies is shown in Figure 8.3. Water bodies with a vulnerability index value of nine or less were classified as being least sensitive to eutrophication, 9 to 12 as being moderately sensitive and greater than 12 being sensitive to eutrophication. Only one water body Freshwater Pond as shown in Figure 8.3 had a vulnerability index value of nine or less and is least sensitive to eutrophication. The remainder of the water bodies have vulnerability index values of 11 and 12. Thirteen water bodies are at the upper limit of the moderately sensitive range and lower limit of the sensitive range (vulnerability index value of 12) and are more susceptible to eutrophication than the other water bodies.

In each cottage carrying capacity method, the same standards (i.e. buffer zone size, area to be reserved for public use, etc.) were used to determine the carrying capacity of each lake or pond. In order to compare the results of a particular method the same standards had to be maintained for all lakes and ponds. In actual practice these standards may change from lake to lake depending on the sensitivity of a lake and the development objectives.

The results of the carrying capacity methods (Table 8.1) to be used in the spectrum analysis are shown in Figures 8.4 to 8.8. The 20 selected lakes and ponds were divided into five geographical zones for comparison purposes. Water bodies located close to each other are more likely to have similar geology, topography, rainfall, runoff and cottage development pressure. The following geographical groupings were made of the selected lakes and ponds:

1. Southern Shore Area (Figure 8.4) - Tors Cove Pond (TC), Hell Hill Pond (HH) and Cape Broyle Pond (CB).
2. Central Avalon Area (Figure 8.5) - Old Mans Pond (OM), Nine Island Pond (NI), Goulds Pond (GO), Hawcos Pond (HA), Middle Gull Pond (MG), Grand Pond (GR) and Ocean Pond (OP).
3. Western Avalon Area (Figure 8.6) - Dennys Pond (DE), Peak Pond (PE) and Junction Pond (JU).
4. Burin Peninsula Area (Figure 8.7) - Freshwater Pond (FR), Garnish Pond (GA) and Salmonier Pond (SA).
5. Clarenville Area (Figure 8.8) - Thorburn Lake (TH), Georges Pond (GE), Lady Pond (LA) and Shoal Harbour Pond.

In the Southern Shore area, Figure 8.4, Tors Cove and Cape Broyle Ponds have experienced a significant level of cottage development while Hell Hill Pond has only nine cottages. All methods indicate that Tors Cove and Cape Broyle Ponds are over developed and no future development should be permitted in these two areas. For Tors Cove Pond, the existing number of cottages are 243 while the Trophic State Approach

FIGURE 8.4 SPECTRUM APPROACH
SOUTHERN SHORE AREA

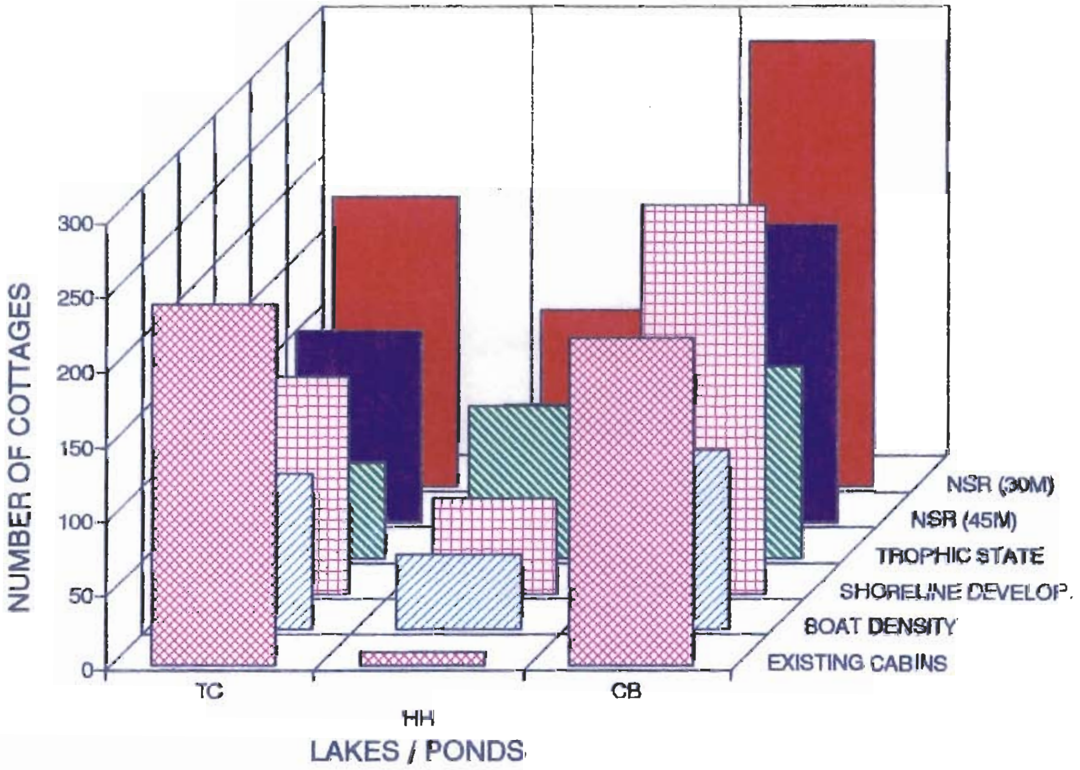


FIGURE 8.5 SPECTRUM APPROACH
CENTRAL AVALON AREA

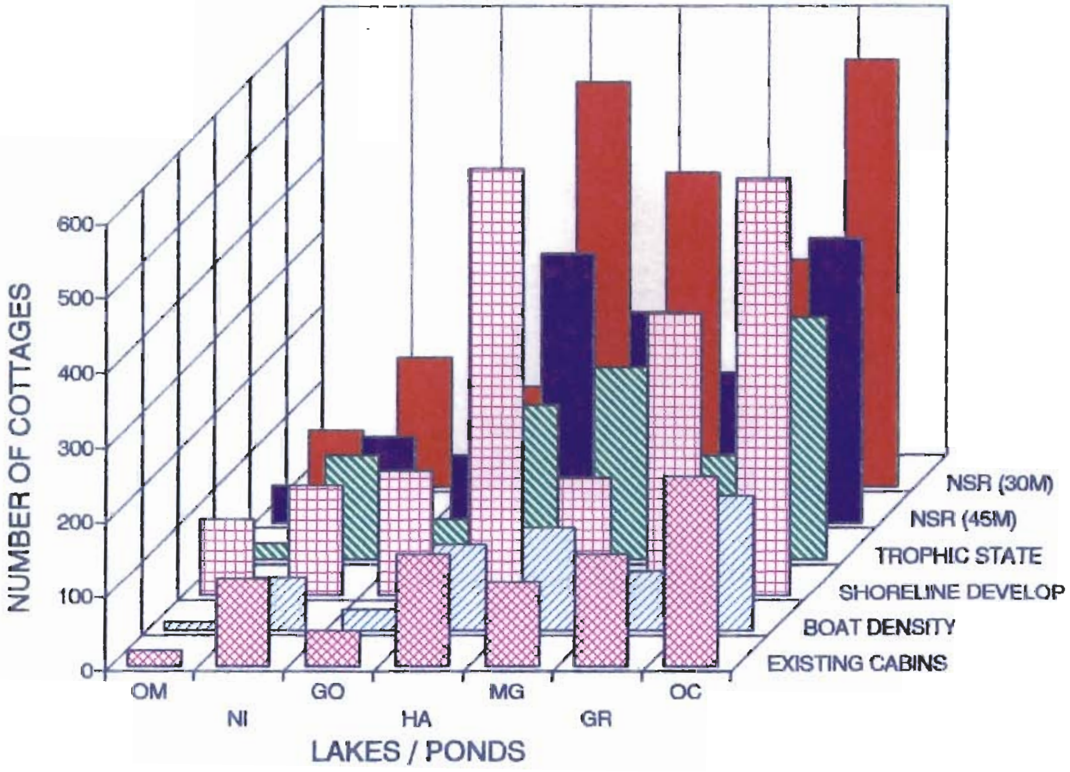


FIGURE 8.6 SPECTRUM APPROACH
WESTERN AVALON AREA

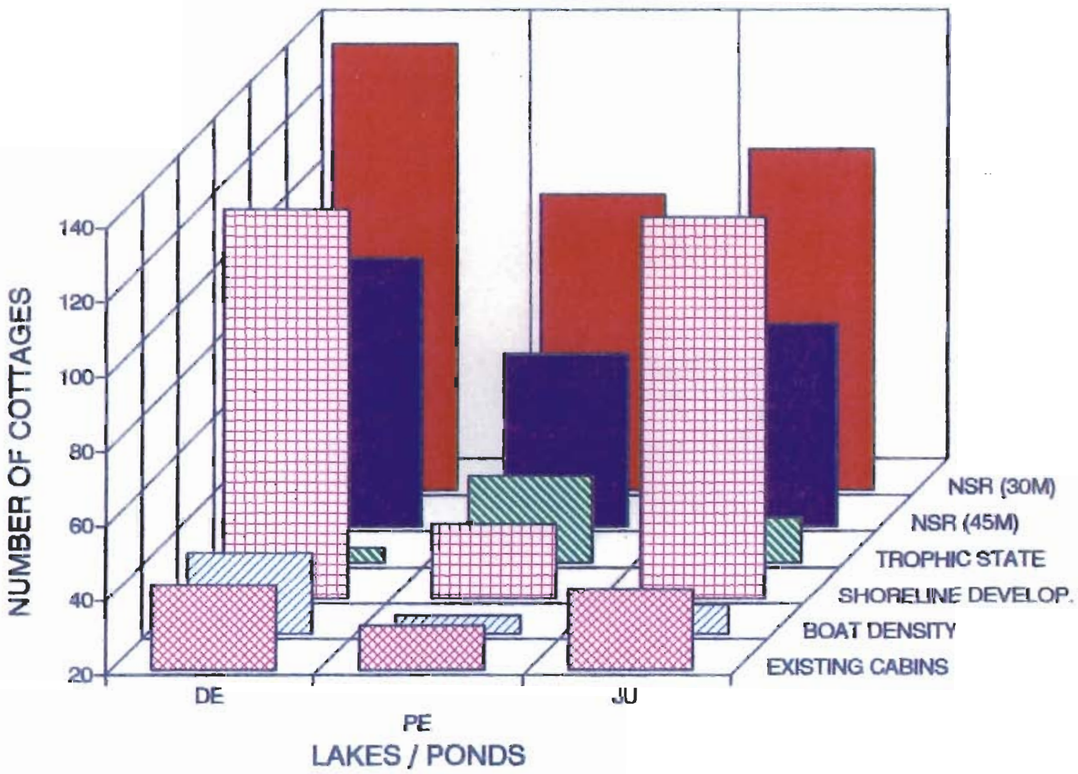


FIGURE 8.7 SPECTRUM APPROACH
CLARENVILLE AREA

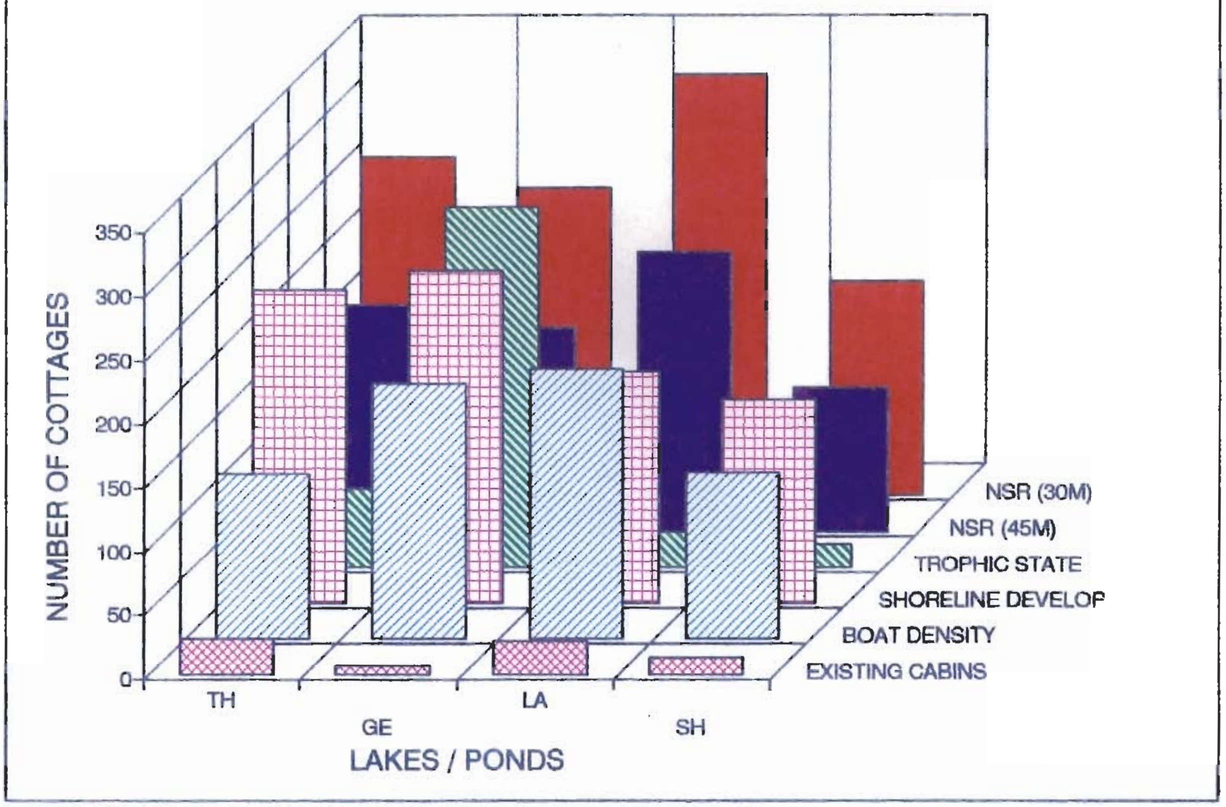
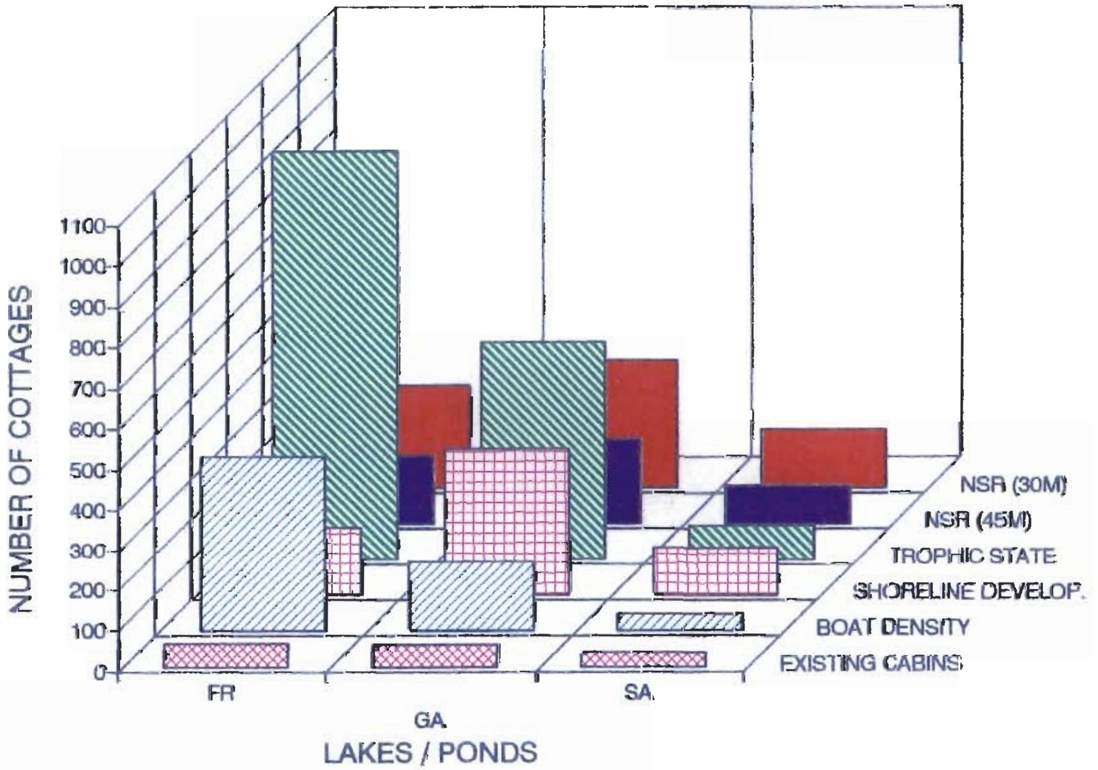


FIGURE 8.8 SPECTRUM APPROACH
BURIN PENINSULA AREA



recommends only 64. A similar type of situation exists in Cape Broyle Pond where the existing number of cottages are 220 and the recommended level of development according to the Boat Density Approach is 121. Hell Hill Pond can sustain additional development and optimum recommended level of development according to the Boat Density Approach is 51.

In the Central Avalon area, Figure 8.5, Old Mans Pond was found as having a cottage carrying capacity of only 11 cabins according to the Boat Density approach, the most restrictive cottage carrying method for Old Mans Pond. Presently, the number of existing cabins on Old Mans Pond has exceeded this capacity by 10 cabins. Nine Island Pond has 47 more cabins within its watershed than the carrying capacity determined by the Boat Density Method. The Boat Density Method predicted the lowest carrying capacity (73 cabins) of the five methods. The carrying capacity of Hawcos Pond is 116 cabins as determined by the boat density approach. There are presently 151 cabins on Hawcos Pond which exceeds the carrying capacity by 35 cabins. All five cottage carrying capacity methods indicate that Middle Gull Pond can support additional cottage development. According to the Boat Density method (138 cabins) another 23 cabins can be supported by Middle Gull Pond before its carrying capacity is reached. Grand Pond is overdeveloped by 69 cabins and the limiting carrying capacity method, the Boat Density approach will support only 82 cabins. The carrying capacity of Ocean Pond is 182 cabins as determined by the Boat Density approach, the limiting carrying capacity method. There are 256 cabins around Ocean Pond which exceeds the carrying capacity determined by the boat density approach by 74 cabins. In most of these cases, the boat density approach recommended the lowest level of cottage development which is due to a relatively small surface area available for boating.

Three water bodies (Peak Pond, Dennys Pond and Junction Pond) were selected for the study in the Eastern Avalon area. There are 43 cabins located around Dennys Pond as shown in Figure 8.6. The trophic state method is the most restrictive cottage carrying capacity method with a carrying capacity of 24 cabins. Peak Pond, like Dennys Pond, has already reached its carrying capacity. There are presently 32 cabins located around Peak Pond and the carrying capacity as determined by the boat density method is 25 cabins. Junction Pond is presently overdeveloped as determined by the boat density method which will support only 28 cabins as compared to 42 cabins which are now located on the Pond.

As shown in Figure 8.7, there are 58 cabins around Freshwater Pond. The cottage carrying capacity of Freshwater Pond is 166 cabins as determined by the Natural Shoreline Reserve and Shoreline Development methods. Garnish Pond like Freshwater Pond can also sustain additional cottage development. There are presently 54 cabins on Garnish Pond and the limiting method the Boat Density Approach recommends a carrying capacity of up to 171 cabins. Cottage development at Salmonier Pond has reached its carrying capacity. The boat density method predicts a carrying capacity of 40 cabins and there are presently 36 cabins within Salmonier Pond's watershed.

In Figure 8.8 the cottage carrying capacity methods indicate that Thorburn Lake can sustain additional cottage development. There are presently 28 cabins on Thorburn

Lake. The restrictive carrying capacity method is the Trophic State approach with a carrying capacity of 61 cabins. All five carrying capacity methods indicate that additional cottage development can be sustained at Georges Pond which at present only has 6 cottages. The carrying capacity of Georges Pond is 159 cabins according to the Natural Shoreline Reserve method based on 45m lot width size. Lady Pond is also under developed according to the results of the five cottage carrying capacity methods. There are presently only 26 cabins on Lady Pond. The limiting carrying capacity method is the trophic state method with a carrying capacity of 28 cabins, however, the Shoreline Development approach, the next limiting method, has a recommended carrying capacity of up to 181 cabins. Shoal Harbour Pond like Lady Pond is also underdeveloped as shown by Figure 8.8. There are 13 cabins within the Shoal Harbour Pond watershed. The Trophic State Approach recommends a carrying capacity of 18 cabins and the next limiting method the Natural Shoreline Reserve method based on 45m lot width size recommends 112 cabins.

The cottage carrying capacity of each water body is listed in Appendix G along with additional development, features of the water body, range of development level choices provided by the spectrum analysis, lake vulnerability index, existing development, present trophic status of the water body, and the reasons why the selected level of development was chosen.

The carrying capacity of the selected lakes and ponds was determined by using the Spectrum Approach and the carrying capacity methods according to the recommendations provided in Section 8.3 *"Summary of Cottage Carrying Capacity Methods"*. Final cottage carrying capacity numbers were determined by reviewing selected parameters related to the water body and any additional information that may affect the cottage carrying capacity and be more of a limiting factor to cottage development than the selected methods.

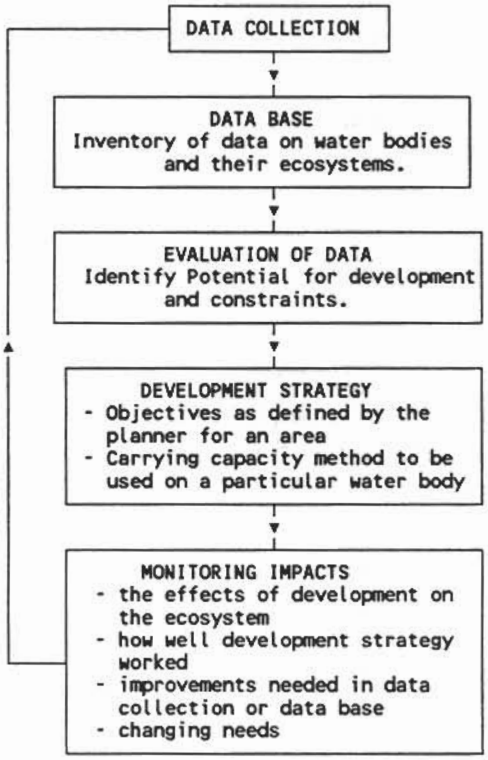
The results obtained through spectrum analysis shows a range of development options. As mentioned earlier, there are limitations in the scope of the methods and these will be reflected in the end results of carrying capacity. To overcome these limitations and environmental related problems, it is recommended that spectrum analysis results be studied along with other site specific information such as topography, soil characteristics, access to the area and other physical features before a final decision is made regarding the number of cottages a water body can support.

9.0 FUTURE COTTAGE PLANNING STRATEGIES

9.1 Cottage Development Planning Process

This section is intended to be an aid to planners in planning cottage development that will create and maintain a desirable environment while promoting health, safety, welfare, recreation and convenience. In order to effectively manage cottage development much time and effort must go in to the planning process. Unguided development has the potential to degrade the environment and destroy our limited natural resources. Based on the results of this study a general guideline for a cottage planning process is outlined in Figure 9.1 and discussed in subsequent paragraphs of this chapter.

FIGURE 9.1 THE COTTAGE DEVELOPMENT PLANNING PROCESS



As shown in Figure 9.1, the planning process consists of five main components: (1) data collection, (2) data storage, retrieval and processing, (3) data analysis and evaluation, (4) development strategy and (5) Monitoring impacts. Among all these components, data analysis and evaluation are most important for successful cottage planning and development.

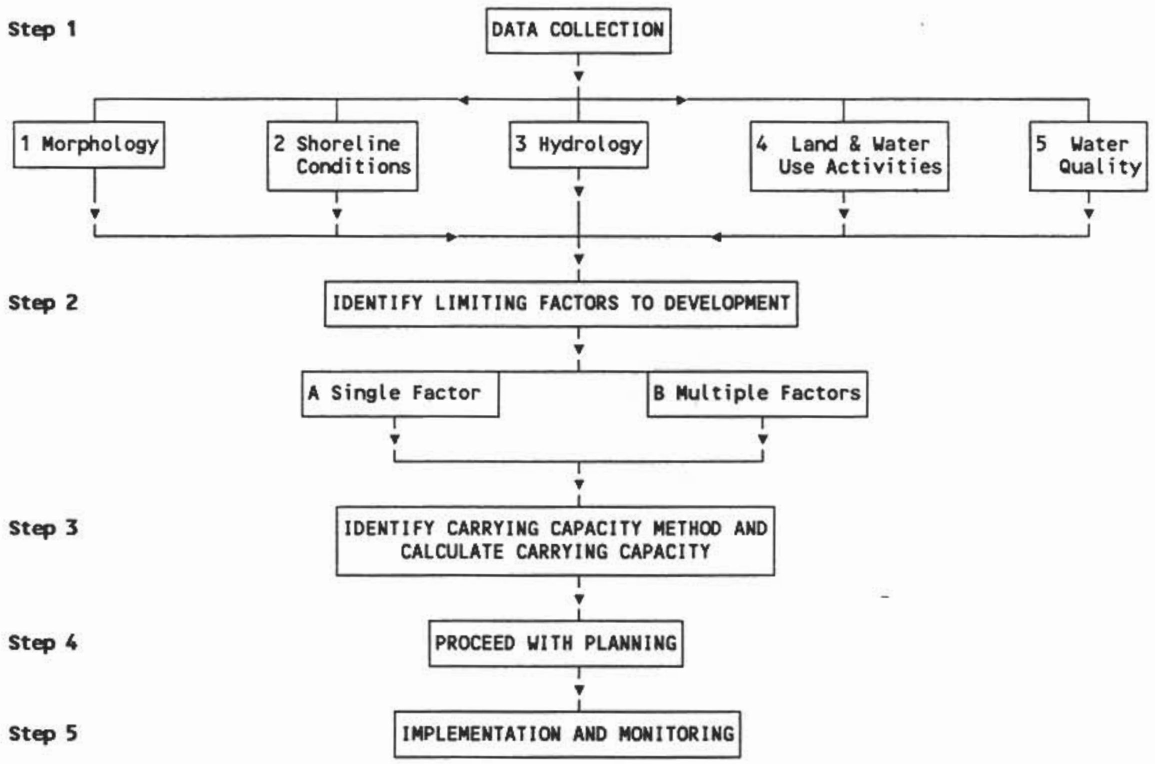
The first step identified in the planning process is data collection. Data collection requires gathering all of the necessary information upon which future decisions on cottage development will depend. Secondly, the data must be stored in a format so that it can be easily assessed and utilized. This can best be accomplished using a data base management system. The method of data storage and retrieval will determine how easily the data can be analyzed and interpreted and the types of analysis and interpretation that can be performed. The next step in cottage development planning is to evaluate the data. The development potential of an area is generally determined at this stage. The development potential of an area and other relevant site specific data are then used in planning and implementing a development strategy for the area. Cottage development in an area will mainly be governed by topographic features, soil characteristics, existing and future water and land use activities and their impacts on water quality. In sensitive areas development can be restricted and like wise in non-sensitive areas where there is a high demand for cottages more emphasis can be placed on sustainable development. The cottage carrying capacity method identified in the data evaluation stage can be modified to meet the site specific conditions and constraints. Finally, a monitoring program should be put in place to determine the effects of cottage development on the ecosystem. The monitoring program should also assess the validity of methods used to determine the level of development, the types of data that need to be collected and the performance of the data base. The data collected and information obtained through the monitoring program will help in improving the planning process for future cottage development.

As discussed in earlier paragraphs, the cottage carrying capacity of a water body is important for both recreational enjoyment and maintaining the ecosystem. Defined limits of cottage carrying capacity are needed so that the recreational benefits of a water body can be utilized and the water bodies' ecosystem maintained at an acceptable and sustainable level. If the cottage carrying capacity is not determined or managed in an appropriate way and development is allowed to continue in an unregulated manner then the ecosystem will deteriorate and normal lake processes will no longer continue. The recreational benefits derived from the water body will also decline. In view of this, it is recommended that guidelines outlined in subsequent sections be adopted to determine the cottage carrying capacity of a water body for future cottage development planning purposes.

9.2 Cottage Carrying Capacity Guidelines

Figure 9.2 shows a schematic diagram to determine the cottage carrying capacity of a water body. The steps and guidelines to be followed are also described.

FIGURE 9.2 COTTAGE DEVELOPMENT PLANNING IN NEWFOUNDLAND



9.2.1 Data Collection and Preliminary Analysis

1. The first step identified in Figure 9.2 for determining cottage carrying capacity is the collection of data. Data will be needed in the following areas: (1) Morphology, (2) Shoreline Conditions, (3) Hydrology, (4) Land and Water Use Activities, and (5) Water Quality to evaluate the cottage development potential of an area. The data required from the five categories listed above is as follows:

Morphology - surface area, flushing rate, inflow and outflow pattern, depth and sensitivity index.
Shoreline - shape factor or shoreline configuration, slope, geology, physiography, soil type and drainage.
Hydrology - sensitivity to rainfall, variations in water table and watershed area.
Land and Water Use Activities - Extent and nature of different water and land use activities occurring in the watershed, and fishing activity including scheduled salmon rivers.
Water Quality - secci disc depth, summer time chlorophyll a, and spring time total phosphorus. Data will also be needed to determine if the water quality meets the Canadian Water Quality Guidelines for various water uses.

The above list includes most of the data needed to characterize a water body and to apply the cottage carrying capacity methods reviewed in this report. The lake vulnerability index, shoreline configuration and flushing rate are particularly important to help determine the carrying capacity. The information required for estimating these parameters can easily be gathered and applied to any cottage carrying capacity study regardless of its scope. The importance of these parameters has been discussed in Section 8.4 *"Application of Selected Carrying Capacity Methods"*.

While the above mentioned data is all that may be needed in most cases to determine the carrying capacity of a water body, additional information may be required depending on the water body and the activities taking place within the watershed. For example, lake's or pond's with part of their shoreline belonging to other stakeholders such as parks, will require additional information on the number of park users who participate in water related activities. The recreation demands by non-cottage owners in parks can be much higher than water bodies not located in parks. This information will be necessary to evaluate the water bodies potential to sustain additional use by non-cottage owners and cottage development.

Information on water quality is required before the carrying capacity can be assessed. The water quality of a lake or pond should meet the limits set by the *Canadian Water Quality Guidelines* for various intended uses. Specifically, cottage development around a water body should meet the Canadian Water Quality Guidelines for: (1) Recreation and (2) Freshwater Aquatic Life. In addition to this the trophic status of a water body should also be assessed. Data should be gathered on summer time chlorophyll a, spring time total phosphorus concentration and secci disc depth. The water quality parameters should meet the following guidelines: chlorophyll a $> = 2.00$ (mg/m^3), total phosphorus $< = 10$ ($\mu g/l$) and secci disc depth > 5 (m) as defined in Chapter 2 *"Lake Trophic State"*. If water quality does not meet the above recommended guidelines, then cottage development should either not be allowed to proceed or restricted depending on the water quality conditions. The level of development will largely depend on the extent of water quality problems and the potential impacts of the proposed development.

2. After the required data has been gathered, then the factors which will limit cottage development should be identified. The limiting factors to cottage development will determine the maximum level of cottage development the water body can support.

3. A sample data sheet to compile preliminary information to assess the cottage development potential of a water body is attached in Appendix H. The information will be useful for preliminary analysis of the area and in selecting the appropriate cottage carrying capacity method.

9.2.2 Selection of Cottage Carrying Capacity Method

In the following paragraphs, the main limiting factors to cottage development will be identified and the approaches that can be adopted based on these limiting factors will be outlined. There can be (A) single factor or (B) multiple factors against cottage development as shown in Figure 9.2.

A. Single Factor

Single factor against cottage development is a factor (example water body size, length of shoreline, soil type, flushing rate, site access, physical features of the site) that will limit cottage development based on their use with the appropriate cottage carrying capacity method. The following is a list of single factors that will limit cottage development and a choice carrying capacity method that can be used to determine the level of cottage development:

(i) Size of Water Body:

The boat density method is recommended for use with water bodies whose surface area is less than 100 hectares. The boat density method in such cases (surface area less than 100 hectares) will provide a conservative cottage carrying capacity estimate.

(ii) Shoreline Features:

If detailed mapping has been completed and the shoreline conditions (soil types, topography or drainage pattern) up to a distance of 200-300m from the high water mark cannot sustain functional septic systems, then the shoreline capability method is recommended for use to determine a conservative cottage carrying capacity estimate for the water body. Functional septic systems require shore land length ranked as cottage capability Class 1 or 2 (see Chapter 4 *"Shoreline Capability Method"*). Shore land length ranked as cottage capability Class 3 or 4 is considered unfit for development and includes soils that are poorly drained or a combination of soil type and slope conditions that rank as poor or very poor on the cottage capability classification scale index.

(iii) Flushing Rate and Water Quality:

Water bodies with a low flushing rate (less than one per year), small out flow and/or high sensitivity index (twelve or greater) may be susceptible to water quality degradation as a result of cottage development. The trophic state method can be used under these circumstances since water quality is the limiting factor to cottage development. The trophic state method, however, may be difficult to apply because of the extensive data collection required (see Section 8.3 *"Trophic State Method Limitations"*). In such cases (low flushing rate, small outflow and/or high sensitivity index) water quality data should be collected and used according to the guidelines provided earlier in this section. The decisions on cottage carrying capacity can be made by using methods other than the trophic state method, which give the lowest level of cottage development.

(iv) Angling Pressure:

The sports fisheries approach can be adopted when angling pressure on a water body is a concern. The sports fisheries method was not reviewed in this report extensively enough for implementation due to insufficient data and should be studied further before being used to predict cottage carrying capacity.

(v) Shoreline Configuration:

For water bodies that are large in size and have a low shoreline configuration ratio (< =1.5), the Natural Shoreline Reserve method can be the most limiting cottage carrying capacity method.

B. Multiple Factors

In some cases, there may be more than one factor which may potentially limit the number of cottages. For example, agricultural development in the watershed of a small size pond has potential to create water quality problems which may limit cottage development. In such cases, where size is a limiting factor, potential water quality impacts of agricultural activities must also be considered. Conservative estimates can be made by selecting a lower level of development (either less cottages or more area to be reserved for the general public) than that predicted by the most limiting cottage carrying capacity method. There is no one formula in such cases which can predict the sustainable level of development of a water body. The spectrum approach (using all of the cottage carrying capacity methods) which provides a range of development can be a useful tool to planners in this situation.

It is recommended that estimates of the carrying capacity should be lower than that predicted by the most limiting carrying capacity method in the following cases:

(i) If land use activities within a watershed have the potential to degrade water quality. For example, extensive forest harvesting, mining or agriculture within a watershed can degrade water quality of a lake or pond with increased sediment and nutrients loadings. Increased sediment and nutrients loadings could change the trophic status of a water body and its recreation potential for swimming and fisheries.

(ii) If the soil conditions (slope and/or soil type) are not adequate for septic systems or the septic systems of existing cottage owners are not built to appropriate standards then water quality problems can occur. This problem would be of particular concern in cases where the water body has a low flushing rate or high sensitivity index. The most common reasons for water quality degradation as a result of septic systems are: (1) Proper buffer zone distances are not maintained between the septic system and the water bodies high water mark; (2) The septic system is located too close to or within the high water mark of a water body; and (3) The septic system is not built to the appropriate standards.

(iii) If existing uses of a water body warrant special consideration. Examples of this include: (1) Water bodies that are being used as popular swimming areas. In such areas the recreational demands placed on the water body can be quite considerable. The maintenance of water quality in these areas is very important for health related reasons. An increase in the number of cottages could further degrade the water quality to a point where it will no longer be safe for swimming; and (2) Fisheries spawning areas (particularly salmon) and waterfowl breeding grounds. Water quality degradation as a result of cottage development may not be acceptable in such areas.

9.2.3 Implementation and Monitoring

Once an appropriate level of cottage development has been determined, then the next step is to implement the planned level of development and undertake a water quality monitoring program. The implementation phase of the development should ensure that cottage development is according to the specified plan and cottage owners have obtained appropriate approvals from all the relevant government departments. It should also ensure that stipulations attached to certificates of approval are complied with. Upon the completion of the planned development, a water quality monitoring program should be established. The water samples should be analyzed for physical parameters, major nutrients and bacteria. The main objective of this monitoring program will be to ensure that water quality is within recommended guidelines and it is fit for recreational activities and other desired uses.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

The conclusions drawn from this study are as follows:

1. The available cottage carrying capacity methods are based on a single factors to determine sustainable levels of cottage development. However, this study has revealed that multiple factors are the most common constraints to cottage development in this province. This makes the cottage development planning process more complex and requires careful integration of all factors in the planning process.

2. There is no single cottage carrying capacity method which can be adopted across the province. The selection of a carrying capacity method for a particular area will depend on site specific conditions, availability of data and constraints to cottage development.

3. The cottage carrying capacity results obtained using various available methods are highly variable and planning based on a single method could lead to an inappropriate level of development.

4. All of the available cottage carrying capacity methods were developed in Ontario, Saskatchewan or other parts of the world where land use and cultural practices, morphological, hydrological and overburden characteristics are quite different from Newfoundland. For this reason, the assumptions used in the formulation of cottage carrying capacity methods are not realistic for Newfoundland conditions. Accordingly, a new set of assumptions, reflecting land use and cultural practices, morphological, hydrological and overburden characteristics of Newfoundland were formulated and used in the spectrum analysis approach.

5. In areas with multiple constraints to cottage development, the application of spectrum analysis will give the planner a range of development potential which in turn will assist the planner in selecting the appropriate level of development.

6. The accuracy of carrying capacity results is highly dependent on the availability and reliability of the required input data. The available database on background nutrient levels and trophic status of a water body, morphological and hydrological characteristics of a water body, physio-graphic characteristics of the watershed, shoreline conditions and capability, per capita use of cottages, etc. was found to be inadequate.

7. The present cottage planning in Newfoundland is based on either the size of a water body or the perimeter of shoreline. The other parameters such as shoreline capability, water quality, vulnerability index, other existing land and water uses are not considered. In addition to this, the assumptions used in cottage planning

are similar to the one used in Ontario and Saskatchewan. This could lead to an inappropriate level of development and other associated environmental problems.

8. The application of spectrum analysis approach to selected recreational water bodies in Newfoundland indicate that eight of the water bodies are under-developed (Hell Hill, Middle Gull, Thorburn, Georges, Lady, Shoal Harbour, Freshwater and Garnish Ponds), three were at carrying capacity or very close to it (Dennys, Peak and Salmonier Ponds) and nine overdeveloped (Tors Cove, Cape Broyle, Old Mans, Nine Island, Goulds, Hawcos, Grand, Ocean and Junction Ponds).

9. Water bodies with a high flushing rate (>10) and a low vulnerability index (<9) will be least sensitive to development and will have greater capacity to assimilate nutrient loading and other water quality parameters while water bodies with a low flushing rate (<2) and a high vulnerability index (>12) will be most sensitive to development.

10. Water bodies with high shoreline configuration ratio (>1.5) will be more sensitive to nutrient loading because of a number of shallow bays. The shoreline configuration ratio is a direct indication of the shape of the shoreline. The higher the shoreline configuration ratio, the more irregular the shoreline will be.

10.2 Recommendations

In order to improve the planning process and effectively manage the cottage development and to create and maintain a desirable environment while promoting health, safety, welfare, recreation and convenience, the following recommendations need to be implemented:

1. The water bodies with recreational potential are under intense pressure for recreational development should be identified across the province. The Land Use Management or Crown Lands Divisions may wish to undertake this inventory through their regional staff members.

2. A database management system with attributes such as surface area, depth, shoreline length, shoreline configuration, drainage area, topography, shoreline conditions in terms of overburden, drainage pattern, existing land uses, etc. should be developed. The system should be as comprehensive as possible. The data collection and compilation can be grouped into two phases: (i) the first phase should cover those water bodies which are under intense pressure for recreational development or active planning, and (ii) the second phase should deal with those which are considered as potential recreational water bodies. The Water Resources Management Division is willing to provide limited support in the design of such a database management system.

3. The Department should take immediate steps to appoint an interdepartmental committee comprising of representatives from the Land Use Management

Division, Crown Lands Division, Water Resources Management Division, Civil/Sanitary Engineering Division, Public Health Inspection Unit of the Department of Health and Federal/Provincial Fisheries. The committee should be responsible to review the future cottage development proposals and provide all the necessary information relating to their respective mandate. For example: Public Health Inspection and Civil/Sanitary Engineering Division members should check whether the soil conditions and drainage characteristics of the area proposed for development can support the proposed sewage disposal system. Similarly, the Water Resource Management Division should look into existing water uses of the proposed water body, hydrologic characteristics of the area, etc. and so on. This integrated approach will ensure successful cottage development and minimize environmental damage and land and water use conflict.

4. All water bodies proposed for cottage development should be monitored for spring time total phosphorus, summer time chlorophyll a and secci disc depth. The water body should be considered for development only if: (i) spring time total phosphorus $\leq$ 10.00 μg/l, (ii) summer time chlorophyll a $\leq$ 7.00 μg/l, and (iii) secci disc depth $\geq$ 2.00 metres.

5. Once a water body proposed for development meets the above criteria, then the Land Use Management Division should prepare a preliminary cottage development proposal, using the format presented in Appendix G for assessment and review by the Interdepartmental Committee.

6. If the review of the preliminary proposal by the Interdepartmental Committee identifies multiple factors as constraint to development, with no serious concerns of environmental impairment, then the Land Use Management Division should select the appropriate methods of cottage carrying capacity based on the preliminary analysis of data and prepare details of a cottage development plan according to the permitted optimum level of development. It is recommended that the spectrum analysis approach should be used if multiple factors are identified as constraint to development. The Water Resources Division is willing to provide a limited level of support in the cottage carrying capacity analysis.

7. The carrying capacity methods presently used by the Land Use Management Division should be replaced by the recommended methods.

8. The recommended assumptions relating to shoreline reserve, buffer zones, number of boats per cabin and area per boats, should be verified from the actual field data and revised in the future if the field data requires such revisions.

9. The areas which have been identified as overdeveloped or at capacity should immediately be frozen for future development and appropriate measures should be adopted to rectify the existing or potential problems.

10. The areas which have been identified as under developed should be monitored for parameters outlined in #4 prior to any future development.

11. If possible at any future time, efforts should be made to collect data on a number of non-cottage users, per capita year cabin use, actual number of boats at any peak time, phosphorous retention and export coefficients, etc. in selected areas across the province.

12. Appropriate measures should be adopted to ensure that actual cottage development is according to the prepared plan and in line with regulatory requirements of all concerned departments.

13. Steps should be taken to inform the general public on the importance of good cottage development practices. For example, manuals/brochures should be prepared as has been done in other provinces, like Ontario, to inform cottagers of common pollution problems that can result from poor building practices and other environmentally unfriendly behaviour. The Land Use Management Division should take a lead role in the preparation of such public information documents. The Water Resources Management Division is willing to cooperate with the Land Use Management Division in the preparation of such a brochure. Cottage owners should also be encouraged to take a more active role in ensuring that the quality of the environment is maintained. The onus should be placed on the users of the resource to see that it is maintained to acceptable standards.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Banfield, C.E., 1981. *The Climatic Environment of Newfoundland.* Natural Environment of Newfoundland, Past and Present, A.G. and J.C. Macpherson, (eds.), Department of Geography, Memorial University of Newfoundland, pp 83-153.

2. Canada-Newfoundland Flood Damage Reduction Program, 1984. *Regional Flood Frequency Analysis for the Island of Newfoundland.* Government of Newfoundland and Labrador, Water Resources Division, Department of Environment and Inland Water Directorate, Environment Canada.

3. Canadian Council of Resource and Environment Ministers, 1987. *Canadian Water Quality Guidelines.* Prepared by the Task Force on Water Quality Guidelines.

4. Dillon, P.J. and Vollenweider, R.A., 1974. *The Application of the Phosphorus Loading Concept to Eutrophication Research.* NRC Associate Committee on Scientific Criteria for Environmental Quality, Environment Canada, Burlington, Ontario.

5. Ecologistics Limited, 1976. *A Study of Land and Water use at Emma and Christopher Lakes.* Saskatchewan, pp 159.

6. Environment Canada, 1982. *Canadian Climate Normals, Volume 3, Precipitation 1951-1980.* Atmospheric Environment Service.

6a. Environment Canada, 1990. *Surface Water Data Atlantic Provinces, 1989.* Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa, Canada.

7. French, Richard H., 1984. *Lake Modelling: State of the Art.* Water Resource Center, Desert Research Institute, Las Vegas, Nevada, CRC Reviews in Environmental Control, Volume 13, Issue 4, pp 311-357.

8. Goulding, Ron, 1989. *A Study on the Effects of Cabin Development on Surface Water Quality of Freshwater Pond and Garnish Pond.* Government of Newfoundland and Labrador, Department of Environment and Lands, Water Resources Division.

9. *Guideline for Land Use Planning.* (MNR, LUCB, Draft 1978).

10. Jaakson, Reiner. *A Spectrum Model of Lake Recreation Carrying Capacity Estimation.* Department of Urban and Regional Planning, University of Toronto, pp 83.

BIBLIOGRAPHY (Cont'd)

10a. Jaakson, Reiner, 1970. *Planning for the Capacity of Lakes to Accommodate Water Oriented Recreation*. Plan: Vol. 10, no. 3.

11. Jamieson, A., 1974. *A Water Quality Atlas for Streams and Lakes of Insular Newfoundland*. Resource Development Branch, Newfoundland Region, Fisheries and Marine Service, St. John's, Newfoundland.

11a. Jamieson, A., 1974. *Results of Water Analysis on Selected Streams and Lakes of Newfoundland and Labrador, 1972-1973*. Resource Development Branch, Newfoundland Region, Fisheries and Marine Service, Department of the Environment, St. John's, Newfoundland.

12. Manitoba Department of Municipal Affairs, 1976. *Shore land Recreation: An Environmental Approach to Development*. Municipal Planning Branch, Planning Guide No. 2, pp 46.

13. Newfoundland Department of Forestry and Agriculture. *Recreation Cottage Planning Guidelines*. Land Management Division, Government of Newfoundland and Labrador.

14. Ontario Ministry of Municipal Affairs and Housing, 1982. *Lakeshore Capacity Study*. Local Planning Policy Branch, Special Studies Section, Toronto, Ontario.

15. Ontario Ministry of Natural Resources, 1979. *Application of the Concept of Carrying Capacity to Planning Water-Based Recreation on Crown Land in Ontario*. Water-Based Recreation Planning Group, Lake Planning Unit, Land Use Coordination Branch.

16. Ontario Planning and Development Department, 1976. *Policies for the Regulation of Lakeshore Development: A Technical Report*. Regional Municipality of Haldimand - Norfolk, Cayuga, Ontario.

17. Regional District of Fraser, Fort George Lakeshore Management Committee, 1980. *Lakeshore Guidelines*. File #6171, Prince George, British Columbia, pp 62.

18. Statistics Canada Census, 1986. *Place Name Reference List Atlantic Provinces*. Catalogue 92-121.

19. *The Boat Limit System as a Constraint to Cottage Development*, Ontario.

20. Vollenweider, R.A., 1976. *Advances in Defining Critical Loading Levels for Phosphorus in Lake Eutrophication*. Canada Centre for Inland Waters, Burlington, Ontario.

BIBLIOGRAPHY (Cont'd)

21. Whelan, W.G. and Wiseman, R.J. *The Limnology and Sport Fish Populations of Three Lakes Located in the Deer Park, Avalon Peninsula, Newfoundland.* Environment Canada, Data Report Series No. NEW/D-75-5, Resource Development Branch, Newfoundland, Region.

21a. Whelan, W.G. and Wiseman, R.J., 1977. *The Limnology and Sport Fish Populations of Three Lakes Located on the Southern Shore, Avalon Peninsula, Newfoundland.* Fisheries and Marine Service, Data Report 26, Research and Resource Services, Department of Fisheries and the Environment, St. John's, Newfoundland.

22. Wiseman, R.J. and Whelan, W.G. *Limnology and Sport Fish Populations of Spread Eagle Peak Pond.* Freshwater and Amadromous Fisheries Management Program, Fisheries and Marine Service, Environment Canada, St. John's, Newfoundland.

APPENDIX A

APPENDIX A

CARRYING CAPACITY DEFINITION

A. ECOLOGICAL CARRYING CAPACITY

1. Ecological Capacity

a) *Edaphic capacity*: Edaphic capacity is the ability of soil to withstand recreation, in terms of resistance to compaction and erosion. This may also refer to its capacity to absorb sewage effluent.

b) *Hydrologic carrying capacity*: This is the capacity based on hydrologic characteristics of the watershed and water body.

c) *Topographic capacity*: This refers to limitations imposed by relief.

B. BIOLOGICAL CARRYING CAPACITY

1. Biological Carrying Capacity

a) *Botanical*: This refers to the ability of vegetation to withstand use.

b) *Zoological*: This refers to the capacity of wildlife to tolerate recreation activities.

c) *Microbiological*: This refers to the level of use which does not create undesirable microorganism levels.

2. Visitor carrying capacity

a) *Social/psychological capacity*: This is related to user satisfaction regarding the number and types of encounters with other people in an area. This will increase with more varied topography or with dense vegetation cover since people will be screened from one another.

b) *Aesthetic carrying capacity*: This is related to user perception of beauty as affected by natural features, by modification of those features, or by deterioration of the environment. Aesthetic carrying capacity is related to social capacity since visitors may be regarded as an intrusion in wilderness areas, or as an asset at a beach.

c) *Spatial capacity*: This refers to the capacity of the space used by visitors in terms of time, the appropriate zoning for various activities, and the density for use within each zone.

d) *Temporal capacity*: This refers to the temporal distribution of use; the seasonal pattern of use intensity and peaks in activities, which will have considerable effects on carrying capacity.

e) *Financial capacity*: This may be (1) the point at which management cost per visitor served begins to rise markedly, or (2) the number of visitors which can be accommodated with the approved level of funding under accepted criteria for maintenance and operations, or (3) the point at which income from visitor fees equals costs and reasonable profit, or (4) the point at which the cost of minimizing adverse environmental costs begin to rise steeply. Financial capacity is closely related to institutional capacity.

C. INSTITUTIONAL CAPACITY

This is the ability of organizations to direct development towards public needs. This involves the limitations imposed by governmental structures, budget and personnel as well as the more general economic and cultural limits of the area on decision-making. Institutional capacity is limited by the size of planning staff, by the strength of land use controls and by other factors such as community attitudes, etc.

APPENDIX B

APPENDIX B

CARRYING CAPACITY USING TROPHIC STATE

Step by step procedure to calculate the carrying capacity of a water body is listed below:

A.0 Determine the Basic Morphometric, Meteorological and Land Use Data.

A.1 Lake Surface Area (A_o) m^2

Determine the surface area of a water body.

Source: 1:50,000 scale topographic map, aerial photographs, fishing/lake maps, any other relevant source.

A.2 Lake Volume (V) m^3

Source: fishing maps, nautical charts

Check with the Department of Fisheries whether above information is available for selected water body, if not then either

i) find the mean depth of water body
ii) use the area from A.1

or use the formula

$$V_1 = \frac{H}{3} (A_1 + A_2 + (A_1 A_2)^{1/2})$$

H = Vertical depth of stratum (m)
A_1 = Area of upper surface of stratum
A_2 = Area of lower surface of stratum

Similarly calculate V_2, V_3 .... for all stratums and $V = V_1 + V_2 + V_3 \ldots$

A.3 Lake Mean Depth (Z) in metres

$$Z = \frac{V \text{ (Lake Volume in m}^3\text{)}}{A_0 \text{ (Lake Area in m}^2\text{)}}$$

If possible, obtain Z from bathometric survey.

A.4 Watershed Area (A_d)

Use 1:50,000 topographic maps to outline the drainage area of each water body by following the high points of the land. Verify the watershed boundary with aerial photographs. Measure the area of the watershed.

A.5 Mean Annual Precipitation (P_r)

Mean annual precipitation from isohyetal maps from the study area or any other source.

A.6 Mean Annual Evaporation (E_v) or Mean Annual Lake Evaporation

Appropriate value for mean annual evaporation in the study area using Evaporation Atlas or any other source.

A.7 Mean Annual Runoff (r)

Appropriate value of mean annual runoff. This can be obtained either by prorating technique using actual MAR data from nearby gauged basin or from MAR isolines maps.

B.0 Determination of Hydrological Characteristics

B.1 Total Outflow Volume (Q) m^3/year

Compare watershed area with surface area of the lake. If watershed area is greater than ten times the surface area of the lake

$$Q = A_d \times r$$

$Q = m^3/\text{year}$; $A_d = m^2$ (watershed area); $r =$ mean annual runoff m/year

If watershed area is less than ten times the lake surface area, then

$$Q = A_d \times r + A_o (P_r - E_v)$$

$A_d =$ watershed area in m^2; $r =$ mean annual runoff m/year; $A_o =$ lake surface area in m^2; $p_r =$ mean annual precipitation m/year; and $E_v =$ mean annual evaporation m/year

B.2 Flushing Rate (ρ)

$$\begin{array}{rl} \rho & = \underline{Q}\ (m^3/\text{year}) \\ V\ (m^3) & = \text{times/year} \end{array}$$

B.3 Aerial Water Load (q_s) (m/year)

$$q_s = \frac{Q \text{ (m}_3\text{/year)}}{A_o \text{ (area of lake m}^2\text{)}}$$

B.4 Retention Coefficient (R) of Phosphorus

$$R = \frac{13.2}{13.2 + q_s}$$

where q_s is the aerial water level

C.0 Estimation of Total Phosphorus Supply

C.1 Phosphorus Contribution Through Precipitation (J_{Pr}) (kg/year)

$$J_{Pr} = L_{Pr} \times A_o$$

J_{Pr} = kg/year; L_{Pr} = phosphorus loading values for precipitation; A_o = lake surface area (m^2)

L_{Pr} is dependent to $\frac{A_d}{A_o}$ and recommended range is 24 - 74.4 $mg/m^2/year$

C.2 Overland Drainage (J_D) (kg/year) (also known as J_E)

Calculate the phosphorus supplied from the drainage basin

$$J_D = A_d \times E$$

J_D = kg/year; A_d = watershed area in m^2; E = phosphorus export value corresponding to each land use category ($mg/m^2/year$) - also known as L_E

Recommended E value for various geological classification and land use is discussed in Section 2.

C.3 Upstream Sources (J_u)* (kg/year)

* may not be applicable in many cases, it is applicable only if pond or lake is connected to another lake/pond at upstream (u/s)

$$J_u = J_T (1 - R^{-1})$$

J_T = total phosphorus entering u/s lake (kg/year); R^{-1} = retention coefficient of u/s lake or pond

Total phosphorus supply from natural sources

$J_N = J_{Pr} + J_D = J_u$

C.4 Total Phosphorus Supply From Artificial Sources (J_A) (kg/year)

Determine N_{cy} (capita years/year/unit)

$$N_{cy} = \frac{\text{(average no. of days spent in cottage) x average no. of persons/cottage}}{365}$$

Artificial phosphorus supply from cottage and resort units

$J_A = s \text{ x } N_{cy} (1 - R_s)N$

s = amount of phosphorus contributed per capita year of use
Assume 0.8 kg/capita year

N_{cy} = number of capita years/year/unit
$R_{\underline{s}}$ = retention coefficient of existing sewage treatment facilities (use table as discussed in Section 2)
N = total number of cottages and resort units

C.5 Total Phosphorus Supply (kg/year)

$J_T = J_N + J_A$ (kg/year)

D.0 Phosphorus Concentration, Chlorophyll a level and Secchi Disc Depth

D.1 Predict existing spring phosphorus concentration.

Existing phosphorus in a water body (during spring or ice free period) (μg/l)

$$P = \frac{J_T (1 - R)}{Q}$$

Compare the value with observed results if available, if too much variation recalculate J_T

D.2 Using the P, calculate chlorophyll a concentration (μg/l)

$\log_{10}(\text{chlor } \underline{a}) = 1.45 \log_{10}(P) - 1.14$

(applicable only if N/P ratio greater than 12)

D.3 Secchi Disc Depth (water clarity)

$$SD = (0.1138 + 0.0386\,[\text{chlor } \underline{a}])^{-1}$$

or

$$SD = \frac{5.21}{(\text{chlor } \underline{a})^{0.41}}$$

E.0 Calculation of Maximum Additional Permissible Developments

E.1 Select maximum chlorophyll a concentration

- will depend on biological, physical, morphometric character and desired uses of a water body

E.2 Calculate maximum acceptable phosphorus concentration

$$\log_{10} (\text{chlor } \underline{a})_{Perm} = 1.45 \log_{10} (P_{Perm}) - 1.14$$

$P_{Perm} = \mu g/l$

E.3 Calculate maximum permissible phosphorus supply ($\mu g/l$)

$J_{Perm} = P_{Perm} \times Q(m^3/year)$

if $J_T > J_{Perm}$ -- no additional development

if $J_T < J_{Perm}$ -- development possible

E.4 Maximum number of additional development units (for developed ponds/lakes only)

$$N_{Perm} = \frac{J_{Perm} - J_T}{s \times N_{cy}\,(1 - R_s)}$$

J_{Perm} = the maximum permissible phosphorus supply (kg/year)
J_T = the total existing phosphorus supply natural + artificial (kg/year)
N_{cy} = the number of capita years per year per unit
s = the amount of phosphorus contribution per capita year of use
R_s = retention coefficient of sewage treatment system

If pond is underdeveloped or one is interested to know the total development capacity of water bodies

$$N_{Perm} = \frac{J_{Perm} - J_N}{N_{cy} \times s\,(1-R_s)}$$

APPENDIX C

APPENDIX C

NATURAL SHORELINE RESERVE METHOD

Calculating the cottage carrying capacity using the natural shoreline reserve method:

1. Measure the perimeter of the shoreline (A) in metres using 1:50,000 NTS maps.

2. Count the number of existing cabins (B) around the shoreline of the water body. This can be obtained either with the help of aerial photographs or from Crown Lands record.

3. Development is only to be allowed on 75% of the natural shoreline.

   Length of shoreline (C) = Perimeter (A) x 0.75

4. Cottage Carrying Capacity

   Potential number = Length of shoreline/Cabin lot size width

5. Development Status (E) = $\frac{\text{Existing No. of Cabins (B)}}{\text{Potential No. of Cabins (D)}}$

   Water body is underdeveloped if (E) < 1.0
   Water body is overdeveloped if (E) > 1.0

6. Number of cabins a water body is under developed or overdeveloped (F).

   Existing No. of Cabins (B) - Potential No. of Cabins (D)

   If (F) is minus, pond/lake is underdeveloped and additional cabin development is permissible.

   If (F) is positive, pond/lake is overdeveloped and no additional development should be permitted.

7. In order to apply the method in Newfoundland, it is recommended to use only 60% of the shoreline perimeter for planning purposes. Forty percent (40%) of the water body should be reserved for future planning, public access and open space.

APPENDIX D

APPENDIX D

SHORELINE CAPABILITY METHOD

The following is a step by step procedure to calculate the cottage carrying capacity using the shoreline capability method:

1. Using topographic maps, mark the perimeter of the shoreline for both topography and soil drainage and reserve 100 metres buffer zone along the shoreline of a water body. Identify the four classifications of each category (topography and soil drainage) up to a distance of 100 metres beyond 100 metres buffer zone.

   Rationale - 1 acre is the maximum cottage lot size and 45 m is the maximum lot width frontage issued by the Land Use Management Division. [45 m (width) X 90 m (depth) = 1 acre (maximum cottage lot size)].

2. Determine the cottage capability of a water body. This can be achieved by overlapping the two maps topographic capability class and soil drainage capability class to determine the derived cottage capability class for the water body.

3. Determine the perimeter of the shoreline for each derived cottage capability class.

4. Determine the desirable number of cottages the water body could support (carrying capacity) by multiplying length of shoreline for each cottage capability Class (1 to 2) times the desirable number of cottages per km length of shoreline.

5. Determine the desirable number of cottages (carrying capacity) by reserving 40% of suitable shoreline in natural state.

6. The potential development capacity of the lake or pond can then be determined by subtracting the desirable number of cottages from the actual number of cottages that exist on the water body. This provided the number of cottages the water body was underdeveloped (positive) or overdeveloped (negative).

APPENDIX E

APPENDIX E

BOAT DENSITY METHOD

The following is a step by step procedure to calculate the cottage carrying capacity using the boat density method.

1. Measure the gross area of the water body.

2. Reserve 25% of the lake in its natural state. Net Area = Gross Area x 0.75

3. Number of Boats (Boating Capacity) = $\frac{\text{Net area of water body}}{\text{4 ha}}$

   - 4 hectares is the boating standard of space required by each boat

4. Number of boats permitted for cottage owners = number of boats (boating capacity) x 0.6

   - 60% of the water body will be reserved for cottage owners and 40% reserved for non-cottage owners

5. Cottage carrying capacity - cottagers share of boats x $\frac{100}{10}$

   or - cottagers share of boats x $\frac{100}{25}$

   Assuming only 10-25% of boats in use at peak times and one boat per cottage owner

6. Cottage development potential = cottage carrying capacity - actual number of cottages on the lake or pond. The number of cottages the water body is underdeveloped is indicated as positive and overdeveloped as negative.

APPENDIX F

APPENDIX F - I

HIGH ENERGY RECREATION CARRYING CAPACITY METHOD

The following is a step by step procedure to calculate cottage carrying capacity using the high energy recreation method.

1. Measure the net area of the water body.

2. Pond boat capacity = $\frac{\text{net area of water body}}{4 \text{ ha}}$

    - 4 hectares is the boating standard of space required by each boat

3. Maximum number of boats the pond can accommodate for cottage owners = pond boat capacity x 0.60

    - 60% of the water body will be for cottage owners and 40% will be reserved for other uses.

4. Cottage boat use = maximum number of boats the pond can accommodate for cottage owners x 0.10

    - Assuming only 10% of the boats in use at peak times and one boat per cottage owner.

5. Cottage development capacity = cottage boat use - existing number of cottages.

    - The number of cottages the water body is underdeveloped is positive and overdeveloped is negative.

6. This is the method currently being used by the Land Use Management Division. It is recommended that use of this method be replaced by the Boat Density Method discussed in the report.

APPENDIX F - II

LOW ENERGY RECREATION CARRYING CAPACITY METHOD

The following is a step by step procedure to calculate cottage carrying capacity using the low energy recreation method.

1. Measure the perimeter of the shoreline.

2. Multiply the perimeter times 0.75 and leave 25% of the shoreline undeveloped.

3. Multiply the perimeter (minus 25%) times 0.75 to leave room for future development. This will reserve a total of 44% of the shoreline in this natural state and for future development.

4. Cottage capacity = perimeter (minus 44%) divided by 45 m.

5. Cottage development potential = cottage capacity minus existing number of cottages where the number of cottages the water body is underdeveloped is positive and overdeveloped is negative.

6. This is the method currently being used by the Land Use Management Division and it is recommended that this method be replaced by the Natural Shoreline Reserve Method used in this report.

APPENDIX G

APPENDIX G

SUMMARY OF SPECTRUM ANALYSIS

SOUTHERN SHORE AREA

Water Body: **Tors Cove Pond**

Range of Development: 64 Cabins - Trophic State Method
193 Cabins - NSR Method (30m)
Vulnerability Index: 12 (Sensitive)
Existing Development: 243 Cabins
Present Status: Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 2.97
2. Flushing Rate: 12.539
3. Watershed Size: 19037 Ha
4. Depth: 9.1 m
5. Lake/Pond Size: 234.4 Ha
6. Water Quality: Data limited - Number of Samples and Parameters. Collected in July 1975. Source - Department of Fisheries and Oceans (DFO) limnology report.

Additional Development: None. Tors Cove Pond has a carrying capacity of 64 cabins based on the Trophic State method.

Reasoning: All cottage carrying methods indicate that the pond is presently overdeveloped. The main reason for this is there are too many cabins presently on the pond.

Water Body: **Hell Hill Pond**

Range of Development: 51 Cabins - Boat Density Method
117 Cabins - NSR (30m) Method
Vulnerability Index: 12 (Sensitive)
Existing Development: 9 Cabins
Present Status: Active Planned

Features of Water Body:

1. Shoreline Configuration: 2.57
2. Flushing Rate: 2.417
3. Watershed Size: 751 Ha
4. Depth: 4.4 m
5. Lake/Pond Size: 114.3 Ha

6. Water Quality: Data limited - Number of Samples and Parameters. Collected in July 1975. Source - Department of Fisheries and Oceans (DFO) limnology report.

Additional Development: Additional cottages may be permitted.

Reasoning: The cottage carrying capacity of the most restrictive method will allow the above number of additional cabins. Since no information is available on bacteriological or chemical water quality and functioning of existing septic systems, it is recommended to conduct water quality monitoring and septic systems surveys prior to further development in this area. Field investigations should also be carried out where possible to verify data used for determining carrying capacity.

Water Body: **Cape Broyle Pond**

Range of Development: 121 Cabins - Boat Density Method
298 Cabins - NSR (30m) Method
Vulnerability Index: 11 (Moderate)
Existing Development: 220 Cabins
Present Status: Active - Unplanned

Features of Water Body:

1. Shoreline Configuration: 4.27
2. Flushing Rate: 10.717
3. Watershed Size: 13598 Ha
4. Depth: 6.6 m
5. Lake/Pond Size: 270.1 Ha
6. Water Quality: Data limited - Number of Samples and Parameters. Collected in September 1974. Source - Department of Fisheries and Oceans (DFO). Also samples collected in Cape Broyle River 1972 and 1973.

Additional Development: None. The carrying capacity of Cape Broyle Pond is 121 cabins based on the boat density approach.

Reasoning: There are presently too many cabins on Cape Broyle Pond.

CENTRAL AVALON REGION

Water Body: **Old Mans Pond**

Range of Development: 11 Cabins - Boat Density Method
101 Cabins - Shoreline Dev. Method
Vulnerability Index: 12 (Sensitive)
Existing Development: 21 Cabins
Present Status: Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 3.57
2. Flushing Rate: 2.236
3. Watershed Size: 87 Ha
4. Depth: 2.5 m
5. Lake/Pond Size: 24.8 Ha
6. Water Quality: Data limited - Number of Samples and Parameters. Collected in May 1975. Water Analysis Data compiled by A. Jamieson.

Additional Development: None. The cottage carrying capacity of Old Mans Pond is 11 cabins based on the Boat Density method.

Reasoning: Old Mans Pond has already reached its carrying capacity.

Water Body: **Nine Island Pond**

Range of Development: 73 Cabins - Boat Density Method
171 Cabins - NSR (30m) Method
Vulnerability Index: 11 (Moderate)
Existing Development: 120 Cabins
Present Status: Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 3.15
2. Flushing Rate: 0.936
3. Watershed Size: 570 Ha
4. Depth: 6.2 m
5. Lake/Pond Size: 162.1 Ha
6. Water Quality: Data limited - Number of Samples and Parameters. Collected in June 1972. Source - Department of Fisheries and Oceans (DFO) limnology report.

Additional Development: None. Nine Island Pond has a cottage carrying capacity of 73 cabins based on the Boat Density method.

Reasoning: The carrying capacity of Nine Island Pond has already been reached. It has a low flushing rate (less than one per year) and relatively small surface water area.

Water Body:	**Goulds Pond**
Range of Development:	28 Cabins - Boat Density Method 166 Cabins - Shoreline Dev. Method
Vulnerability Index:	12 (Sensitive)
Existing Development:	47 Cabins
Present Status:	Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 3.98
2. Flushing Rate: 1.515
3. Watershed Size: 174 Ha
4. Depth: 3.1 m
5. Lake/Pond Size: 62.4 Ha
6. Water Quality: 18 water quality samples were collected between 1982 and 1986 by the Water Resources Division of the Department of Environment and Lands. (In brief, total phosphorus values ranged from between 0.007 to 0.225 (mg/l). Based on the results of the sampling, Goulds Pond is in a hypereutrophic state with a mean total phosphorus value of 0.08mg/l. High incidence of both total and faecal coliforms were recorded indicating deteriorated bacteriological water quality.

Additional Development: None. The carrying capacity of Goulds Pond is 28 cabins based on the Boat Density method.

Reasoning: Goulds Pond has already reached its cottage carrying capacity. This is primarily due to the ponds small size. The water quality concerns warrant special consideration. As a result of the deteriorated water quality an investigation should be undertaken to address the problem. In most cases where similar problems have been noted septic system failure is the leading cause of such problems. A septic system survey should be completed for the area.

Water Body:	**Hawcos Pond**
Range of Development:	116 Cabins - Boat Density Method 571 Cabins - Shoreline Dev. Method
Vulnerability Index:	12 (Sensitive)
Existing Development:	151 Cabins
Present Status:	Frozen - Planned

Features of Water Body:

1. Shoreline Configuration: 7.90
2. Flushing Rate: 2.204
3. Watershed Size: 1295 Ha
4. Depth: 3.4 m
5. Lake/Pond Size: 256.8 Ha
6. Water Quality: A total of 23 water quality samples were collected by the water Resources Division of the Department of Environment and Lands. In brief the bacteriological results meet the Canadian Drinking Water Quality standards for recreation but not the more stringent drinking water standards and the mean total phosphorus value is 0.069 mg/l indicating hypereutrophic conditions. Water quality sample collected by DFO May, 1974. Source - DFO Limnology report.

Additional Development: None. The carrying capacity of Hawcos pond is 116 cabins based on the Boat Density method.

Reasoning: The shoreline configuration is very high which is an indication of a highly irregular shoreline. The vulnerability index is also high which indicates the ponds sensitivity to eutrophication. Hawcos pond has already reached its carrying capacity. Water quality problems are a concern at Hawcos Pond and a survey of septic systems should also be completed.

Water Body:	**Middle Gull Pond**
Range of Development:	138 Cabins - Boat Density Method 419 Cabins - NSR (30m) Method
Vulnerability Index:	11 (Moderate)
Existing Development:	115 Cabins
Present Status:	Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 5.63
2. Flushing Rate: 0.558
3. Watershed Size: 1114 Ha
4. Depth: 10.3 m
5. Lake/Pond Size: 306.6 Ha
6. Water Quality: Data limited - Samples and parameters collected in July 1970. Source - DFO limnology report.

Additional Development: Few additional cabins may be possible. The cottage carrying capacity is 138 cabins based on the Boat Density method.

Reasoning: This lake is very close to its development limit according to the boat density method. The lake has a sensitivity index of 11 and a low flushing rate (0.558). The shoreline is also very irregular. For these reasons it is recommended to conduct a water quality and septic system survey before additional developments are approved in this area.

Water Body: **Grand Pond**

Range of Development: 82 Cabins - Boat Density Method
377 Cabins - Shoreline Dev. Method
Vulnerability index: 12 (Sensitive)
Existing Development: 151 Cabins
Present Status: Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 5.26
2. Flushing Rate: 2.488
3. Watershed Size: 1243 Ha
4. Depth: 3.9 m
5. Lake/Pond Size: 182.1 Ha
6. Water Quality: 22 water quality samples were collected by the Water Resources Division of the Department of Environment and Lands from 1982 to 1986. Bacteriological results indicate some values above the Canadian water quality standards for recreation. The mean total phosphorus value is 0.034 mg/l indicating the water body has presently reached a eutrophic state. Water quality samples also collected by DFO in July, 1972. Source - DFO limnology report.

Additional Development: None. The carrying capacity of Grand Pond is 82 cabins based on the Boat Density method.

Reasoning: This pond has already reached its development limit. Grand Pond also has a high vulnerability index (12) and a fairly irregular shoreline. Water quality problems are also occurring at Grand Pond. A survey of the areas septic systems should also be completed to determine if malfunctioning systems are the cause of the water quality problems.

Water Body: **Ocean Pond**

Range of Development: 182 Cabins - Boat Density Method
569 Cabins - NSR (30m) Method
Vulnerability Index: 12 (Sensitive)
Existing Development: 256 Cabins
Present Status: Frozen - Planned

Features of Water Body:

1. Shoreline Configuration: 6.66
2. Flushing Rate: 1.741
3. Watershed Size: 2150 Ha
4. Depth: 4.5 m
5. Lake/Pond Size: 404.4 Ha
6. Water Quality: Data limited - Number of samples and parameters. Collected May 1972 and February 1973. Source - Results of water analysis collected by A. Jamieson.

Additional Development: None. Ocean Pond has a carrying capacity of 182 cabins based on the boat density method.

Reasoning: This pond has already reached its carrying capacity. Ocean Pond also has a high vulnerability index and an irregular shoreline.

WESTERN AVALON AREA

Water Body: **Dennys Pond**

Range of Development: 24 Cabins - Trophic State Method
139 Cabins - NSR (30m) Method
Vulnerability index: 12 (Sensitive)
Existing Development: 43 Cabins
Present Status: Active - Unplanned

Features of Water Body:

1. Shoreline Configuration: 3.38
2. Flushing Rate: 6.376
3. Watershed Size: 2195 Ha
4. Depth: 4.6 m
5. Lake/Pond Size: 92.8 Ha
6. Water Quality: Unknown

Additional Development: None. Dennys pond has reached its carrying capacity based on the Trophic State method.

Reasoning: Dennys Pond has reached its carrying capacity. Dennys Pond has a moderate vulnerability index (10) and a high flushing rate (6.376). The carrying capacity as determined by the Boat Density method (42 cabins) has also been reached.

Water Body: **Peak Pond**

Range of Development: 25 Cabins - Boat Density Method
99 Cabins - NSR (30m) Method
Vulnerability index: 12 (Sensitive)
Existing Development: 32 Cabins
Present Status: *Frozen - Planned*

Features of Water Body:

1. Shoreline Configuration: 3.20
2. Flushing Rate: 6.830
3. Watershed Size: 337 Ha
4. Depth: 1.3 m
5. Lake/Pond Size: 54.7 Ha
6. Water Quality: Data limited - water quality samples collected in July 1973. Source - DFO limnology report.

Additional Development: None. The carrying capacity of peak pond is 25 cabins based on the Boat Density method.

Reasoning: The carrying capacity of Peak Pond has been reached primarily due to its small water body size.

Water Body: **Junction Pond**

Range of Development: 28 Cabins - Boat Density Method
122 Cabins - Shoreline Dev. Method

Vulnerability Index: 12 (Sensitive)
Existing Development: 42 Cabins
Present Status: Active - Planned

Features of Water Body:

1. Shoreline Configuration: 3.32
2. Flushing Rate: 18.327
3. Watershed Size: 2512 Ha
4. Depth: 3.1 m
5. Lake/Pond Size: 61.9 Ha
6. Water Quality: Data Limited - samples and parameters collected in July 1986. Source - DFO limnology report.

Additional Development: None. The carrying capacity of Junction Pond is 28 cabins based on the Boat Density method.

Reasoning: Cottage development at Junction Pond has reached its carrying capacity as a result of the ponds small water body size. Junction pond however has a high flushing rate (18.327) and high vulnerability index (12).

BURIN PENINSULA AREA

Water Body:	**Freshwater Pond**
Range of Development:	166 Cabins - NSR (45m) and Shoreline Development Method 1001 Cabins - Trophic State Method
Vulnerability Index:	9 (Low)
Existing Development:	58 Cabins
Present Status:	Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 1.89
2. Flushing Rate: 1.315
3. Watershed Size: 14887 Ha
4. Depth: 16.5 m
5. Lake/Pond Size: 960.6 Ha
6. Water Quality: A water quality investigation was completed by the Water Resources Division of the Department of Environment and Lands in 1989. The results of that investigation indicated high bacteriological levels and recommended restrictions be placed on cottage development.

Additional Development: Additional development may be possible according to the Natural Shoreline Reserve and Shoreline Development methods. The carrying capacity is 166 cabins based on these methods.

Reasoning: The carrying capacity of the lake has not been reached according to the NSR (45m) and shoreline development methods. There is a provincial park on one side of the pond that has not been taken into consideration by this study to determine cottage carrying capacity. Before any additional cottage development is allowed to take place the water quality should be investigated as recommended by the report mentioned above and a septic system survey should be completed. Cottage development should also be located at an acceptable distance from the high water mark of the pond. In any future development, percentage of shoreline under Parks jurisdiction should be taken into consideration.

Water Body:	**Garnish Pond**
Range of Development:	171 Cabins - Boat Density Method 532 Cabins - Trophic State Method
Vulnerability index:	12 (Sensitive)
Existing Development:	54 Cabins
Present Status:	Active - Unplanned

Features of Water Body:

1. Shoreline Configuration: 3.77
2. Flushing Rate: 22.2
3. Watershed Size: 19243 Ha
4. Depth: 3.1 m
5. Lake/Pond Size: 379.6 Ha
6. Water Quality: A water quality investigation was completed by the Water Resources Division of the Department of Environment and Lands in 1989. The results of that investigation indicated high bacteriological levels and recommended restrictions be placed on cottage development. In 1991 a follow up investigation was started and preliminary results from this study also indicate increased bacteriological levels.

Additional Development: Additional development may be possible. The carrying capacity is 171 cabins based on the Boat Density method.

Reasoning: All methods indicate Garnish Pond can sustain more development. There have been water quality problems with Garnish Pond that have not been identified by this study. No further development should be considered until remedial measures are adopted to over come the existing water quality related problems. Garnish Pond has a very high flushing rate (22 times per year). A number of cottages are located within the high water mark of the pond and are flooded during high flow conditions. The development within the high water mark and non-functional septic systems are the probable cause of water quality problems.

Water Body: **Salmonier Pond**

Range of Development: 40 Cabins - Boat Density Method
143 Cabins - NSR (30m) Method
Vulnerability Index: 12 (Sensitive)
Existing Development: 36 Cabins
Present Status: Active - Planned

Features of Water Body:

1. Shoreline Configuration: 3.57
2. Flushing Rate: 2.088
3. Watershed Size: 1260 Ha
4. Depth: 9.2 m
5. Lake/Pond Size: 89.2 Ha
6. Water Quality: Limited data - Number of samples and parameters. Data collected in May, 1973. Source - DFO limnology report.

Additional Development: A few additional cabins may be possible. The carrying capacity is 40 cabins based on the boat density method.

Reasoning: This is the maximum number of cabins the boat density method will allow.

CLARENVILLE AREA

Water Body: **Thorburn Lake**

Range of Development: 61 Cabins - Trophic State Method
263 Cabins - NSR (30m) Method
Vulnerability index: 11 (Moderate)
Existing Development: 28 Cabins
Present Status: Active - Unplanned

Features of Water Body:

1. Shoreline Configuration: 3.64
2. Flushing Rate: 0.557
3. Watershed Size: 2523 Ha
4. Depth: 12.3 m
5. Lake/Pond Size: 289.3 Ha
6. Water Quality: Limited data - two samples collected in June, 1972. Source - Results of water analysis by A. Jamieson.

Additional Development: Additional development up to 61 cabins may be possible according to the Trophic State method.

Reasoning: The pond has a very low flushing rate (0.557 times per year) and may be a cause of water quality problems. Additional development may be planned provided there are no water quality problems and functional septic systems can be installed.

Water Body: **Georges Pond**

Range of Development: 159 Cabins - NSR (45m) Method
281 Cabins - Trophic State Method
Vulnerability Index: 11 (moderate)
Existing Development: 6 Cabins
Present Status: Frozen - Unplanned

Features of Water Body:

1. Shoreline Configuration: 2.66
2. Flushing Rate: 0.631
3. Watershed Size: 1988 Ha
4. Depth: 6.1 m
5. Lake/Pond Size: 445.4 Ha
6. Water Quality: Water quality monitoring program undertaken by the Water Resources Division of the Department of Environment and Lands indicated bacteriological contamination of water.

Additional Development: Additional development may be possible. The carrying capacity of Georges pond is 159 cabins based on the Natural Shoreline Reserve method 45 metre lot width sizes.

Reasoning: All methods indicate this pond can sustain more development. The flushing rate of Georges Pond however is quite low (0.631 times per year) and the watershed is fairly small in size (1988 Ha). The pond however is a protected water supply and cottage development has presently been frozen. A detailed water quality and septic systems survey will be required prior to any future development in this area. Present policy of this Department does not encourage cottage development in protected water supply areas.

Water Body: **Lady Pond**

Range of Development: 28 Cabins - Trophic State Method
328 Cabins - NSR (30m) Method
Vulnerability Index: 11 (Moderate)
Existing Development: 26 Cabins
Present Status: Active - Planned

Features of Water Body:

1.	Shoreline Configuration:	3.55
2.	Flushing Rate:	0.558
3.	Watershed Size:	6868 Ha
4.	Depth:	25 m
5.	Lake/Pond Size:	470.2 Ha
6.	Water Quality:	Unknown

Additional Development: Additional development may be possible. The cottage carrying capacity of Lady Pond is 28 cabins based on the Trophic State method.

Reasoning: The low flushing rate (0.558 times per year) is a concern for water quality problems and thus development should be subjected to water quality and septic systems surveys. If functional septic systems are not being maintained or can not be put in place than additional development should not be allowed.

Water Body: **Shoal Harbour Pond**

Range of Development: 18 Cabins - Trophic State Method
167 Cabins - NSR (30m) Method
Vulnerability index: 12 (Sensitive)
Existing Development: 13 Cabins
Present Status: Active - Unplanned

Features of Water Body:

1. Shoreline Configuration: 2.31
2. Flushing Rate: 1.485
3. Watershed Size: 4099 Ha
4. Depth: 6.7 m
5. Lake/Pond Size: 290.5 Ha
6. Water Quality: Unknown

Additional Development: Additional development may be possible. The cottage carrying capacity of Shoal Harbour Pond is 18 cabins based on the Trophic State method.

Reasoning: All methods other than the Trophic State method indicate a much greater cottage carrying capacity. Additional development may be considered subjected to the results of water quality monitoring and septic system surveys. The site should also be surveyed to see if functional septic systems can be put in place.

APPENDIX H

APPENDIX H

PRELIMINARY ASSESSMENT OF THE COTTAGE DEVELOPMENT POTENTIAL OF A WATER BODY

1.0 Existing Land Use

Type	Area in Hectares	Percentage of Total Watershed Area	Tenure					NTS Map Number	Map Symbol
			Crown	Lease	Licence	Private	Illegal		

2.0 Existing Water Uses
(Please provide brief information on instream and withdrawal water uses.)

Municipal water supply: ______________________________

____

Industrial water use (pulp & paper mill, mine, etc.): ______________________________

____

Water recreational use (national park, provincial park, existing cottages, scheduled salmon river, canoe route, etc.): ______________________________

____

Other: ______________________________

____

____

3.0 Watershed Characteristics

Drainage area of watershed (A_d) __________ hectares
Surface area of water body (A_0) __________ hectares
Average depth of water body (d) __________ metres
Mean annual precipitation (P) __________ metres
Mean annual runoff (r) __________ metres

Soil Types and Depth (overburden)

Silty clay ☐ Shoreline length ____ km % of total shoreline _______
Depth _______ m
Clayey silt ☐ Shoreline length ____ km % of total shoreline _______
Depth _______ m
Sandy silt ☐ Shoreline length ____ km % of total shoreline _______
Depth _______ m
Silty sand ☐ Shoreline length ____ km % of total shoreline _______
Depth _______ m
Sandy gravel ☐ Shoreline length ____ km % of total shoreline _______
Depth _______ m
Rock & boulders ☐ Shoreline length ____ km % of total shoreline _______
Depth _______ m

Shoreline configuration $S = \frac{L}{2\pi\sqrt{A/\pi}}$

where S = shoreline configuration
L = length of shoreline of lake
A = area of lake (from planimeter measurement)
$\pi = 3.14$

Shoreline suitable for development ____________ km
Shoreline considered for development ____________ km

5.0 Water Quality Data

Secchi disc depth ____________ m
Colour ____________ TCU
Turbidity ____________ NTU
Total Dissolved Solids (TDS) ____________ mg/l
pH ____________ μg/l
Total phosphorus ____________ μg/l
Chlorophyll a ____________ μg/l
Chlorides ____________ mg/l
Total coliform ____________ #/100 ml
Faecal coliforms ____________ #/100 ml
Morphoedaphic Index (MEI) $\frac{(TDS)}{d}$ ____________

Trophic classification (please see attached table)

oligotrophic ☐ mesotrophic ☐ eutrophic ☐

NOTE: Water quality data on some of the above listed parameters may be available with the Federal Department of Fisheries and Oceans or Provincial Department of Environment and Lands and Department of Health. However, it is recommended that at least two to three water samples should be collected and analyzed during spring and summer months to provide information on background water quality and trophic status of a water body. Sampling sites should be decided in consultation with the Water Resources Management Agreement.

6.0 Water Table and Test Pits Data

Water Table Monitoring

Piezometer identification ____________
Construction date ____________
Location __________ Ground elevation ____________ metres
Top of pipe elevation ____________ metres
Depth of pipe below ground ____________ metres
Thickness of unsaturated overburden ____________ metres
Water table elevation (spring) ____________

Water table elevation (summer) ____________ metres
Water table elevation (fall) ____________ metres

Test pits

Test pit identification ____________
Location __________ Ground elevation ____________ metres

Test pit depth
Sieve analysis data

Soil permeability data

NOTE: Actual number of piezometers and test pits and their locations will be decided in consultation with the Department of Health and Civil/Sanitary Engineering Division of the Department of Environment and Lands. Guidelines for assessment of unserviced subdivision and cottage lot developments should be followed in conducting the above investigation.

7.0 Parameters for Lakeshore Development

Total area of lake ____________ hectares
Area available for boating ____________ hectares
Average depth of lake ____________ metres
Average groundwater table depth ____________ metres
Average thickness of unsaturated overburden
Properties of unsaturated overburden ____________
Hydraulic residence time ____________ years
Total shoreline length ____________ km
Shoreline suitable for development ____________ km
Existing use of shoreline ____________
(such as parks, campgrounds, etc)
Shoreline configuration ratio ____________
Average shore land slope ____________ %
Trophic classification of water body ____________

NOTE: The above listed parameters will provide useful information on development limits in a particular planning area and will be useful in selecting an appropriate method to determine the cottage carrying capacity of a water body.

TROPHIC CLASSIFICATION OF LAKES BASED ON CHLOROPHYLL a, WATER CLARITY MEASUREMENT, AND TOTAL PHOSPHORUS VALUES

Trophic Classification	**Total Phosphorus μg/l**	**Chlorophyll μg/l**	**Secchi disc (m)**
oligotrophic	< 10	< 7	> 3.7
mesotrophic	10 - 20	7 - 12	2.0 - 3.7
eutrophic	> 20	> 12	< 2.0