THE ECOSYSTEM:

A CONCEPTUAL FRAMEWORK FOR IDENTIFYING THE ECOLOGICAL IMPLICATIONS OF PLANNING OPTIONS

by

MICHAEL GERARD POWERS

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Department of COMMUNITY AND REGIONAL PLANNING

The University of British Columbia
Vancouver 8, Canada

Date MAY 2, 1972

ABSTRACT

The current problem of environmental deterioration is the result of society's perceived independence from nature. Through adoption of a systems perspective, however, one recognizes the need to relate man to his natural environment. In particular the concept of the ecosystem provides a theoretical model that recognizes the complex interdependence of man, land, and living systems. The development and application of the ecosystem concept suggests a variety of necessary changes regarding the traditional view of man/environment relationships and their incorporation into the planning process. These changes include:

(1) the necessity of recognizing the symbiotic relationship between man and land;

(2) the development of a boundary-oriented view of ecosystem stability; and

(3) the need to adopt a planning strategy involving small yet diverse interventions to provide alternatives of action, maximum diversity of public choice, and systems stability.

In the present study the theoretical and practical aspects of the ecosystem concept are applied to a specific land-use planning problem study to determine:

(1) man-other organisms-physical environment interrelations;

(2) the ecological implications of alternative development proposals upon those relationships; and

(3) proposals for a comprehensive land-use plan recognizing the integrity of the ecosystem.

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CHAPTER I

INTRODUCTION

Regional planning seeks to tie a variety of issues, such as housing, employment, and regional economic development, together. Until quite recently planners have focused mainly upon economic and social development. However a rational plan must give greater weight to other concerns, such as environmental quality, for reasons discussed below. This concern must extend beyond the solutions to immediate problems and consider the long term impact of urban structure and function on other processes. In this light the acquisition and utilization of knowledge in the planning process is seen in a much larger context.

The establishment of a basic conceptual framework that incorporates the variety of inputs planners are concerned with is an essential first step. A systems overview provides the basic conceptual framework for a "comprehensive" approach as it encompasses the relationships of objects to each other, their environment and environmental processes. Environment in this case applies to the environmental aspects of man's society (e.g., housing conditions) as well as physical and biological interactions.

As I shall point out in the next few pages planners have ignored, both in theory and practice, the incorporation of ecological considerations into the planning process. While the scope of this thesis does not allow for an approach that solves all planning problems it will attempt to make the planning process more comprehensive. An example of the systems approach will be presented emphasizing the input of ecological considerations in the planning process. The first conceptual requirement of a systems overview is a clearer definition of problems with an emphasis on analysis and understanding interactions among variables (VanDyne, 1969). A systematic overview of past and present perceptions of "environmental" problems and the traditional approaches to problem identification, analysis and solution is a necessary prerequisite to suggesting a specific approach that incorporates ecological considerations into the planning process.

SYMPTOMS OF A LARGER PROBLEM

Pollution

Until recently mankind has taken for granted those processes which provide him with the basic requisites of life: clean air and water; abundant energy; and a healthful nutrient supply. Man has historically perceived the resources necessary for the development of our urban-industrial society to be in abundance and that resource supply or sinks were determined by price. But now we are acutely aware of increasing air, water, and soil pollution and scarcity of resources.

Pollution occurs through the excessive output of chemical materials, organic wastes, radioactive particles, or other substances which the environment can no longer absorb through the normal processes of dilution, circulation, and decay. Pollution problems in themselves are not new, on the contrary, pollution was given a great deal of consideration at the time of the Industrial Revolution and before.

However, because of increasing population, urbanization, and an emphasis on material production which precipitates large scale environmental contamination the magnitude and urgency of regional and global imbalances have no precedent.

Independent Approaches to Environmental Problems

While many may recognize the seriousness of our various environmental problems our traditional methods of problem identification, analysis, and solution are inadequate. An important factor characterizing our approach to many problems of society is that we don't even properly identify the problems, only their symptons. Cooley (1953), in discussing the overexploitation of the Alaska Salmon Fishery, observes that solutions are voiced as if there were only one culprit and one problem. This limited view creates new problems, at times more severe than the original one as the complexity and interrelated nature of problems are ignored. Excessive division of responsibility or government is a fundamental reason for this myopic approach.

Responsibility for our biophysical and socio-cultural environments has been excessively subdivided among a variety of departments and specialists in education and government. For example, Leighton (1966) notes that there are 360 governmental agencies in the United States - local, state, regional, federal - that are partly or entirely concerned with air pollution. Governmental institutions have also become fragmented in their internal responsibilities as in the Departments of Highways (concern with roads) and Agriculture (concern with crop production). Therefore departments are forced to concentrate on parts of problems and not on the whole problem and freeways are constructed over prime farmland opening the area up to housing. Recognition of interdependencies among the various components of our human and "natural" environments and the adoption of a comprehensive view is impossible without a co-ordinated approach.

Examples of the interrelationships among various components of the biophysical and socio-cultural environment can easily be noted. Location of pollution producing industries should take into account knowledge of climatology since drainage of polluted air into valleys at nighttime can be a critical factor (Lawrence, 1954) as many urban centers are located in valleys, e.g., Vancouver, B.C., Los Angeles, California. In this example one can see the interrelationship between air, land and industrial location. Similarly, misuse of land through poor logging or agricultural practices may result in erosion and (among other things) consequent siltation of streams affecting aquatic habitats, and ultimately man's food supply.

Ignorance of Resource Interrelationships

While the interrelationships of land, water and air are critical these resources are often allocated and managed in isolation from one another. A regional plan is also a plan for land-air-water use although this is seldom recognized by the planning profession. A case in point is the Lower Mainland Regional Plan for the Lower Mainland Region of B.C. (Hope to Vancouver) which ignores the air and water systems as they relate functionally to land.

Partial recognition of the interrelated nature of problems has recently evolved. Soil, water, and air pollution can be seen as a cluster of a closely related problem -- environment contamination

Society's perception and concern for a variety of interrelated problems; such as environmental contamination, unemployment, and poverty defines the metaproblem (Chevalier, 1969). The concept of the metaproblem forces us to recognize the need for a comprehensive approach to problem identification, analysis, and solution.

The Federal Government may be on its way to realizing the existence of metaproblems and treating them accordingly. A conceptual first step in the right direction was taken with the creation of the new Department of the Environment. However, this will only be successful in "solving" metaproblems if all the various sections in the Department of the Environment are co-ordinated in their attacks on metaproblems and the department is also related to the activities of other departments which identify socio-cultural interests of the society. As Chevalier observes:

> "The new scale of organizations and complexity of relationships between organizations will profoundly affect the definition of problems and ... their solution."
> (Chevalier, 1969)

Technological and Economic Bias in the Planning Profession

The last few sections have emphasized the need to approach problems with a view towards their interrelated nature. To date, planners have adopted the traditional view of the "one problem-one solution" approach. This view originates from an over emphasis on the benefits of technology and a heavy reliance on economic theory.

We haven't been able to solve many problems of society because we have been overly preoccupied with technology and its benefits to man without realizing its impacts on our environment. For instance, only a few individuals have objected to the loss of agricultural land caused by expanding urban areas. The technologist responds by emphasizing increased yields and efficiency (in economic terms) on remaining lands due to the application of, for example, fertilizers and pesticides. This view ignores the effects that fertilizers and pesticides have had on our environment.

The belief that technology can provide the solution to all our problems is still quite widespread. Planners should realize the dangers in such a faith. Urban freeways were supposed to reduce travel time but their construction fostered a greater demand for their use. Consequently travel time was not reduced and other problems were created. A deadly combination is the quick technological fix and what Forrester (1969) calls the counter-intuitive responses of dynamic systems.

Society has repeatedly used an economic rationale to justify its action, ignoring the effects of those actions on the environment. Resources have been allocated via the market system. As Black (1969) and Pearse (1968) note, the belief is still prevalent that internal regulation of private business can prevent problems of resource depletion or environmental contamination. As will be pointed out below, a serious flaw exists in this attitude.

The use of resources from the environment by private business often imposes additional costs on other users. The activities of one industry (e.g. waste disposal into a stream) may generate "real" effects upon another industry or entire community (e.g. spending money to clean the polluted water) (Herfindahl and Kneese, 1965). These effects are termed externalities by economists and they cannot be remedied by the market system. The "services" provided by the environment are free and as no prices on environmental media exist the usual market mechanisms are not effective (Bower, 1971). One clear result of this free goods attitude is the scarcity of certain animal species and biological areas. The "irreproducibility" of these unique phenomenon has been ignored by traditional economic theory (Krutilla, 1967).

The planning profession has primarily concerned itself with the analysis of man's economic system, with the extensive use of the tools of economic analysis developed in project and market studies. Examples are seen in the central business district and economic base studies along with cost-benefit analysis. No specific tools, much less a general framework, exist in planning for incorporating man/environment relationships.

Gottman (1961) discussed the rapid urbanization of the Northeastern seaboard of the United States and we are all aware of expanding metropolitan regions. However, schemes developed to accommodate future expansions have assumed unlimited resources and ignored the problems of waste disposal or pollution (cf. Doxiadis, 1966).

The planning profession has given low priority to natural environmental issues (Galloway and Huelster, 1971). When the environmental issues have been identified:

> "... the planning profession has tended either to perceive natural environmental issues in a tangential way, or to take a view so cosmic and catholic that it has been of limited utility in the development of substantive planning theory and methodology." (Galloway and Huelster, 1971).

An Awakening

While this analysis of the planning profession has focused upon the planner's ignorance of complex man/environment relationships there are signs that the profession is beginning to consider environmental impacts in the development of plans and policies. New schools of environmental studies have been established over the past few years at York University and the University of Waterloo and more recently at the University of Calgary. Interdisciplinary studies are relating planning departments to the disciplines of forestry, zoology, and economics (cf. Holling, 1969). City and regional planning agencies are coming into contact with universities through computer simulation studies. While these efforts may point us in the right direction, they do not in themselves constitute a methodology or more important a philosophy that will result in adaptable and open ended planning that actively considers man/environment interrelationships.

PROBLEM SYNTHESIS

The identifiable problems mentioned above can be synthesized into one critical concept. Pollution, the overexploitation of resources and an emphasis on the technologic and economic approaches to resource use and development which result in a deterioration of environmental quality are the result of man's perceived separation from environmental processes. Tuan (1968) and White (1966) trace the separation of man from nature to Christian dogma. Mare (1964) discusses the historical evolution of man's arrogant view of himself as conqueror of nature which emerged during the Renaissance. Wherever the origin may lay man is viewed as the dominant figure and nature as his servant.

The anthropocentric view of the natural environment recognizes few limits to man's economies and societal activities. The anthropocentric notion is self-delusory as it fails to take into account the fact that man is not only a social animal, characterized by highly complex social behaviour, but also a biological one. Therefore, his ultimate bonds are the same that control the lives of other organisms - the environment in which he lives and the genetic framework which he has inherited (Watts, 1970).

Surely, man has the power to alter the landscape to suit only his needs, but does he have the right? This appears to be a question of ethics. Albert Schweitzer has pointed out in his book *My Life and Thought* that a fault of traditional ethical philosophy is that it only dealt with man's relationship to himself and not to his natural environment.

A NEW DIRECTION

Leopold (1949) recognized the need for a basic ethical relationship between man and land. Ethics in this case refers to the mode of guidance relative to an individual's relationship to the community:

> "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in that community, but his ethics prompt him to co-operate ... The land ethic simply enlarges the boundaries of the community to include soils, waters, plants, and animals, or collectively, the land .... In short, a land ethic changes the role of *Homo sapiens* from conqueror of the land community to plain member and citizen of it. It implies respect for his fellow members, and also respect for the community as such." (Leopold, 1949, p. 219).

The "new" ethical basis of man's relationship to his environment must be directly related to the planning process in order to broaden the profession's perspective of man/land relationships. The complexity of today's interventions and the accumulation of interventions over the years requires a broad understanding of organism/environment interrelationships.

The development of an ecological point of view in the planning profession is seen as a new approach so that complex man/environment relationships are recognized in the planning process.

Thesis Rationale

At this time planning theory has no general concept that relates ecological considerations to the planning process. While planners may observe and record facts little progress in the development of an ethical relationship between man and land will arise until a practical model that develops co-ordinative concepts relating man and environment is constructed. Attempts have been and are being made throughout North America to develop such concepts (cf. Hills, 1971; McHarg, 1969). These attempts are in conformity with Kuhn's (1970) notion of the need to initiate exploratory thrusts in different directions to establish the credibility of a new concept. He terms this the pre-paradigmatic phase in the development of ideas. It is in this spirit of inquiry that this thesis is undertaken.

In this thesis the hypothesis approach is forsaken as the concept under development is not amenable to "proof" at this time. The approach is oriented towards the development of a specific concept that assists planners in the rationalization of human interventions into natural systems. This concept arises from a systems view of the world based on a philosophy of viewing the optimum relationship between man and nature as a symbiotic one.

SCOPE AND OBJECTIVES

The land ethic that will supplement and guide economic and social basis for land assignment presupposes a mental image of land as an interacting system. An operational concept which is useful in the analysis of the interacting system is the ecosystem. The ecosystem is the unit which includes all the organisms of a given area interacting with the physical environment so that there is an exchange of materials between living and non living parts (Odum, 1971). Any analysis of an ecosystem must consider the behaviour of the system when all the components are together and man is recognized as one of the important components. As man and environment can be directly related, the ecosystem concept is a logical framework for identifying the ecological implications of land/air/water use options.

The formal structure of a comprehensive ecosystem approach is elaborate (cf. Odum, 1971; VanDyne, 1969), but easily grasped. Most users of the concept have left out substantial portions of the system in order to reduce the number of variables and relationships to be considered. This is necessary as the art of model building is the art of simplifying complicated problems (Lowry, 1967).

It is recognized that the natural environment is but one of several major issues considered in the planning process. However, all planning issues interact to some degree and before "rational" planning solutions can be reached, the planner must be:

1) technically aware of the impact of land/water/air use alternatives on ecological systems, and

2) be in a position to suggest land uses and attendent

strategies arising from knowledge of complex organism environment interactions.

So one can comprehend the potential of the ecosystem concept as a systematic and objective mechanism for evaluating the ecological consequences of human activity, a specific case study area will be chosen. Boundary Bay in the Lower Mainland Region of B.C. appears to be an excellent choice for a number of reasons:

1) Boundary Bay comprises a rich biological environment which is "relatively" simple and comprehendable.

2) An adequate, if not complete, data base is available for the study area.

3) Boundary Bay is readily accessible to a burgeoning population of over one million.

4) Growing population will increase use of the area accentuating present resource conflicts and creating new ones.

5) An international border and Canadian jurisdictional conflicts compound problems in terms of management policies and plans.

6) No fixed policy re: the future development of Boundary Bay.

METHODOLOGY

Chapter II describes the ecosystem concept. Identification of ecological processes through this concept require one to relate two rather distinct bodies of literature: on the one hand that which has alluded to man's structural positions and functional role in the ecosystem, and on the other, that which has been concerned with the development of ecological theory separate from man's impact. A complete synthesis is not within the scope of this paper but the development of the ecosystem concept useful to the planning process using the practical and theoretical aspects of research is possible. The chapter also specifies some general properties of systems that are found in ecosystems.

Chapter III describes the "natural" ecosystem of Boundary Bay. Thus part of the theory in Chapter II is cast in terms of a case study. The physical environment is described and is then related to the biological environment. Man is conceptually segregated from a description of the "natural" ecosystem for purposes of studying the unique attributes of the ecosystem.

Chapter IV describes past and present uses of Boundary Bay and annotates future demand upon the resources. Emphasis is placed on man's demands upon the resource base and his impact upon the ecosystem (i.e., changes in ecosystem structure and function). Future demands upon the area over the next ten years are examined.

Chapter V critically evaluates four development alternatives for the study area and presents a plan and attendent strategies for the development of Boundary Bay. Alternatives are evaluated with the use of the material presented in Chapter III and a proposal that recognizes the integrity of the Boundary Bay ecosystem is developed.

Chapter VI emphasizes the implications of the land ethic philosophy to the practice of regional planning, emphasizing the importance of ecological considerations in the planning process. Changes in the planning process that appear to be necessary are discussed.

CHAPTER II

THE ECOSYSTEM AND THE SYSTEMS CONCEPT

THE ECOSYSTEM - HISTORICAL DEVELOPMENT

The concept of the ecosystem dates back many years. Forbes (1887) use of the term "microcosm" indicated he was aware of the need for ecologists to study species' interrelationships and the conditions affecting the interactions between species and their environment.The term ecosystem itself was proposed by Tansley (1935), a plant ecologist, as the system resulting from the integration of all living and non - living factors of the environment. Thus Tansley gave formal expression to a variety of concepts expressing the same idea emphasizing the most important aspect of an ecosystem: that it is a system composed of interacting parts forming a complex whole.

The first clear exposition of an ecosystem, especially in terms of energy dynamics in ecosystems, was by Lindeman (1942). While Lindeman and a few others recognized the need to emphasize functional relationships, stress was placed on the descriptive order of parts (structure) for many years in ecological study. For example, the "typical" ecology book emphasized the delineation of the individual influences of the environment and separate recognition of the various roles of organisms (cf. Clarke. 1954). Evans (1956) recognized the need for ecologists to utilize the ecosystem concept as the ecologist

> "...is primarily concerned with the quantities of matter and energy that pass through a given ecosystem and with the rates at which they do so...as well as the kinds of organisms that are present in any particular ecosystem and the roles that they occupy in its structure and organization" (Evans, 1956, p.1127).

Odum recognized the importance of Lindeman's and Evans contribution in his classic textbook when he defined ecology as the study of the structure and functional processes of nature and expanded the basic framework of ecological study.

ECOSYSTEM, SYSTEM AND COMPLEXITY

While the concept of a system reaches far back in time there is no general agreement regarding the specific definition of a system. For example, Forrester (1968, p. 1-1)defines it as a "grouping of parts that operate together for a common purpose," VanDyne (1969, p.1) recognizes an "interacting, interdependent complex," and Catanese and Steiss, (1968, p.173) view a system as "any entity, physical or conceptual, which is composed of interrelated parts." The definition of system utilized for this thesis will be - *an interacting and interdependent set of components and processes forming a complex or unitary whole*. This definition of a system emphasizing dynamic interrelationships among components and processes easily relates to the definition of ecosystem presented by Odum (1971, p.8):

> "Any unit that includes all the organisms (i.e. the community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and non living parts) within the system is an ecological system or ecosystem."

A principal attribute of a system is that we can only hope to understand a system by viewing it as a whole. This point cannot be overemphasized as the characteristics of the whole are not explained from the characteristics of the isolated parts. This approach recognizes that the whole is more then the sum of its parts (Bertalanffy, 1968).

Each system has a definite arrangement of parts (i.e., a structure) and performs certain functions. A defined set of procedures or processes also occur as the system moves through various stages over time. Each system:

> "...produces a set of outputs (which are related to its functional aspects). These outputs, in turn have a feedback effect on the system as a whole by providing new inputs in subsequent cycles...." (Cantanese and Steiss, 1968 p. 174).

By determining the structure of a system we learn how its components and processes are related. Knowing the structure and function, the system becomes predictable.

Complexity of systems revolves around three main points:

1) the number of distinguishable parts,

2) the number of recognizable states the parts can assume, and

3) the relationships between different parts of the system under study.

Complexity is handled by scientists in a variety of ways, the most common being a narrowly defined objective and a restriction on the accuracy and length of recording data. The observer is important as he describes the level of discrimination to be used, he selects those specific relationships to be measured and he defines the system boundary according to his interests (Schultz, 1969).

The description of complex systems which contain a number of components and processes involves breaking the system into a series of subsystems (Watt, et. al., 1969). This input/output web presents the complexity of systems while easing the problems of system description. Divisions of the ecosystem into subsystems in this thesis are based on the author's review of the literature in this field (cf. VanDyne, 1970; Odum, 1971) and the needs of the planner. The first basic division is into abiotic and biotic systems.

THE ABIOTIC SYSTEM

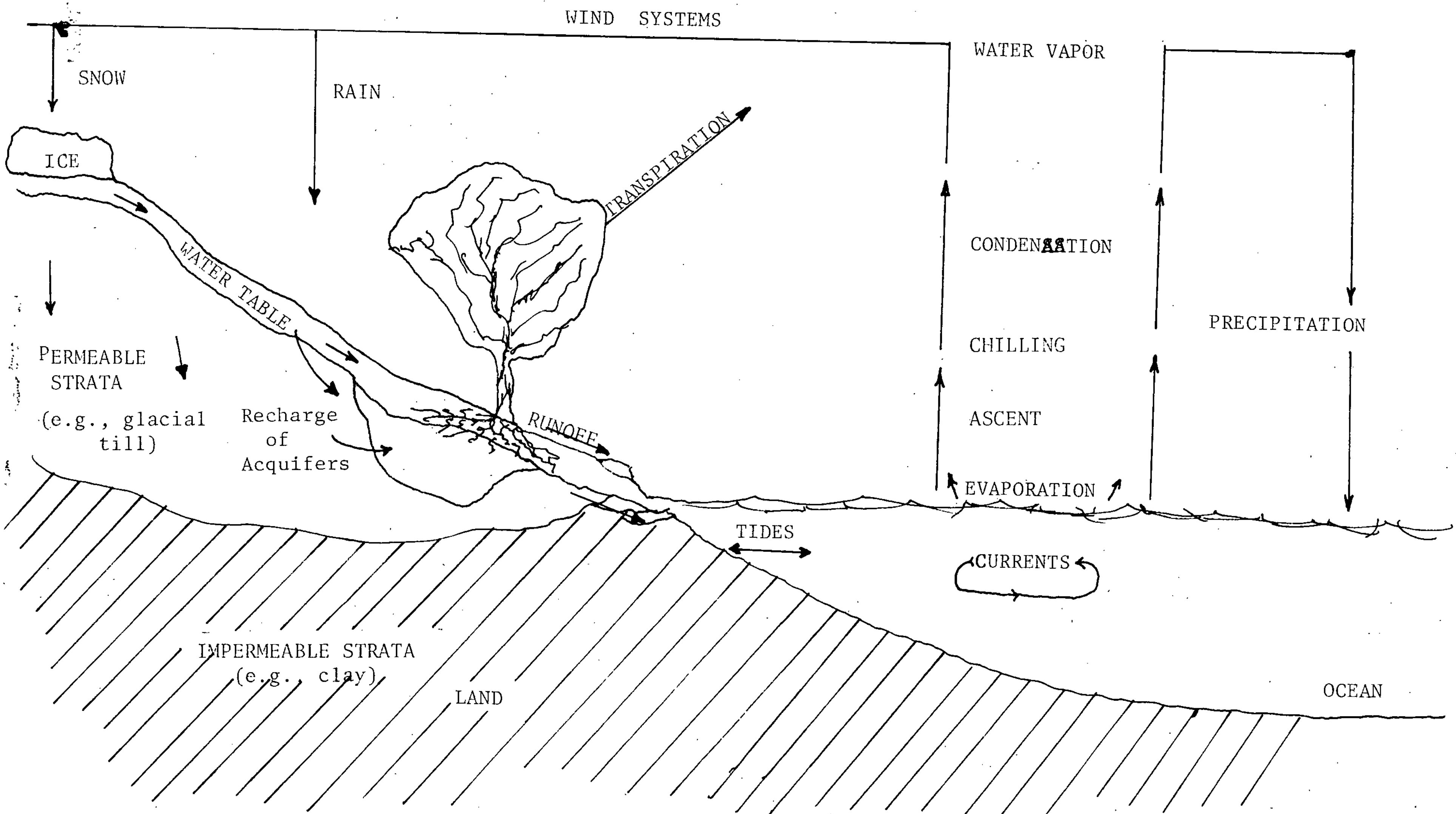
The first subsystem we will focus upon is the abiotic portion of the ecosystem. The abiotic environment in this thesis will contain two subsystems: the hydrologic system and the physical system.

Hydrologic System

Figure 1 presents a general pictorial review of the water or hydrologic cycle. Input of solar energy results in evaporation of water from water bodies and transpiration from the vegetation. Water is then transfered to other areas by wind systems where it returns to earth by precipitation. Precipitation on land causes the underground water table to be recharged and that which is not absorbed returns to the ocean via streams. Circulation in water bodies by currents and tidal action.

We now see that water circulates on the earth in a complex series of pathways known collectively as the hydrologic cycle. A finite supply of fresh water places limits on the numbers of organisms in the environment. Water is also an important medium of transport for materials and organisms and provides a home for a variety of organisms. Man is directly tied to the availibility of fresh water as it is essential to his continued existence. He has affected the hydrologic cycle by reducing ground water reserves through pumping and increasing runoff through, for example, a removal of the vegetation. Generally the concept of the hydrologic system serves to introduce the basics of climate (e.g., wind,

Figure 1: The Hydrologic Cycle
(Adapted from Kuenen, 1955)



rain,...etc.), and provides a general framework for duscussing man - other organism-environment interrelationships as specifically applied to water.

Physical System

Planners have traditionally needed information on the geology of an area (e.g., location of faults), the soils (e.g., bearing strength for structures), and relief (e.g., placement of transporation networks). Ecologists have been more concerned with biogeochemical cycles (i.e., the circulatory movement of elements through the ecosystem), and the relationship of individual factors (e.g., salinity, pH, and temperature) to the chemical requirements of organisms. This section, however, will emphasize individual physical factors and biogeochemical cycles and the case study will place geology, soils, and relief in their proper perspective as one of many factors in the concept of the physical environment.

Physiological interactions of organisms and the distribution and abundance of populations of organisms are directly or indirectly affected by the relative availability of such basic necessities as: water, light, heat, oxygen, and carbon dioxide. There are a variety of factors which produce environmental limitations that restrict the numerical or physiological growth of organisms, among these are: temperature, winds, pressure, pH, and salt concentrations. Ecologists still don't know what most of the detailed physiological responses to particular environmental parameters will be. As all environments are changing continuously, often according to diuranl, seasonal, and annual trends at one and the same time, these responses are much more complex than might appear at first sight. The importance of physical factors from an ecological viewpoint is shown in the principle of limiting factors and the concept of biogeochemical cycles.

The Principle of Limiting Factors

The growth and succes of organisms in terms of abundance and distribution is determined by a set of limiting factors incorporating the two dimensional aspect of "limiting factors." These two dimensions are (Reid, 1961):

1) the environmental supply of nutrients needed for metabolism and growth, and

2) the tolerance of an organism to a given range of environmental conditions and factors.

The first factor incorporates Liebigs Law of the Minimum (1840) which states that an individuals growth is regulated by that essential substance occuring in least quantity.

The tolerance organisms have toward a given range of environmental conditions has developed over a long process of evolutionary selection. This results in a certain biological specialization among organisms. The alteration of environmental conditions has proved especially critical to a <u>population's</u> chance of survival. This is aptly illustrated by man's introduction of synthetic compounds into the environment, which has produced a variety of lethal and sublethal effects. These compounds do eventually take the same biogeochemical pathways as the other compounds essential to life. It is clear that major modifications of ecosystems may result from the use of pesticides although the full effects of pesticides on individual organisms and entire ecosystems are unknown (Watts, 1971).

Ecologists, recognizing the principle of limiting factors, and man's continued modification of the environment, have established water and air quality criteria necessary for the survival of organisms. The criteria recognize the two dimensions to the concept of limiting factors. Minimal quantities of nutrients essential for the existence of organsims are set as are restrictions on the quantity and type of synthetic chemicals in our water and air systems, recognizing the limited tolerance of organisms to many of our synthetic waste products. These criteria have been useful to governments as guides in the establishment of standards and objectives which attempt to minimize the output of those substances affecting plant and animal populations.

Biogeochemical Cycles

Biogeochemical cycles involve functional relationships between organisms and environment as exemplified by the pathways along which the chemical elements essential to life move through. Organisms require at least 30 to 40 elements for their growth and development. As an ecosystem has no extra terrestrial sources of supply the elements (e.g., carbon, nitrogen, sulfur, and phosphorous) must be continually recycled through the ecosysem if it is to persist. There is also a need to understand the principle of material cycling in order to perceive one of the more dangerous and subtle threats to the existence of living organisms. This threat is the potential for severe alteration of ecological systems through chemical pollution.

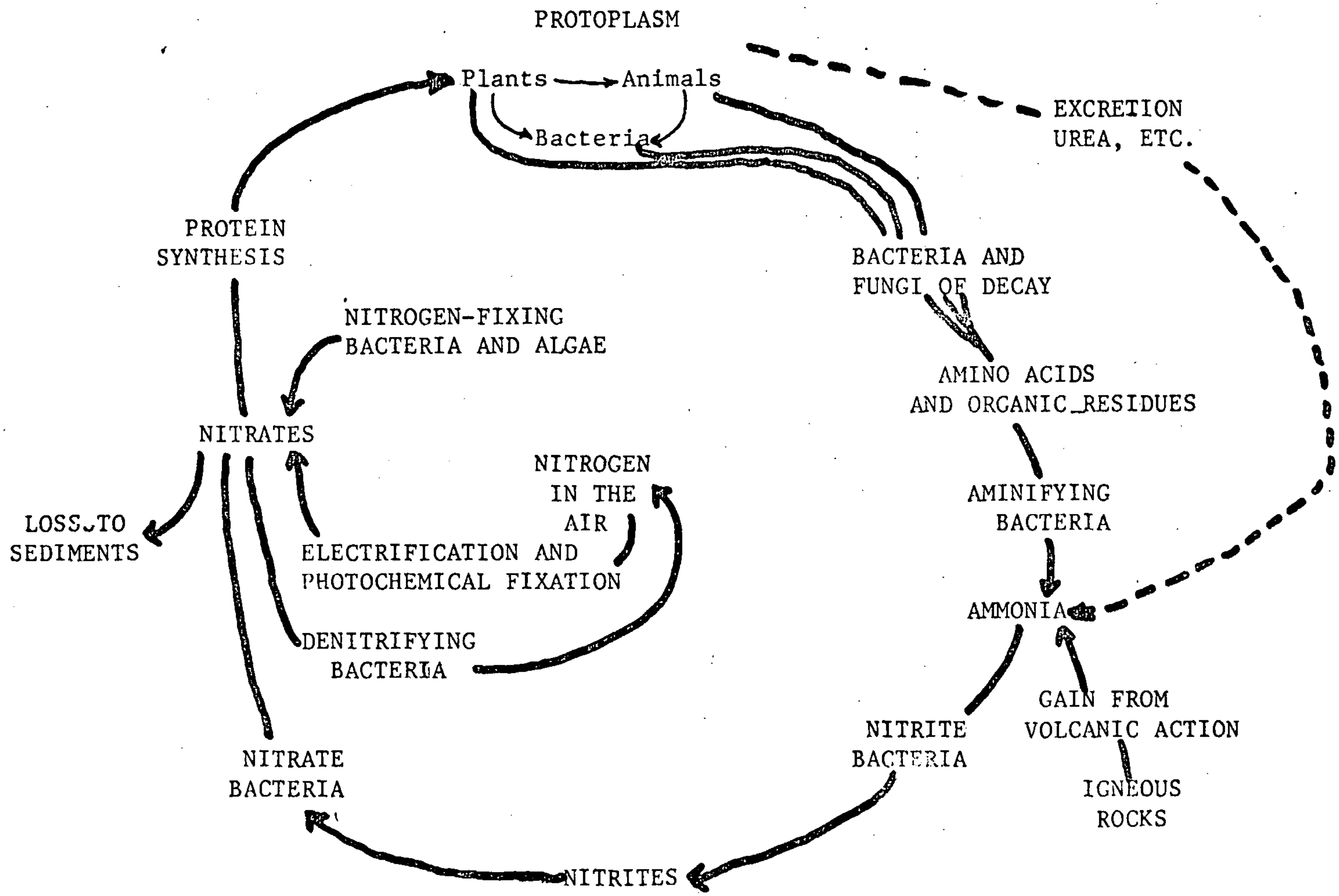
Chemical elements are brought into ecosystems from several pool areas in the ocean, atmosphere, soil, and bedrock. These chemical elements are processed by organisms to form new biological compounds necessary to sustain life. The compounds eventually return to the abiotic environment (poor areas) through respiration, decay, and litter fall (Watts, 1971). Most of the chemical element stocks are maintained by biogeochemical cycles.

The nitrogen cycle, presented in Figure 2, is a complex gaseous-type cycle. This intricate cycle is very important, as nitrogen is a critical component of amino acids, the building blocks of protein. We shall begin to look at the nitrogen cycle in the atmosphere where we find approximately 80% of the gas on this planet (Odum, 1971). A portion of this gas is removed from the atmosphere by microbial action and incorporated into living tissue. This process is called nitrogen fixation. The fixed nitrogen can then be taken up by plants and assimilated into protein. Later this material is either returned to the environment, or is consumed by animals before its return. With the former, its degradation occurs and ammonia is released. This ammonia is changed first into nitrites and then into nitrates by microorganisms through a process known as nitrification. A natural microbial process, denitrification, then removes most of the nitrate by changing it to nitrogen or to nitrous oxide. These forms are lost to air where the cycle is continued.

THE BIOTIC ENVIRONMENT

The living portion of the ecosystem is our next area of concern. We find that the biotic world is organized along a gradient of increasing

Figure 2: <u>The Terrestrial Nitrogen Cycle</u>
(Source:Odum, 1971)



complexity, (e.g.....-cell-tissue-organ-organ system-....etc.). Studies in ecology have essentially been restricted to populations, communities, and ecosystems. A population is a group of the same species which exists within definable limits of space and time. The community includes all the populations occupying a given area. The concept of community arises from the consideration that groups of species exibit interdependent relationships and seem to act as one unit. This is caused by the establishment of interrelationships among species over evolutionary time (Pimentel, 1964).

Concepts Relating to Populations and Species

A convienent starting point is to focus upon the biological nature of populations. Initially there are a variety of population parameters that must be considered. These are presented in Table 1.

TABLE I

POPULATION PARAMETERS

PARAMETERS	DEFINITION	IMPORTANCE
1) Natality	Birth rate	Adds to population
2) Mortality	Death rate	Substracts from population
3) Individual growth rate	$\frac{\text{Biomass Productivity}}{\text{Population}}$	Governs biomass productivity
4) Population dispersal	Movement from place of birth to place of breeding	Continued changes in the spatial and temporal distribution of animals.

Moreover, a variety of factors effect the population parameters and thereby productivity (Watt, 1969):

1) Other organisms of the same species
2) Other organisms of different species
3) Disease
4) Resources (influenced by quantity, quality and distribution of reources over space and time)
5) Weather
6) Site factors
7) Density

Man must recognize the interrelationships of these factors. For example, severe weather conditions may directly or indirectly increase mortality. An animal may freeze to death or he may die because of a reduced food supply caused by severe weather conditions. A shortage of food may also decrease growth rates of populations. Man has had tremendous effects on population numbers and productivity via ruinous exploitation rates and through pollution.

The phenomenon of population growth and decline helps to introduce a general property of ecosystems - feedback. The concept of feedback arises from Control Theory: there are two types (Forrester, 1968).

1) "positive feedback -- generates growth processes wherein action builds a result that generates still greater action," and

2) "negative feedback - seeks a goal and responds as a consequence of failing to achieve the goal."

Population growth is an example of positive feedback as young produce more young when they mature. Such growth is some populations is regulated by density which feeds back (negative) by way of behavioural mechanisms to reduce the reproductive rate thus maintaining a population size within set limits. Feed back is critical as it acts to achieve homeostasis (e.g. maintenance of a steady state) within the system and helps to explain purposeful, adaptive, and regulatory behaviour in systems (Hardin, 1966).

Some feedback processes reacts immediately to changes in population while others react after a long delay (Varley, 1953). For example, predators can immediately increase their rate of attack on growing numbers of prey, but increases in predator density are not felt until the next generation (Holling, 1966). Another example is the dependence of the predaror's attack rate on its nutritional history. These examples point out the effect of temporal lags on systems performance and the historical nature of systems responses. The historical aspects emphasizes that events of one moment are a function of the previous history of the system (Holling, 1969).

The concept of population dynamics is especially useful in determining the effect of man's attempts to harvest populations. For example, the age structure, or number of individuals in any age group, is critical as it partially determines the birth and death rate. Studies of age structure are useful in determining the effects of harvest practices on population vigour and stability. Population analysis is complicated by important factors like migration, dispersal (i.e., movement from place of birth to place of breeding), competition between organisms of the same species as exemplified by territoriality and interspecific competition found in the concept of the ecological niche.

Niche and Habitat

The concepts of niche and habitat is usually found in a discussion regarding species in a population. The habitat of an organism is the particular environment, both living and nonliving, it occupies.

In addition to occupying space an organism performs a function. This role an organism plays in the environment is refered to as the niche. Some species feed on a variety of plants, animals, insects, etc. and have a broad ecological niche while others are more restricted and have specialized niches.

The respective niches of organisms are the result of a long periof of evolutionary selection. As nottwo species in a community occupy the same nich species tend to complement each other. Species may have a niche in more than one geographic area as do migrating species. Niches may change throughout the life history of an organism as it may have different food requirements at different stages of its existence. The concept of the niche is especially critical in reference to the introduction of exotic species of plants or animals into the receiving community.

Community Energetics and Organization

The community is the living portion of the ecosystem. Emphasis in this discussion is on the structure and function of communities and ecosystems. Aknowledge of structure and function is essential before interventions by man take place.

Energy Flow

Our initial concern will be community energetics or the initial input of energy and how it flows through the community to be utilized by its members. Initial input of solar radiation, water (HOH), and carbon dioxide (CO_2) to green plants results in primary production. This is the storage of energy by the creation of tissue using the photosynthetic and chemosysnthetic activities of the producer organisms. The conversion of the light energy of the sun to energy of chemical bonds in photosynthesis is is accordance with the 1^{st} law of thermodynamics as energy is neither created nor destroyed. The stage at which the suns energy is transfered into utilizable energy is termed the first trophic level (Odum, 1971). The organic matter is then consumed by primary consumers (hervirores of the second trophic level). Storage of energy by the consumers is termed secondary production. This "energy" is then eaten be members of a third trophic level - the secondary consumers.

Green plants are primary producers, herbivorous animals are primary consumers and carnivores and scavengers are secondary consumers. Decomposers then utilize the dead debris of plants and animals and take in the remaining energy, releasing CO_2, H_2O and heat. A by-product -CO_2- is released in respiration by the various organisms and photosynthesis continues with CO_2 and additional inputs of sunlight.

The transfers of energy between trophic levels is in accordance with the 2^{nd} law of thermodynamics as there are losses of usable energy. The consequence of this law is that no transfer of energy is 100 percent efficient. For example, only about 1% of the suns energy falling on green plants is converted to usable energy and about 10% of this is actually consumed by animasl. This is why grains constitute a large portion of man's diet - greater efficiency of production.

A difficulty arises in placing animals at specific trophic levels. Many animals are omnivorous and cannot be assigned to any one level (Phillipson, 1966). Analysis of ecosystems must therefore emphasize the various niches an animal may occupy in ecosystems in relation to trophic structure.

Trophic Web

The structure and function of a community can be described in terms of the structure of the trophic web in that community. A trophic web is the branches and cross connections between a variety of food chains. A food chain is the transfer of food energy from the primary producer through a series of organisms with repeated eating and being eaten (Odum, 1971).

The structure of the trophic web is a complex network of food and feeding relationships of plants and animals. Man is constantly changing the organizational structure of plant and animal communities by annihilation of species, creation of monocultures through his agricultural practices, and by forest management practices based on harvesting one species of trees at a given age. The effects of these changes may be quite different at different trophic levels. It appears that a short and simple trophic pyramid constitutes the best way to utilize the output of the ecosystem from the standpoint of community energetics (Watt, 1969).

There is a tendency toward the concentration of toxic substances as one goes up the trophic level via the food web. This concentration is characteristic of those substances which exibit high solubility in fatty substances and low solubility in water (e.g., dichloro diphenye trichloro-ethane -DDT). Man must develop more sophisticated measures of pest control least he be the victim of his own pesticide.

Succession

The influence of the biotic community on the physical environment of the ecosystem prompts discussion of another important concept, that of succession. The complexity of succession is recognized by Odum (1969) as he incorporates three characteristics in his definition:

> "(1) Succession is the orderly process of community changes; these are directional and, therefore, predictable. (2) It results from the modification of the physical environment by the community. (3) It culminates in the establishment of as stable ecosystem as is biologically possible on the site in question."

Ecosystems with no disturbance from the outside change in a progressive and directional way. The "end" product of this successional change, termed the community climax, is a steady state exibiting equifinality. Equifinality means that similar climax formations may develop from different initial vegetations (Whitticker, 1952). The final* state that results from this directional change will be altered if the initial conditions vary or the course of natural changes is altered. Therefore, the steady state is independent of initial conditions and is determined by system parameters which vary with time.

Most ecosystmes are characterized as open systems, ass they need an energy supply for maintenance and preservation. Open systems also exchange energy and materials with other systems and this causes directional changes in the system. The direction is ecosystems is towards a steady state with minimum entropyoor, conversely, high internal order (Odum, 1971). High internal order of ecosystems can refer to the filling of all available niches in an ecosystem. The process of succession also tends toward both the steady state and minimum entrophy.

* Final is a bit misleading as some degree of change is always occuring in communities.

The principles of ecological succession are very relevant when considering man's modification of ecosystems. A listing of these principles is presented in Table 2. An expanded discussion of these principles is helpful:

1)Community energetics: The Production/Biomass ratio refers to the flow of energy per unit biomass and the importance lies in the empirical relation between structure and energy fow per unit biomass. As P/B approaches 1 energy fixed tends to be balanced by the energy cost of maintenance. As P increases efficiency usually decreases. Addition of nutrients into a lake results in Production/Respiration more than 1 and the system is pushed back to an earlier stage.

2)Community Structure and Life History: There is a tendency toward increased variety and decreased dominance of species over the long run . Margalef (1963) suggests larder species are the result of greater storage capacities in animals annd more complex life histories. Thus animals are adapted to exploiting seasonal or periodic releases of nutrients more common in mature ecosystems.

3)Nutrients and Growth Form: Various studies have shown that nutrient pathways are increasingly refined as an ecosystem matures. Thus small amounts of nutrients are lost from ecosystems. Reproduction rates of organisms tend to stabilize after a time.

4)Overall Homeostasis: The strategy of ecosystem development results in maximum protection from environmental perturbations as exemplified by increased symbiosis, nutrient conservation and diversity of structure. While the degree and rates of changes as well as the time required to reach a steady state may vary the end result is the same

TABLE 2

EXPECTED TRENDS IN ECOSYSTEM DEVELOPMENT
Adapted from Odum (1969)

ECOSYSTEM ATTRIBUTES	DEVELOPMENTAL STAGES	MATURE STAGES
Community Energetics		
1. Gross production/community respiration (P/R rating)	Greater or less than one[1]	Approaches one
2. Gross production/standing crop biomass (P/B ratio)	High	Low
3. Biomass supported/unit energy flow (B/E ratio)	Low	High
4. Net community production (yield)	High	Low
5. Food chains	Linear, predominantly grazing	Weblike, predominantly detritus[2]
Community Structure		
6. Total organic matter	Small	High
7. Inorganic nutrients	Extrabiotic	Intrabiotic
8. Biochemical diversity	Low	High[3]
9. Pattern diversity	Poorly-organized	Well-organized
Life History		
10. Niche specialization	Broad	Narrow
11. Size of organism	Small	Large
12. Life cycles	Short, simple	Long, complex

ECOSYSTEM ATTRIBUTES	DEVELOPMENTAL STAGES	MATURE STAGES
	Nutrient Cycling	
13. Mineral cycles	Open[4]	Closed
14. Role of detritus in nutrient regeneration	Unimportant	Important
15. Nutrient exchange rate between organisms and environment	Rapid	Slow
	Selection Pressure	
16. Growth form	Intrinsic rate of increase	Growth oriented towards an upper assymptote
	Overall Homeostasis	
17. Internal synbiosis	Undeveloped	Developed
18. Nutrient conservation	Poor	Good
19. Stability (resistence to external perturbations)	Poor	Good
20. Entrophy	High	Low

---

[1] As an example organic pollution P/R less than one.

[2] Various reasons for reduced grazing - one example increased predation.

[3] Increase in variety of plant pigments.

[4] Eg., need for fertilizer in commercial crops production.

-- maintance of structural integrity and stability of functional relationships.

The general relevance of the development sequence to land water use planning is emphasized through the following "mini model" (of Table 2) which considers 6 general characteristics of young and mature ecosystems (Odum, 1972):

Young Ecosystems	Mature Ecosystems
Production	Protection
Growth	Stability
Quantity	Quality

Man's system emphasizes maximum production (in terms of highest caloric yield) as opposed to the ecosystems goal of maximum protection from environmental perturbations. Thus it is not surprising that we have experienced a variety of problems in integrating our social system with the natural functioning of ecosystem processes. Forestry and agricultural practices prevent maturity of ecosystems and emphasize production. Monocultures tend to invite pest outbreaks and hybridization to increase production has resulted in a breeding out of natural and chemical defenses of plants.

Man's system (in terms of trends in ecosystem development) is in youth as exemplified by a high birth rate, rapid economic growth, and exploitation of immediately accessible and unused resources. Man's system must recognize that essential life cycle resources, recreational, and aesthetic are only provided by "less productive" landscapes. Man must mature and, for example, reduce the birthrate and begin to recycle more of his resources. More emphasis must be placed on planning the entire landscape with a variety of environments providing a diversity of choice.

While it is impossible to have all six characteristics of young and mature ecosystems at the same time, planners should recognize the desirability of having all six characteristics in the aggregate. Moderate quality and moderate yield of all the landscape can result from a compromise or we can compartmentalize the landscape so as to obtain high production units and predominantly protective units with different planning strategies applied to each unit (Odum, 1972). A compartmental approach over the long run emphasizes the determination of limits to the manipulation of each compartment before stress in ecosystems is manifested.

STRESS IN ECOSYSTEMS

Symptoms of stress in ecosystems signify the limits to which the system can respond to environmental changes. Stress is manifest throught the alterations in the abundance and distribution of entire populations with attendent changes in growth, births, deaths, niches, etc. It also refers to externally imposed changes in community structure and function (e.g., alteration of successional stages). Change itself does not necessarily precipitate a dramatic chain reaction of responses by species of the community because they have experienced changes over their evolutionary history. The system has built up an internal resilience or elasticity and can adapt before a change in the structure of the state of the system occurs (Holling, 1971). Slow environmental changes over a long period of time allow a system to change its state naturally by means of adaptive evolution.

Man places stress upon ecosystems because his changes are too sudden, violent, or arhythmic for adaptive change. The limits of internal resilience are exceeded and the system is dramatically altered. For example, consider the Great Lakes. Man has drasticly altered this system:

1) with massive inputs of pollution which has accelerated the natural (successional) process of eutrophication (i.e., nutrient enrichment) by 150,000 years,

2) by inadvertantly introducing sea lampreys to the upper lakes through the Saint Lawrence Seaway, and

3) by poor regulation of the commercial fishery which has severly affected the present and future potential of the fishery harvest (Charlier, 1969).

As a result the water is unfit for most uses without heavy treatement and desirable species of fishes have been disappearing as undesirable species (e.g., the lamprey) have increased and taken their place.

SUMMARY AND CONCLUSIONS

In manipulating the ecosystem man has seldom foreseen the full consequences of his actions. Planners must recognize the limited adaptability of ecosystems to survive human interference and incorporate considerations of internal resilience --chemical, physical and behavioural threshoulds - into plans and policies. The complexity of the ecosystem demands a rational framework of analysis. In managing or manipulation of the ecosystem man must recognize that is is capable of only limited explotiation. These limitations should set constraints on man's behaviour and the ecosystem concepts itself should constitute the conceptual framework for questioning the potential impact of his actions on the environment.

CHAPTER III

THE BOUNDARY BAY ECOSYSTEM

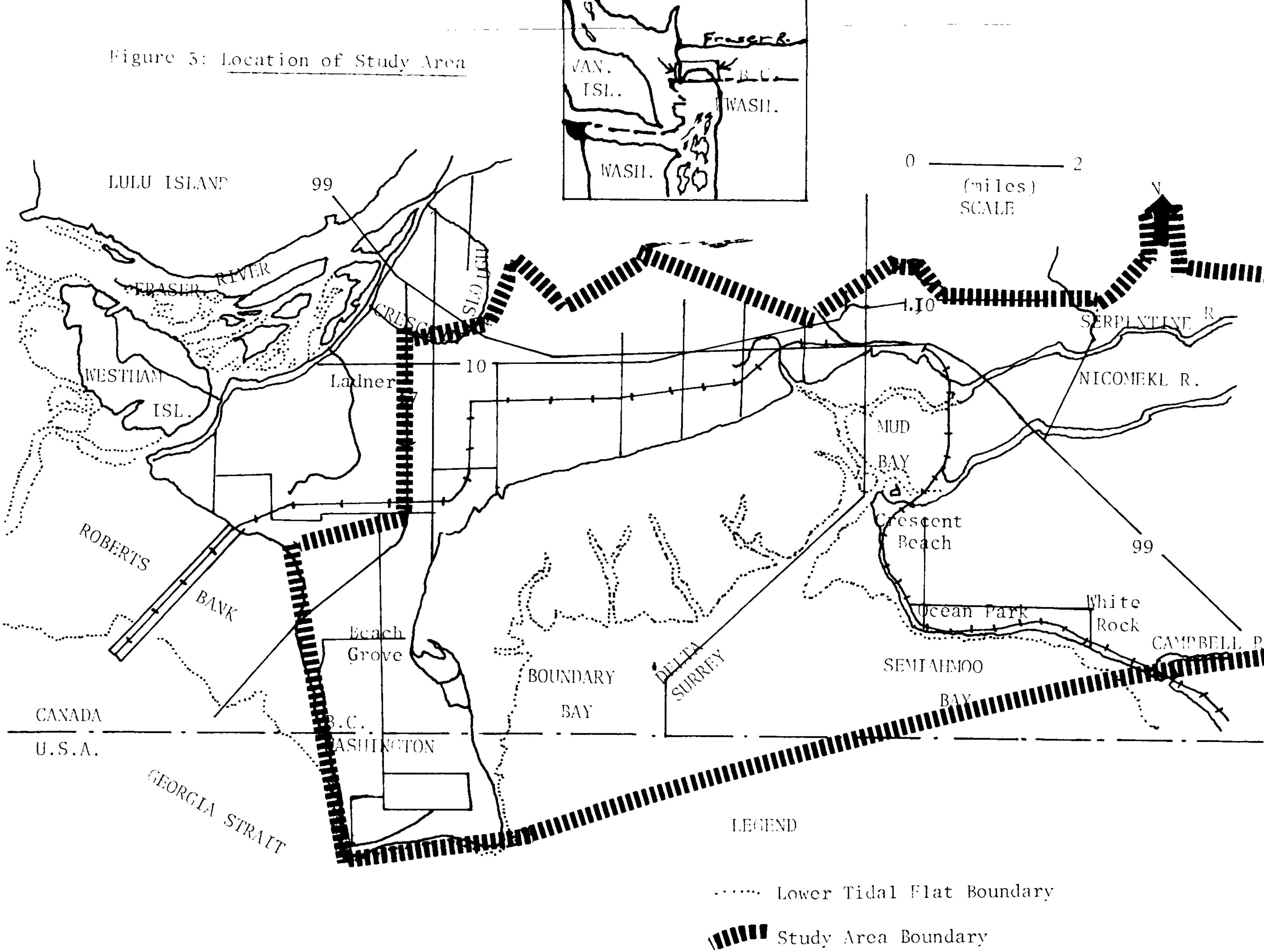
LOCATION OF STUDY AREA

As Shown in Figure 3, Boundary Bay lies on the south side of the Fraser River Delta in the Lower Mainland Region of British Columbia, approximately twelve miles south of Vancouver. The study area is outlined in a solid black line. Beginning in the southwest the Point Roberts and Beach Grove areas are included. Continuing north along Highway 17 the western boundary is terminated at the junction of highways 17 and 99. The northern boundary is a terminated a border between a peat bog on the west and a high plateau on the east with farmland to the south. The eastern boundary is located for the author's objectives as there were no "convenient" physiographic, ecological differences. Semiahmoo Bay and the waters between Semiahmoo and Point Roberts are included, due to the interchange of nutrients and water with Boundary Bay. The term Boundary Bay used throughout this thesis includes Mud Bay, Semiahmoo Bay (inclusive of their tidal flats) and all the waters between Semiahmoo Bay and Point Roberts. The upland areas, to the study area boundary, and Boundary Bay are termed the study area.

THE PHYSICAL ENVIRONMENT OF BOUNDARY BAY

The chosen physical variables are important as they:

Figure 5: Location of Study Area



1) partly determine the potential production of plant and animal communities, and

2) constitute part of the initial limitations to development by man.

The physical parameters are discussed under two headings:

1) the mineral-organic matrix including aspects of geology, topography, sediments, and soils; and

2) the Hydrologic system.

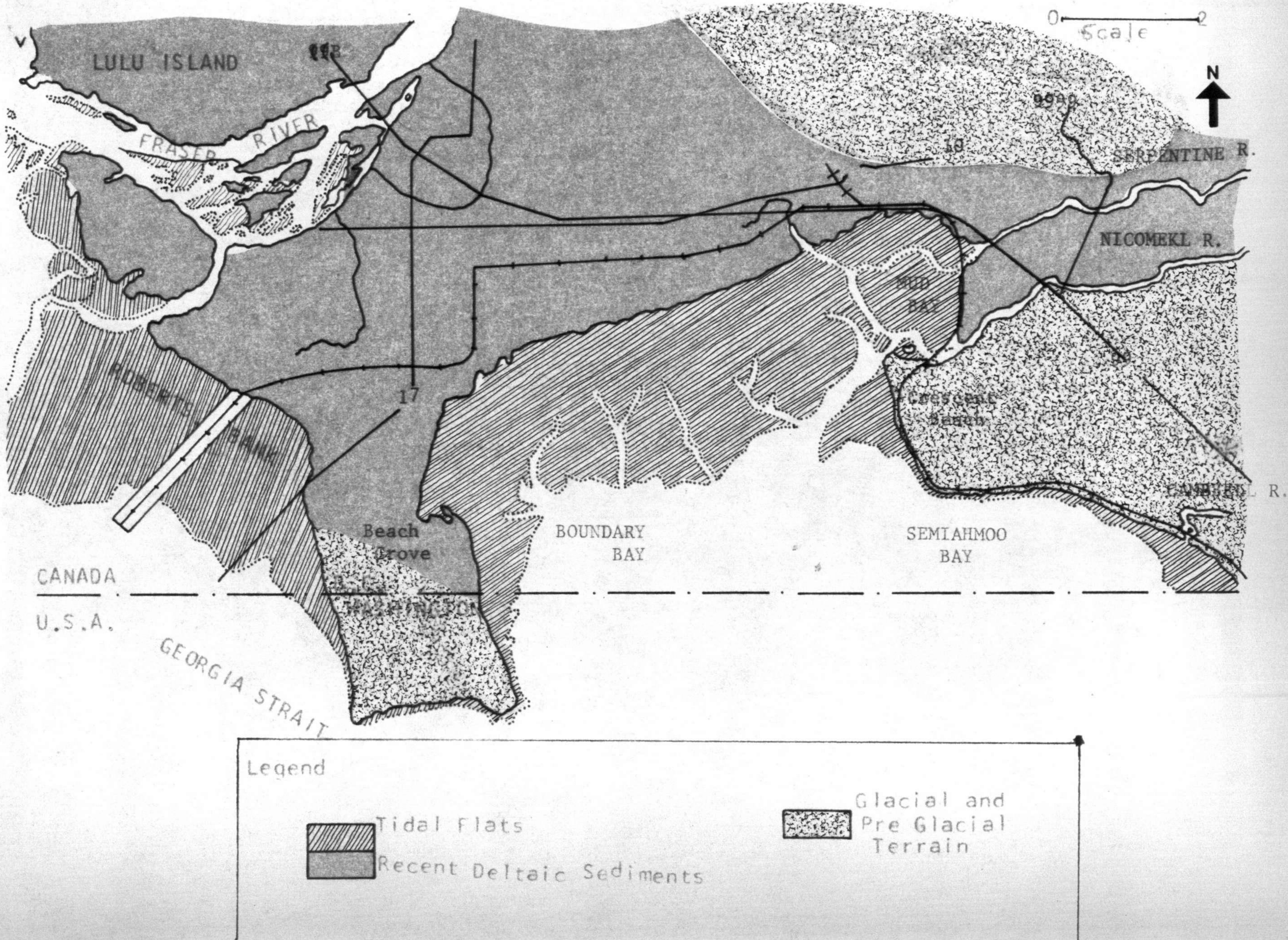
Mineral-Organic Matrix

Geology

The geology of Boundary Bay (Figure 4) is a reflection of its proximity to the Fraser River and the initial influences of glacial (sand and gravel) outwash from the Fraser. (Glacial outwash is sand and gravel deposited by streams issuing from glaciers.) Although the Fraser River no longer directly affects Boundary Bay, the extensive tidal flats at Boundary Bay were deposited by the river which at one time emptied into Boundary Bay. These are referred to as "sub-aqueous topset beds" by Mathews and Shepard (1962). Bedrock, lies approximately 2000 feet underneath these beds.

Flanking the tidal flats to the west is the Point Roberts Peninsula, an island-like drift hill joined to the mainland by the advancing Fraser River Delta (Johnston, 1921). The peninsula, of Pleistocene age, plays an important role in separating the active western part of the Fraser Delta from Boundary Bay. The area north of the Bay is the Fraser Delta composed of recent (less than 8000 years old)

Figure 4: Geology of Study Area
(Source: Kellerhals and Murray, 1969)



deltaic sediments. The area south and east of Crescent Beach and the aforementioned Point Roberts Peninsula are comprised of Pleistocene glacial tills and fluvio-glacial deposits (Garrison, *et.al.*, 1969).

Topography

The relief of the study area is quite varied. A large section of the study area which is nearly flat, averaging 4 to 5 feet above mean sea level, corresponds to the location of recent deltaic sediments in Figure 4. To the east and west of Boundary Bay itself the land rises to a maximum of 350-425 feet above mean sea level being associated with the glacial and preglacial terrain outlined in Figure 4.

Boundary Bay gains its distinctive character from its tidal flats. Tidal flats are the muddy areas between lines of mean high and mean low tide with a small gradient of elevation change. They usually occur on coasts where tidal range is high, where a lot of sediments are contributed to the sea, where the waves are unable to beat in full force against the shore and where the dip of the sediment/water interface is low. All of these factors are present in Boundary Bay. Tide flats in the Bay "... dip uniformly seaward at 1.1 ft./1000 ft. from an elevation of +4 feet (mean high tide) to -8 feet (mean low tide) approximately 2.5 miles offshore. Farther seaward the sediment water interface steepens to about 2.5 ft./1000 ft. down to -20 ft. elevation, beyond which another relatively flat bottom is present" (Kellerhals and Murray, 1969, p. 70).

Modification of the "uniform dip" occurs with tidal channels (five in number) and gullies at the lowermost portion of the tidal flats. The tidal channels in Boundary Bay serve two purposes: they facilitate tidal exchange and expedite sediment removal. The main channel which cuts obliquely across the tidal flat area marks the joining of the Nicomekl and Serpentine Rivers on the east and a small drainage channel on the north. Landward from the lower tidal flats is an area of "intermediate" tidal flats characterized by incomplete drainage with water remaining in shallow depressions at ebb tide. This area experiences long periods of exposure and submergence. An interesting aspect of the topography is that the shoaling effect of the tidal flats absorbs the bulk of the storm waves and reduces storm wave height (BACM, 1970).

Soils

The Point Roberts area is of Pleistocene origin and it is comprised of glacial till. Approximately one-third of the area is classed as agricultural land by the United States Department of Agriculture but agriculture is limited due to poor drainage.

The fertile lowland soils have their origin in the deltaic deposits of the Fraser, and form the prime agricultural soils as they are protected from the salt water by a system of dykes. The soils map (Figure 5a) provides a basic overview of soils suitable for different types of agricultural uses. Figure 5b presents information on foundation conditions and slope in excess of 20%.

Surface Sediment Distribution

The surface sediment distribution in Boundary Bay is shown in Figure 6 and the discussion below on the distribution of the sediments comes from Kellerhals and Murray (1969).

Cobbles and Pebbles

The gravel derived from the Pleistocene uplands of Point Roberts

Figure 5a: Agricultural Soils, and Slope Greater Than 20% (Source: Greater Vancouver Regional District Base Maps)

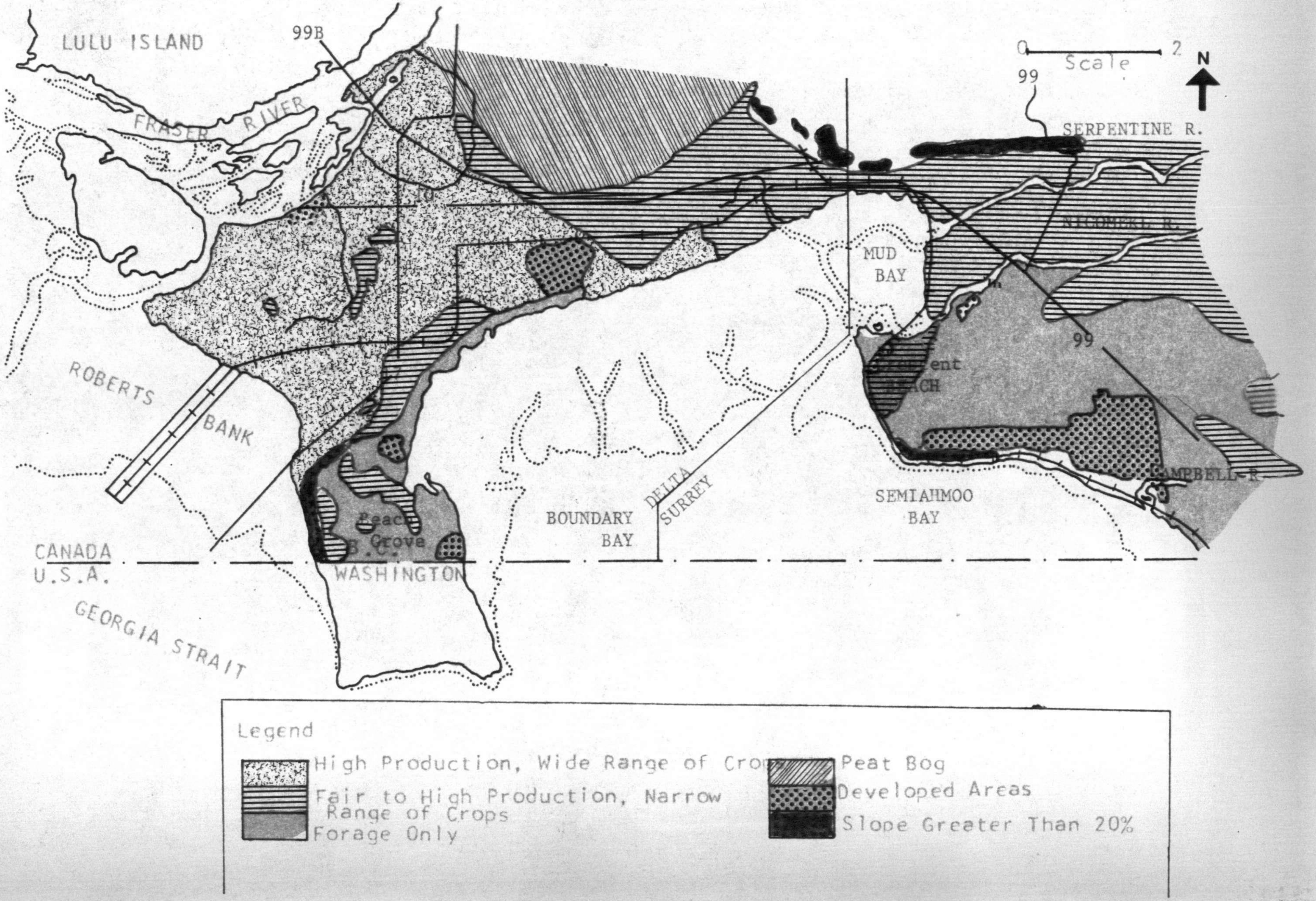


Figure 5b: Foundation Conditions
(Source: Greater Vancouver Regional
District Base Maps)

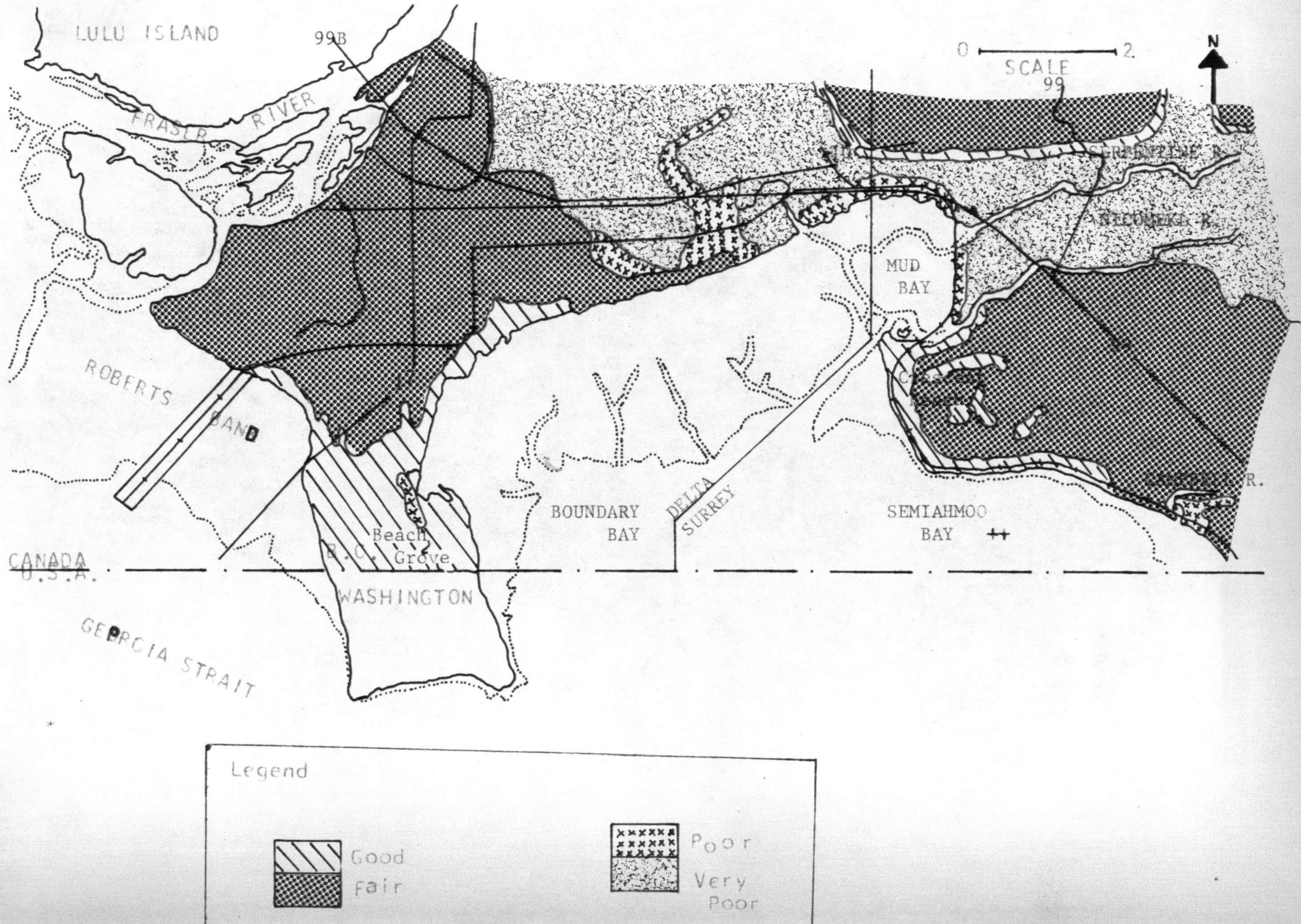
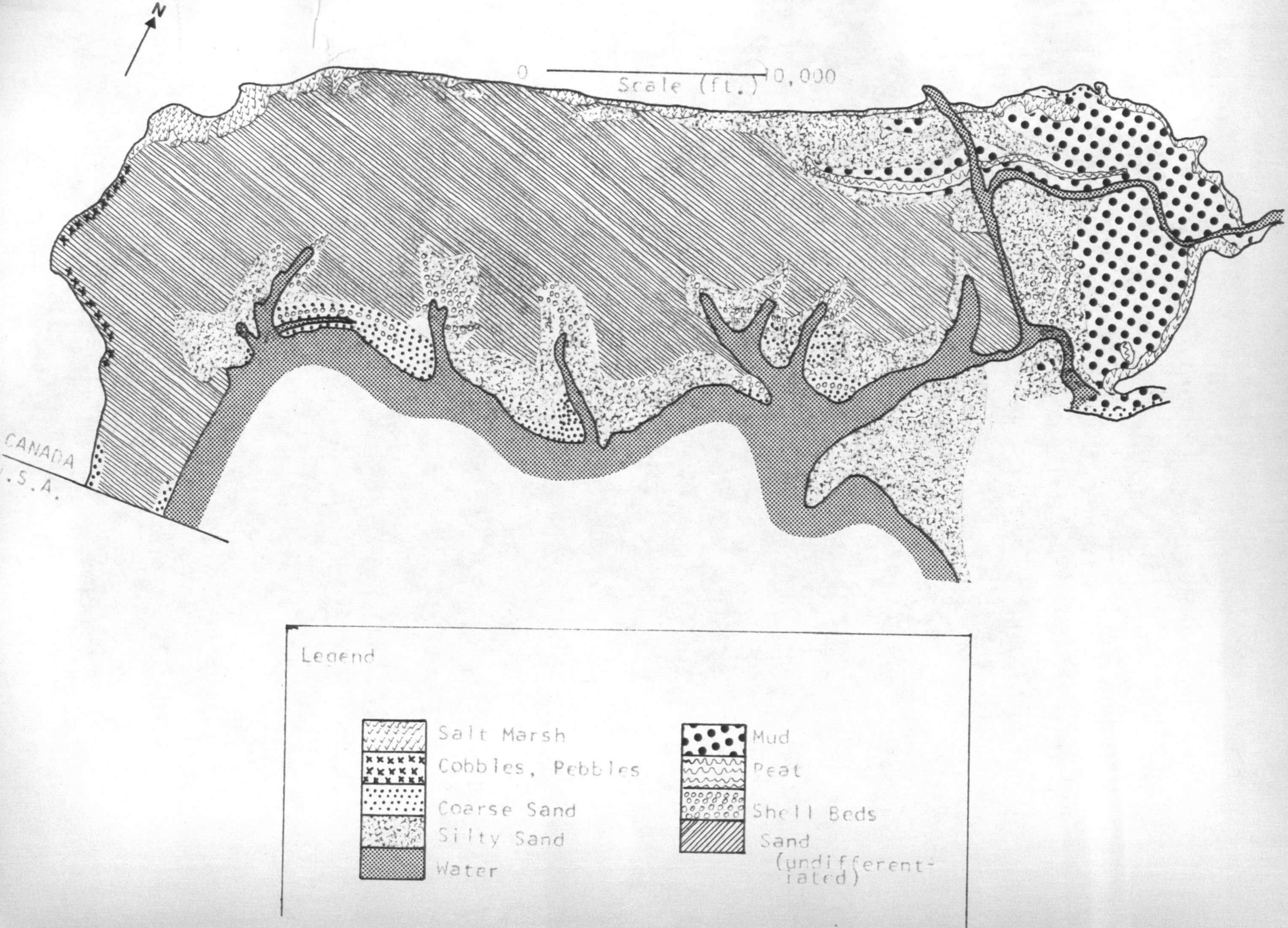


Figure 6: Surface Sediment Distribution On the Tidal Flats of Boundary Bay (Source: Kellerhals and Murray, 1969)



lies in a restricted area on the beach on the northwest side of Boundary Bay as the current is not capable of transporting this material very far.

Sands

Coarse sand lying on the outer edge of the tidal flats is probably a result of heavy wave action but is partially derived from the erosion of the Pleistocene sediments of Point Roberts. Silty sand is the dominant bottom sediment in the western part of Mud Bay (Northcote, 1961). An analysis of the mica content suggests the Fraser River is also an important source of sand for Boundary Bay. Undifferentiated sand lies on the seaward border of algae mats and is derived from the eroding Pleistocene uplands.

Mud and Peat

Northcote (1961) suggests these sediments are of glacial origin. Three main sources of sediments are:

1) the supported sediment load of the Nicomekl and Serpentine Rivers,

2) eroded cliffs of the area around Point Roberts and White Rock, and

3) suspended sediment brought in by the tides and currents.

The Nicomekl and Serpentine River Valleys consist mainly of peat underlain by impervious layers of clay and silt (Sprout and Kelly, 1961). In addition a large peat bog marks the northern boundary of the study area.

Salt Marsh

Salt water marshes occur when sediments from fresh water drainage systems raise the surfaces of tidal flats above mean high water level (Odum, 1971). A salt marsh occurs at the northern fringe of the tidal flats and varies in width from a maximum of 2000 feet in the west to tens of feet in the east. A smaller marsh, approximately ten acres in size occurs near the foot of Oliver Road where a small ditch enters the Bay. This ditch marks the eastward end of Boundary Bay and westward limit of Mud Bay. Three-quarters of a mile east, a marsh of about sixty acres in size is in the form of a long eastward running spit. An extensive marsh of about 225 acres is located between the Serpentine and Nicomekl Rivers. Sediments consisting of peat, silty clays and sand are present in the marsh. At the edge of the marsh one finds disarticulated shells washed up by storms. Erosion of the salt marsh is occurring in the eastern part of the area.

Shell Beds

Shell beds are present on the lower tidal flat area near the numerous channels. The majority of the shells are broken with the identifiable shells of the common blue mussel (*Mytilus sp.*), the horse clam (*Schizothaerus sp.*), the butter clam (*Saxidomus sp.*), the cockle (*Clinocardium sp.*), and a few oyster fragments (*Ostera sp.*) present (Taylor, 1970).

Summary

The distribution and abundance of sediment in Boundary Bay is controlled by a variety of factors:

1) turbulence of the water,

2) current direction,

3) source of sand, and as we shall see

4) members of the community in any given area.

The Hydrologic System

Climate

If one uses Koppen's climatic classification scheme, available data shows that Boundary Bay lies within a cool summer Mediterranean climate. In comparison with the rest of Canada, this climate is unique as it is quite moderate. The area is protected from direct exposure to rain storms arriving from the west and southwest over the Pacific Ocean by the mountains of Vancouver Island and the Olympic Mountains of North-west Washington. Good climate data can be obtained from data of nearby stations (Table 3). Additional data is provided for Ladner as it closely approximates the climate of Boundary Bay.

The nearest weather station providing data on sunshine is the Vancouver International Airport which records 1922 hours per year. There is every reason to believe that Boundary Bay receives more sunshine than the airport. The growing season extends from mid-March to late November or early December with an annual frost free period of 200 days (Taylor, 1970). Temperatures in Mud Bay are probably higher in summer as larger areas of sand and mud are laid bare at low tides. These tidal flats are also the location of ground fogs in winter.

Taylor (1970) suggests the winds in Boundary Bay are similar to those recorded at Vancouver International Airport. Apart from the familiar afternoon sea breezes characteristic of coastal areas,

TABLE 3.

METEOROLOGICAL INFORMATION AVAILABLE FOR THE STUDY AREA
(Source: *Climate of British Columbia*, 1966)

AREA	AVERAGE TEMPERATURE (^{o}F)			AVERAGE PRECIPITATION (In.)			SNOWFALL (In.)
	Annual	June, July, August	November, December, January	Annual	June, July, August	November, December, January	Annual
Ladner	49	60.3	39.6	37.8	1.3	5.5	14.2
White Rock	50	61.1	40.3	41.2	1.4	5.7	14.2
Vancouver International Airport	50	62.0	39.3	41.6	1.4	5.8	19.2

FROST DATA
(Source: Chapman, 1952)

	Number of Years	Average Frost-free Period	Last Frost			Early Frost		
			Early	Average	Late	Early	Average	Late
Ladner	34	182 days	Apr. 8	March 7	June 17	Sept. 3	Oct. 17	Dec. 5

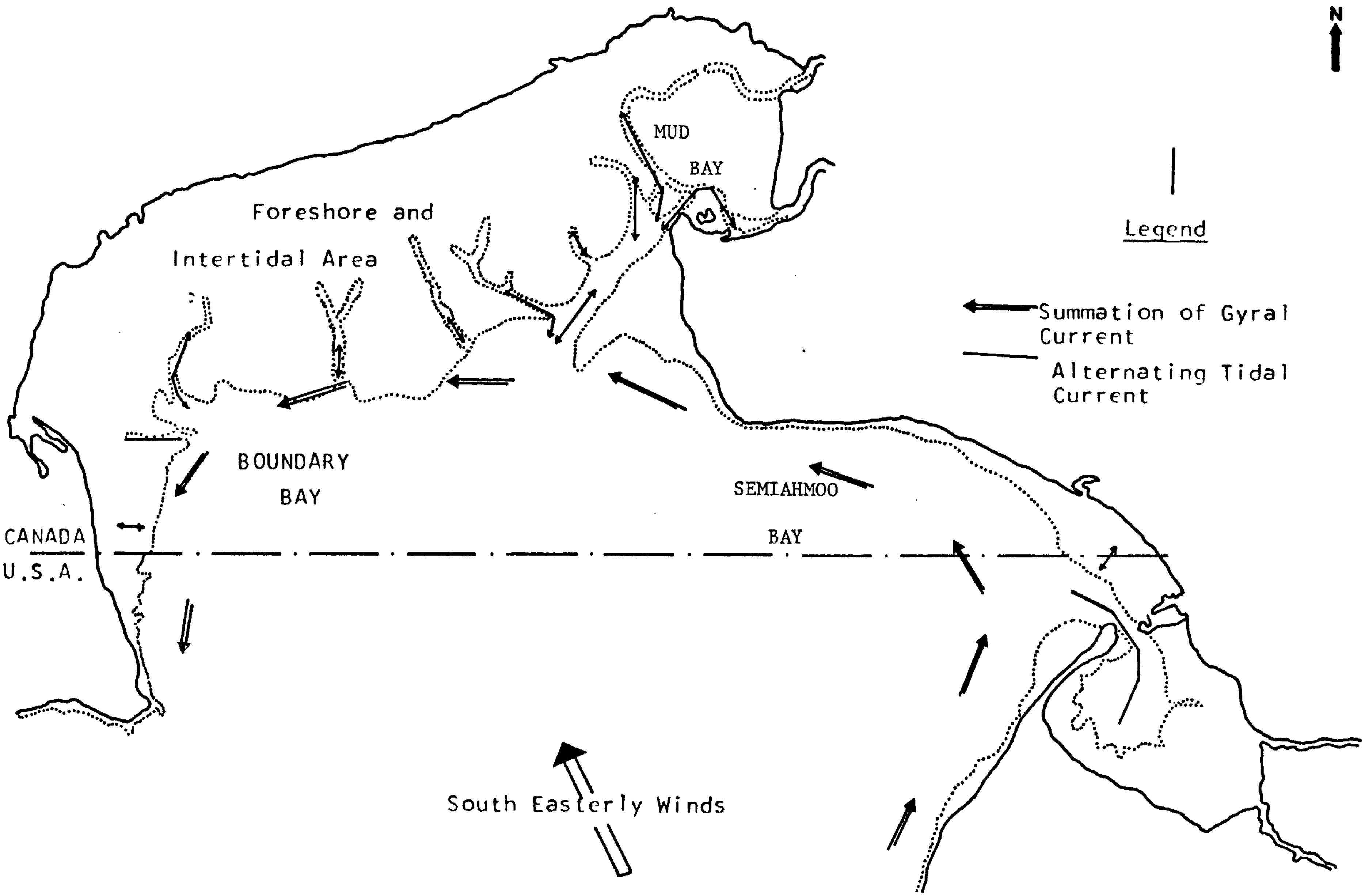
prevailing winds tend to be from an east to southeasterly direction in winter and a slight shift to the west in summer. October and November see the days of the strongest winds in the area although from personal observation Mud Bay appears to be protected from the stronger winds by its indentation from Boundary Bay. Winds are important when water depths are small as they modify tidal flow and currents.

Currents and Tides

Ocean currents in the region are from the south flowing in a northerly direction through the Strait of Georgia. This flow pattern is modified in Boundary Bay as wind plays an important role in the movement of surface currents, as it generally does in all bays and inlets. In Boundary Bay wind driven surface currents travel in a counter-clockwise direction (Church and Rubin, 1970). The wind and currents are perfect examples of transport media that connect the ecosystem of Boundary Bay with its outside environment (Figure 7).

Tides enter the Bay from the south alternately filling and draining the tidal flats via the tidal channels. Thus the bottom topography affects the strength and direction of the tidal streams. Flood (incoming) tides entering the bay are more concentrated on the eastern side (Taylor, 1970) while ebb (outgoing) tide is more concentrated on the western side (Taylor, 1970). Taylor also notes the semi-diurnal nature of tidal movements with two high waters and two low waters each day. Ebb tide velocity was recorded by C.B.A. Engineering Ltd., of Vancouver, B.C. in 1959 and the maximum velocity was 83.8 cm./sec. Tides are critical as they provide the main source of energy for rapid nutrient cycling.

Figure 7: Winds and Currents in Boundary Bay
(Source: Church and Rubin, 1970)



Rivers and Land Drainage

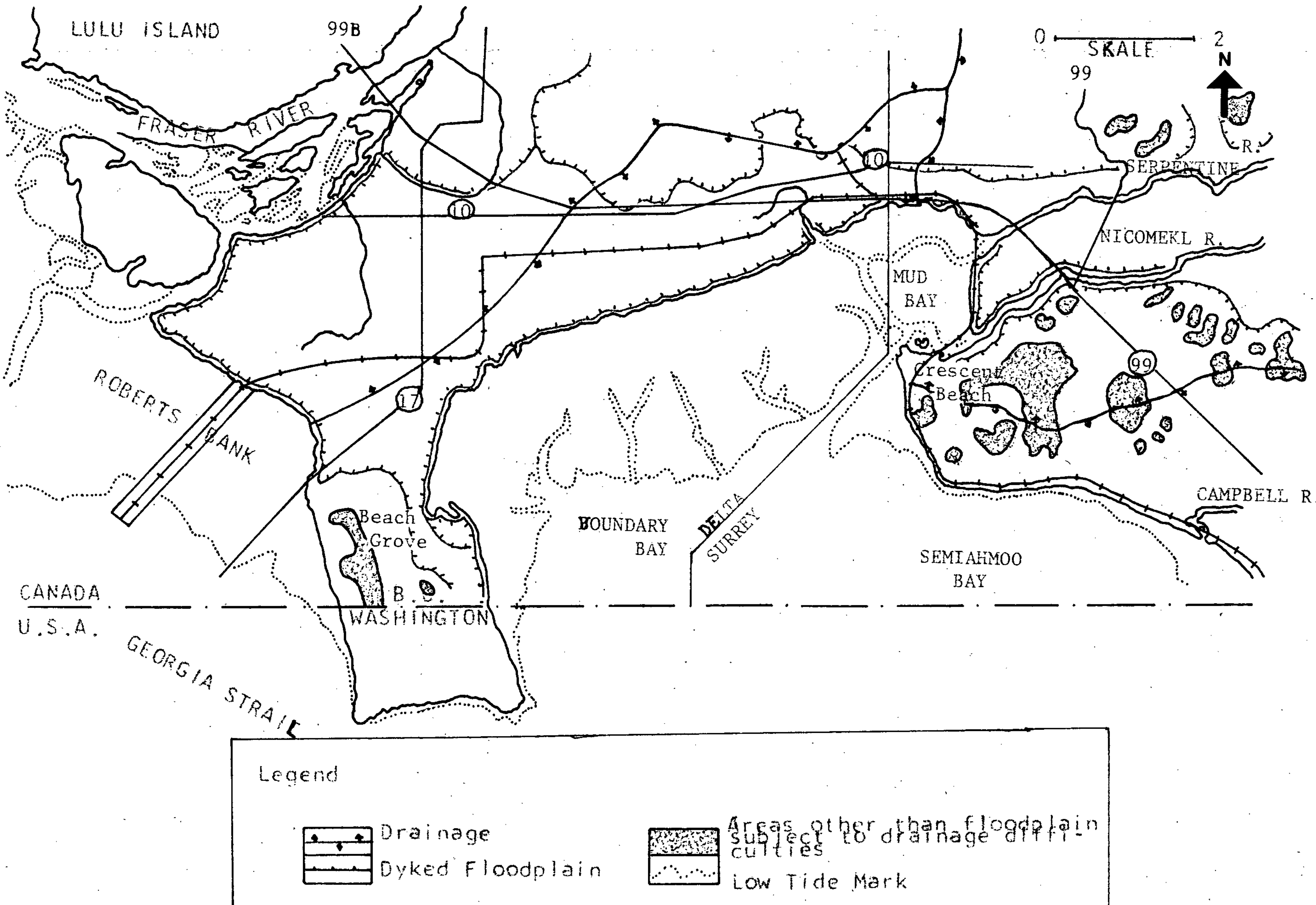
Feeding into Mud Bay are three rivers - the Nicomekl, Serpentine, and the Campbell. These rivers, the several ditches which drain adjacent farmlands and the tidal erosion of adjacent cliffs provide Boundary Bay with a constant stream of inputs. This input may be a transfer of inorganic and organic material from the terrestrial system to the aquatic system as in the case of cliff erosion. Organic materials already present in the river waters is another type of input.

River flow data for the two rivers (Nicomekl and Serpentine) is very poor. Upstream records indicate that the summer flows are less than ten cubic feet per second and maximum flows during the winter usually range from 100 cubic feet per second to 200 cubic feet per second on the Serpentine River near Fort Kell (approximately 18 miles north-east of Boundary Bay) and 500 - 700 cubic feet per second on the Nicomekl River 15 miles east of Boundary Bay (Canada, Inland Waters Branch, 1968). Figure 8 shows the flood plain associated with these two major rivers (in terms of river flow) in addition to those other areas susceptible to flooding.

Generally the drainage is poor, as the extensive areas of silt, clay and till are nearly impervious and permit little downward percolation of water. For example, the Mud Bay Foreshore is characterized by silty surface and in areas where underground stream flow percolates to the surface - quicksand. Lowland soils are poorly drained for a variety of reasons (Sprout and Holland, 1959):

1) high tides in winter,
2) high precipitation in winter,
3) high water caused by the spring run-off,

Figure 8: Hydrologic Characteristics of the Study Area (Source: Greater Vancouver Regional District Base Maps)



4) low elevation of lowland soils, and

5) sandy substratum under the lowland soils which allows for lateral movement of water in the lower soil horizons.

Figure 8 shows those areas subject to drainage difficulties due to slope and soil characteristics.

Water Mass Properties

There is definite spatial heterogeneity in the physical properties of Boundary Bay water masses. This is quite common in estuarine areas as tidal flats have greater Dissolved Oxygen (D.O.) concentration and temperature variation than do the main channels (Bella, 1968). This variation in D.O. and temperatures is related to the variations in water levels with the tides. For example, in late August water temperatures on an incoming tide in the Mud Bay area are as high as 68°F at three feet deep (Benson, 1962). Taylor (1970) reports temperatures of 60°F. in the channel approaching Crescent Beach in early August of 1970 and a 79°F. temperature in eighteen inches of water 200 yards off shore from Beach Grove on incoming tides. These temperatures are hardly characteristic of the cold Pacific Ocean. The high water temperatures are related to the exposure of the mud flats at low tide to the sun.

Salinity values are high for Boundary Bay and the waters are relatively clear. With the normal low tides of summer, depressions with poor lateral drainage accumulate salt. Evaporation of water from these depressions plays an important role in concentrating salts. Most reports on Boundary Bay report salinity values to be high but give no specific data.

Benson (1962) cites a pH (water) reading of 6 - 7 near the tidal verge (high tide border) at Mud Bay and a more basic reading of 11 near the railroad crossing. His results are similar in substance to soil chemistry tests carried out by Clark, Gobin, and Sprout (1961) in a nearby location.

THE BIOTIC ENVIRONMENT

Kellerhals and Murray (1969) in their study of the tidal flat area of Boundary Bay grouped plant species and associated fauna into five recognizable floral and faunal communities at different levels of the tidal flats, sand dollar community, and the eelgrass community. Four basic characteristics account for the differences in the communities:

1) differences in the substrata, e.g. slope, type, grain size of particles,

2) properties of the water mass, e.g. nutrients, salinity, temperature,

3) water motion variables such as current flow, and

4) interrelationships between the various biological forms.

Salt Marsh

Salt marshes are known to be among the most productive natural ecosystems of the world. A variety of reasons account for their productiveness (Odum, 1959); among these are:

1) constant input of nutrients from the land and sea,

2) rapid circulation of nutrients and food due to tidal action,

3) a variety of life forms, and

4) year round primary production.

In addition the soils usually provide a fertile bed for the growth of aquatic plants and fresh water aids the growth of plant species (Harris, 1965). The marshes are important to the sedimentation process as they act as sediment traps during storm tides of high spring tides.

Marsh plants are found in bands or zones in large parts due to the gradients of salinity and duration of submergence during tidal cycles (Hinde, 1954). In Boundary Bay a dense cover of halophytes (salt tolerant plants) accumulated driftwood, seaweeds, and other material predominate. Benson (1962) identifies two specific salt marsh communities in the Mud Bay section of the study area - Grass meadow community and the *Salicornia* community. Zonation of plant species is evident in these communities. The grassmeadow community lies in the higher (landward) portion of the marsh. Approximately 70% of the plants are represented by one species - *Distichlis spicata*. The growth of this marsh invades (process of succession) the *Salicornia* community located seawards at the lower part of the marsh.

In the transitional area (ecotone) between the two communities tarweed (*Crindelia stricta*) is common. On the outer edge of the *Salicornia* community is Pacific Glasswort (*Salicornia pacific*). This plant is important as it prepares the way for invading grasses from the Grassmeadow community by gradually raising the level of the marsh.

Salicornia is instrumental in strong, turf development and is restricted to those areas below mean high tide (Benson, 1962). In the more established areas *Cuscuta sadina*, a parasite on glasswort is abundant. Arrowgrass (*Triglochin maritima*) is scattered throughout this community.

Salt marsh fauna essentially consists of soft shelled clams (*Mya sp.*) and the common blue mussel (*Mytilus sp.*) who utilize the seaward portion of the marsh. A variety of snails (*Cerithium sp.*) are also found in the seaward portion of the marsh and located in mean tidal channels and ponds are the shore crabs such as *Hemigrapsus sp.* (Kellerhals and Murray, 1969). Information regarding the abundance and distribution of other insects, crustaceans, etc. is not available.

The marshes of the Boundary Bay ecosystem perform a variety of functions in relationship to the entire ecosystem, such as:

1) the halophytic plants are the base for a food web serving waterfowl and filter feeders,

2) the area is a nursery ground for small fish and crustaceans, and

3) provision of feeding and resting ground for waterfowl.

Tidal Flats

Tidal flats are critical to the Boundary Bay ecosystem as they provide a habitat for an abundant fauna. The algae are the primary producers and are a major food source in the tidal flat zone but little is known specifically about their productivity. However, the productivity of algae may equal that of the higher yields from cultivated crops (Pomeroy, 1959).

Another major source of food is detritus, the mixture of organic material and the decomposing bacteria working on it. The detritus is derived from dead organisms in the water and also from the breakdown of the marsh plants. The slope edge of the tidal flat is a concentration point for organic detritus and, consequently, one focal point of production.

Another major source of primary production are the aquatic plants - eelgrass and marine phytoplankton are important here. Thus the mud flats are a key transitional habitat combining food sources from marsh and aquatic habitat into a form which many birds, fish and mammals depend upon.

High Tidal Flats

Seaward of the salt marsh is the high tidal flat. In the western section of Boundary Bay these flats are being built up with the advancing salt marsh. The vegetation is composed of halophytes which rise about one or two feet above the general level of the flat. These hummocks in themselves act as sediment traps and a seasonal growth of blue-green algae mats (*Microcoleus sp.*) provides a further sediment trap (Kellerhals and Murray, 1969).

The main primary producers in the area are the blue-green and green algae, *Microcoleus sp.* and *Enteromorpha sp.* respectively. The algae and the limited number of halophytes in the area feed the largest percentage of ducks and shorebirds which use the Bay (Church and Rubin, 1970). Other species of fauna are scarce due to two environmental limitations:

1) long exposure at low tide, and
2) resistence to burrowing by the algae mat.

Fauna consists primarily of species or burrowing shrimp (*Callianassa californiensis*) and a variety of snails. Polychaete worms, especially Lugworm (*Arenicola*) occur in shallow depressions in the area. They break down the detritus and their action brings to the surface organic foods useful to other creatures. In this way Lugworm is a critical organism in the cycling of nutrients for without it nutrients would be lost to deeper sediments.

Intermediate Tidal Flats

There are a variety of reasons to account for the lack of vegetation in the intermediate tidal flats. Limiting factors such as shifting sediments and rapid changes in drainage channels are combined with prolonged periods of exposure and submergence and result in a rigorous habitat.

Paradoxically while there is a lack of vegetation, the animal community has more species than the high tidal flats and includes an abundance of burrowing shrimp, the familiar polychaete worms, and several species of oysters east of Mud Bay (Taylor, 1970). The Japanese oyster (*Crassostrea qigas*) is abundant in the Mud Bay area and the littlenecked clam (*Venerupis japonica*) is common in the inter-tidal zone.

Primary production in this area of Boundary Bay results from phytoplankton arriving with the incoming tide. Red algae, especially the dominant *Rhodophycophyta*, is dominant from the lower inter-tidal regions to deeper waters and is an important food source for filter feeders (e.g. bivalve molluscs). Decaying plants washed into this area provide detritus which is used as food by the filter feeders.

Lower Tidal Flats

Sand Dollar Community

The Sand Dollar Community lies on the unvegetated portion of the sandy flats and is characterized by sand-dollars (*Echinarachnius excentricus*) and purple starfish (*Pisaster ochraceus*). Horse clams (*Schizothaerus nuttallii*) and butter clams (*Saxidomus gigantens*) are quite common as are many polychaete worms (Taylor, 1970).

Eelgrass Community

Eelgrass community contains the "... most varied and diverse fauna in Boundary Bay" (Kellerhals and Murray, 1969, p. 83). The eelgrass beds are associated with the five main drainage channels of Boundary Bay but changes in the location and abundance of the eelgrass occurs frequently. This is due to tidal action which constantly reworks and shifts the sediments thereby affecting the suitability of the area as an eelgrass habitat.

Eelgrass (*Zostera marina*) extends all along the Pacific Coast of North America from San Diego to Alaska (Einarsen, 1965). It occurs in waters of protected bays and forms dense beds over muddy bottoms. Roots and creeping rhizomes are generally imbedded in the mud. Sea lettuce (*Ulva sp.*) is associated with the beds of eelgrass and constitute an important source of primary production.

Studies show that *Ulva sp.* and *Zoestera sp.* are highly productive food sources: "On the moisture free basis, protein and crude fiber content of seagrassI was almost equal to alfalfa hay protein... The

* Seagrass is the same as eelgrass.

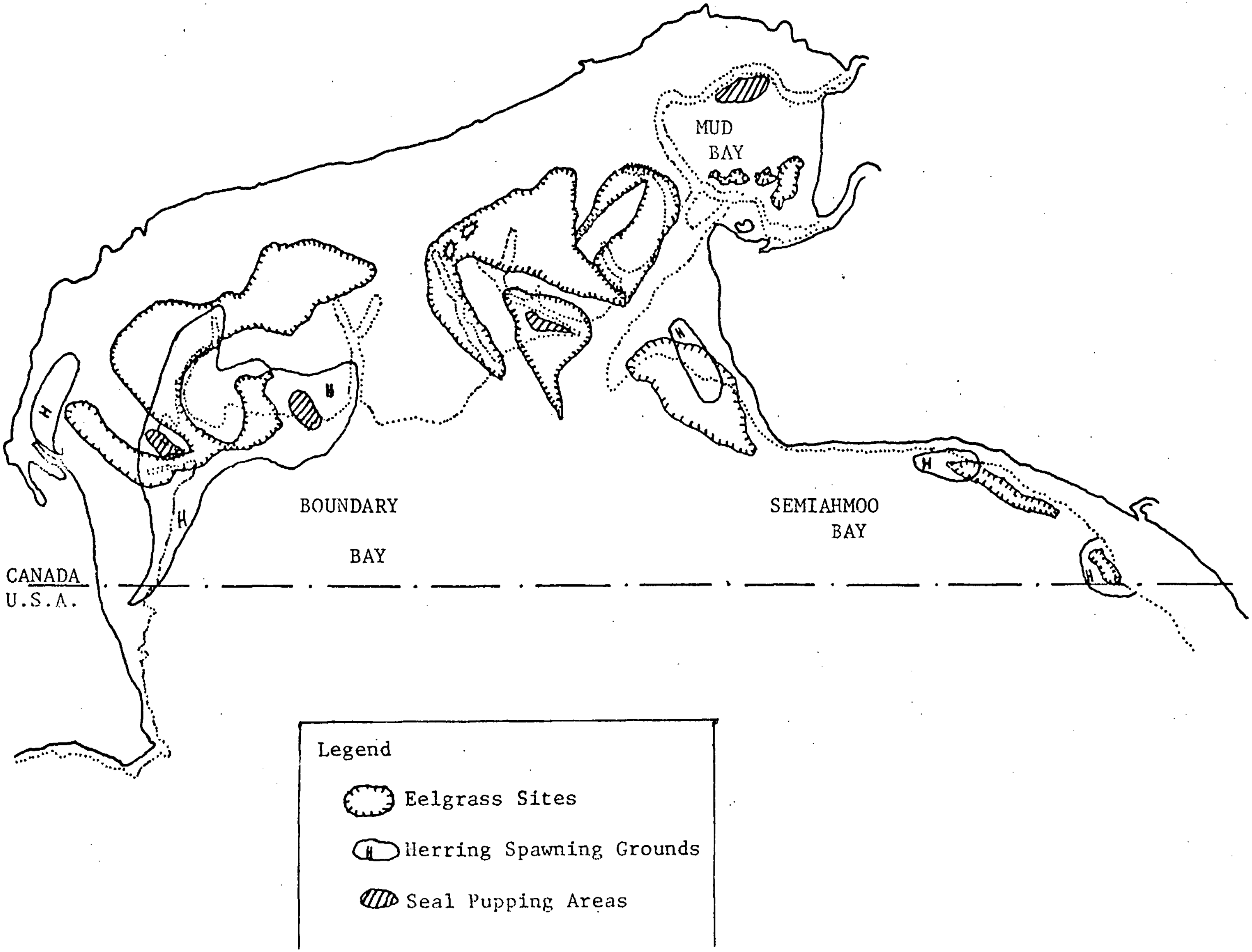
digestible protein content of seagrass was as high as good quality of prairie hay protein" (Akyildiz, 1962). Einarsen (1965) shows that nutritional values of eelgrass and sea lettuce prove adequate for good health and are by themselves an adequate diet for the Pacific Black Brant. The brant are solely dependent on these two sources of food and are, incidently, a yearly visitor to Boundary Bay on their northward migration.

The eelgrass serves a variety of functions in addition to their contribution to primary production. Church and Rubin (1970) point out that scavengers and filter feeders (such as bivalve molluscs and polychaete worms) are dependent on the eelgrass to trap food material carried into their habitat. As was mentioned before, polychaete worms, particularly the lugworm (*Arenicola*), perform the important task of bringing to the surface of the substratum large quantities of buried sediment. Kellerhals and Murray (1969) show this accumulating bottom sediment is high in organic content. Thus appreciable quantities of organic food are made available to other creatures.

The importance of the eelgrass community can be seen in the variety of species dependent on the eelgrass for food and habitat. The eelgrass provide a habitat for crabs (*Cancer magister*), starfish (*Pisaster ochraceus*), and cockle clams (*Clinocardium nuttallii*) (Taylor, 1970). In addition to these "permanent" residents the eelgrass is vitally important to the Pacific herring (*Clupea pallasii*) and a variety of waterfowl. Both the herring and the black brant waterfowl requirements require separate description.

Herring spawn on the eelgrass beds in late May with the larvae hatching approximately two weeks later. Figure 9 shows the relationship between eelgrass distribution and the herring spawning ground. A change

Figure 9: Eelgrass Production Areas, Herring Spawning Grounds, and Seal Hauling Out Sites In Boundary Bay (Sources: Church and Rubin, 1970; Morris, personal communication)



in environment is typical of the larval stage and studies show that migration occurs between inshore spawning grounds and an open sea feeding ground (Clemens and Wilby, 1961). The herring larvae in Boundary Bay are carried from their spawning grounds by the counter-clockwise current in Boundary Bay around Point Roberts until they are caught in the northward flow of the Strait of Georgia and are swept toward the Fraser River (Church and Rubin, 1970). The herring are a fundamental source for many marine species. Eggs are eaten by fish and waterfowl, especially ducks and gulls. Larvae are eaten by fish and a variety of plankton feeders such as jellyfish and crustaceans. Larger herring are consumed by seals, a variety of fish, and waterfowl.

Gates (1967) suggests that the eelgrass is responsible for the importance of tide flats as stopover and feeding areas for the Black Brant during the spring migration. Knowledge of the feeding habits of the Black Brant prove this to be true. The diet of the brant does not include a great variety of plant and animal matter. In fact the brant feed exclusively on eelgrass and sea lettuce (Einarsen, 1965).

The area of Point Roberts to Crescent Beach is the feeding and resting grounds for the brant in late March and early April. The population of Boundary Bay varies from 30,000 to 50,000 in the last three weeks of March and this figure "...may compromise 30-50% of the entire count of black brant on wintering grounds in the United States in January" (Benson, 1964). Boundary Bay is the last major stopping point before they proceed to the spring nesting sites on the Yukon-Kuskokwin Delta in Alaska and the Arctic Siberian coast.

Seaward of the Flats

Seaward of the tidal flats there is a rapid drop off which receives detritus from the salt marsh and tidal flats and has an abundance of phytoplankton. Invertebrates are common to the area as are a variety of fish. Numerous ducks use the area in search of food and as resting sites.

Fish, Waterfowl and Seal Populations

There are a few populations which are extremely difficult to place in any one community as they use a number of areas in Boundary Bay at one time or another.

Salmon spend an important part of their life history in Boundary Bay. Young fry after leaving the Nicomekl and Serpentine Rivers remain in the shallow waters of the Bay for several months and adult salmon returning to spawn pass through the waters of the Bay. Coho, steelhead and cutthroat trout also utilize the fresh waters of the Nicomekl and Serpentine Rivers and the salt water of the Bay during various stages of their life histories.

Other species such as surf smelt and capelin spawn in Boundary Bay. They eat small crustaceans and worms and are in turn eaten by salmon and logfish. Starry flounder and yellow shiner feed on crustaceans, clams, as well as on the smaller fishes. Sandlance who feed on plankton are food for chinook and coho salmon, ling cod, and halibut. Similarly, stickleback are an important food for many fish and waterfowl, particularly ducks.

Waterfowl are abundant throughout the Bay and they deserve a separate discussion. The entire Lower Mainland Region by virtue of its size, location, and its moderate winter climate makes it one of the most important wintering areas for waterfowl in Canada. While Boundary Bay contains only 27% of the foreshore areas of the Lower Mainland, 40% of the waterfowl visit there (Russell and Paish, 1970). The Bay attracts about fifty species of birds including ducks, shorebirds, herons, and gulls (Taylor, 1970).

The area of Boundary Bay serves the waterfowl in a number of ways. It provides them with food in the form of eelgrass, sea lettuce, algae, and a variety of marsh plants. The waterfowl are dependent on delta agricultural lands for feeding and nesting requirements. Subtidal marshes in the area provide key sands and gravels for digestive processes of waterfowl. Open water provides the waterfowl with an opportunity to rest and satisfy additional food requirements.

The continued inflow and outflow of waterfowl during their seasonal movements is as yet unmeasured. Therefore it is hard to predict the true value of wintering grounds of the area. Sporadic estimates have been made by the Canadian Wildlife Service in aerial census flights. Up to 75,700 dabbling ducks (which include four main species) have been counted in the area on a single census flight (Taylor, 1970). Table 4 shows cumulative counts for certain selected species of waterfowl. The largest segment of Pacific flyway sandpipers also stop in Boundary Bay and their numbers are estimated in the thousands.

As well as important seasonal migration movements through the area there is also a daily movement of waterfowl due to feeding requirements and periods of inclement weather. Populations of pintail, widgeon,

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TABLE 4.

CUMULATIVE COUNTS OF WATERFOWL SURVEYED IN BOUNDARY BAY DURING PERIOD APRILL 1966 - JANUARY 1970
(Source: Taylor, 1970)

Month	Mallard	Widgeon	Pintail	G.W. Teal	Scaup	Classified Total	Unident	Grand Total
September	196	110	3,537	1,324	2,000	7,592	425	7,592
October	13,598	38,463	39,525	20,845	80,300	192,731	49,072	241,803
November	65,803	49,367	77,645	38,619	5,685	237,119	71,130	308,249
December	48,238	28,558	66,643	11,465	4,600	159,504	25,706	185,210
January	14,022	16,193	9,995	454	227	40,871	3,609	44,480
February	2,643	1,791	5,133	2,519	-	12,086	867	12,953
March	2,437	761	7,203	120	-	10,521	582	11,103
April	2,045	7,210	2,820	3,848	-	15,923		15,923
Period Total	148,962	142,453	212,501	79,194	92,812	676,347	151,391	827,313
% of Class Total	22.0	21.7	31.5	11.7	13.7			
Adjustment	25.5	24.4	36.6	13.5	Boundary Bay % Dabblers (Scaup Omitted)			
Comparison	17.	37.	23.	21.	Delta Regional % Dabblers			

Nots: Counts not comparable between months as number of survey flights vary.

and teal move to the Cloverdale area (approximately seven miles east) and into the marshes between Boundary Bay and Cloverdale nightly to feed. When strong November and December winds force birds off Sturgeon Bank and Robert's Bank, up to 20,000 ducks have been counted in Boundary Bay (Taylor, 1970). These ducks feed on snails, shellfish, and other marine organisms. With strong easterly and westerly winds there are periodic inland flights to the Matsqui and Sumas area, approximately thirty miles east of Boundary Bay (Renewable Resources Report, 1961).

The five main drainage channels associated with the lower tide flats are vitally important to a harbour seal (*Phoca vitulina*) population in Boundary Bay. The seal population appears to remain fairly constant and 1970 estimates place the population at approximately 275. The seals spend much of the summer hauled upon favoured sandbars (Figure 9). The sandbars allow the seals space to rest, and the bars slope quickly into water deep enough to provide good escape facilities (Fisher, 1952). The months of February and March mark an increase in seal numbers with the appearance of spawning herring in the Bay (Church and Rubin, 1970). In April the seals move to the mouth of the Fraser River to intercept the annual olichan (*Thaleich pacificus*) run (Taylor, 1970). Following this run the seals return to Boundary Bay to spend the summer. The pupping season occurs at the end of July and for the most of August. The sand bars provide a safe area on which to give birth to the young seals.

BOUNDARY BAY ECOSYSTEM - AN OVERVIEW

Boundary Bay is truly an open system characterized by a constant flux of water, nutrients, and animal populations. Through this flux the Bay is directly tied to other areas. The ecosystem interacts with other ecosystems on a regional scale through, for example, the hydrologic cycle (inputs from the Nicomekl, Serpentine, and Campbell Rivers) and via the movements of waterfowl into and out of the area. Astrong tie acrosses international boundaries in the form of currents flowing into Boundary Bay and on a larger, continental scale as exemplified by the Pacific FlyWay.

Some species spend days in the area, others their entire lives. A large portion of the yearly waterfowl populations that frequent the Bay utilize the area during the winter season. Other species are tied to the Bay through their life cycles, as seen in the seal, herring and anadromous fish populations.

Species utilize the variety of habitat the Bay offers. Waterfowl make use of the entire area as they frequent open water for resting and feeding, the tidal flats for food requirements, marsh areas for resting, feeding and protection, and the farmlands of Delta and Surrey for feeding and nesting requirements. An overview of the distribution of flora and fauna in Boundary Bay is shown in Table 5 as adapted from Kellerhals and Murray (1969).

A rich supply of nutrients produced in the Bay ecosystem forms the basis of food chains that support a variety of organisms including fish and waterfowl. Figure 10 generally portrays the food web relationships in Boundary Bay illustrating the complexity of connections among different species. In review we find that detritus as a food source is equally as important as the eelgrass, algae and halophytic plants.

Practical application of ecological concepts presented in

TABLE 5

COMPARATIVE DISTRIBUTION OF FLORA AND FAUNA IN BOUNDARY BAY
(Adapted from Kellerhals and Murray, 1969)

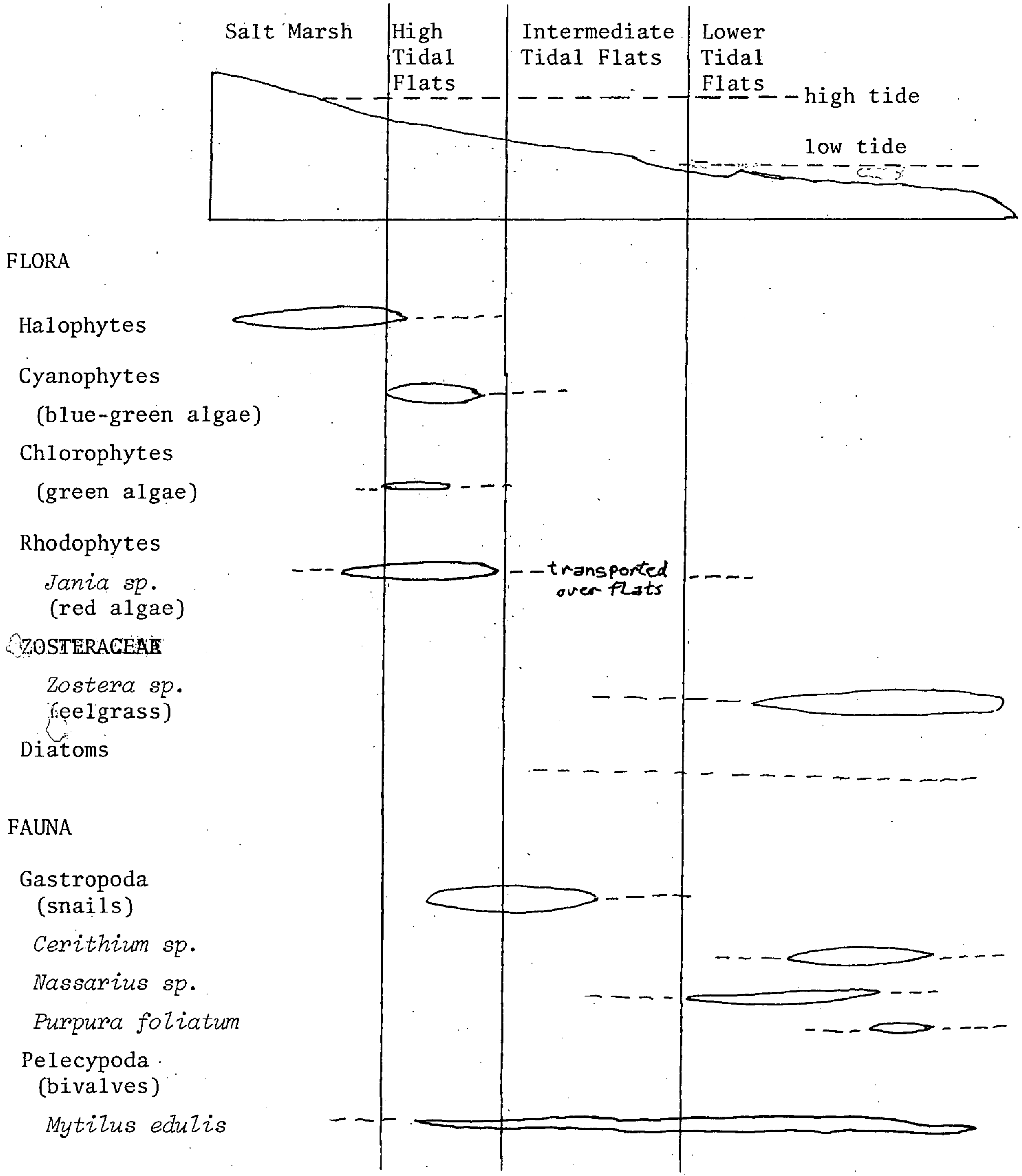

TABLE 5
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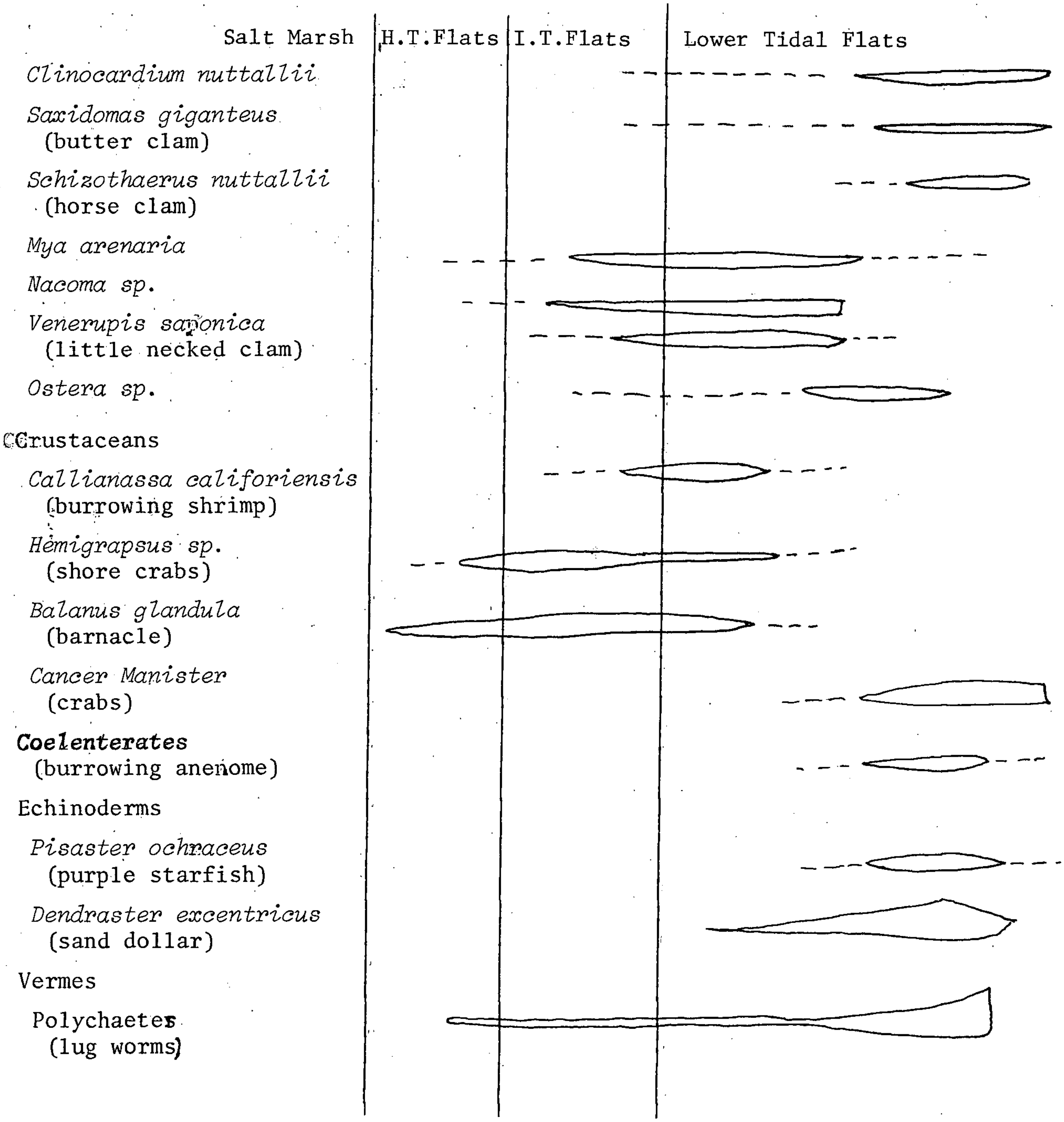
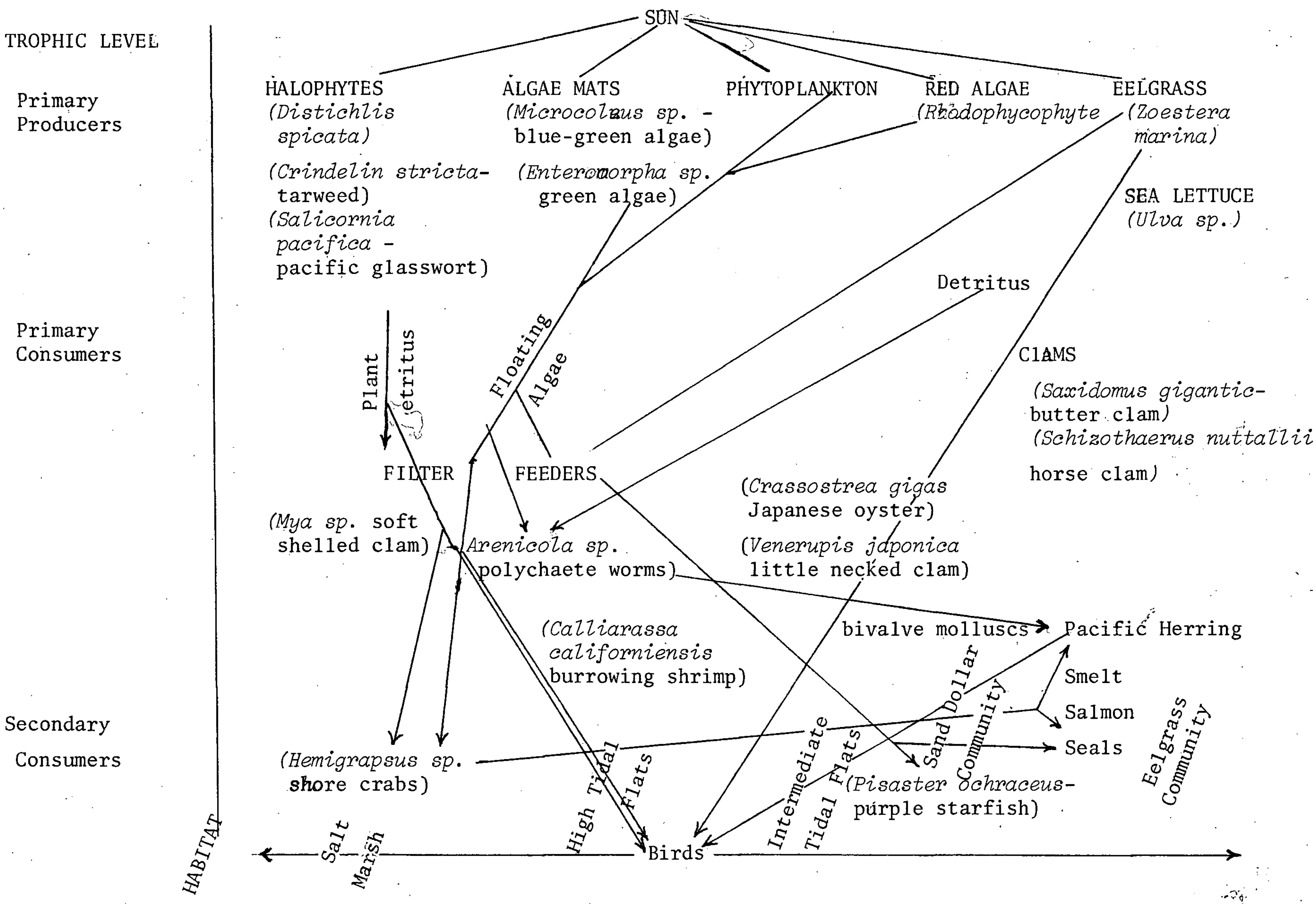


FIGURE 10

OVERVIEW OF FOOD RELATIONSHIPS IN BOUNDARY BAY



Chapter II is evident. The process of succession occurs with the vegetation hummocks which trap sediment preparing the way for an advancing salt marsh. The important niche of a worm (Lugworm) which prevents the loss of key nutrients to bottom sediments has been emphasized. The physical and biological environments are directly related through, for example, the relationship between sand and gravel deposits and members of specific communities and; by the influence of sedimentation processes on the distribution and abundance of eelgrass. In addition a moderate climate provides the temperatures suitable for a wintering population of waterfowl.

CHAPTER IV

MAN AND THE BOUNDARY BAY ECOSYSTEM

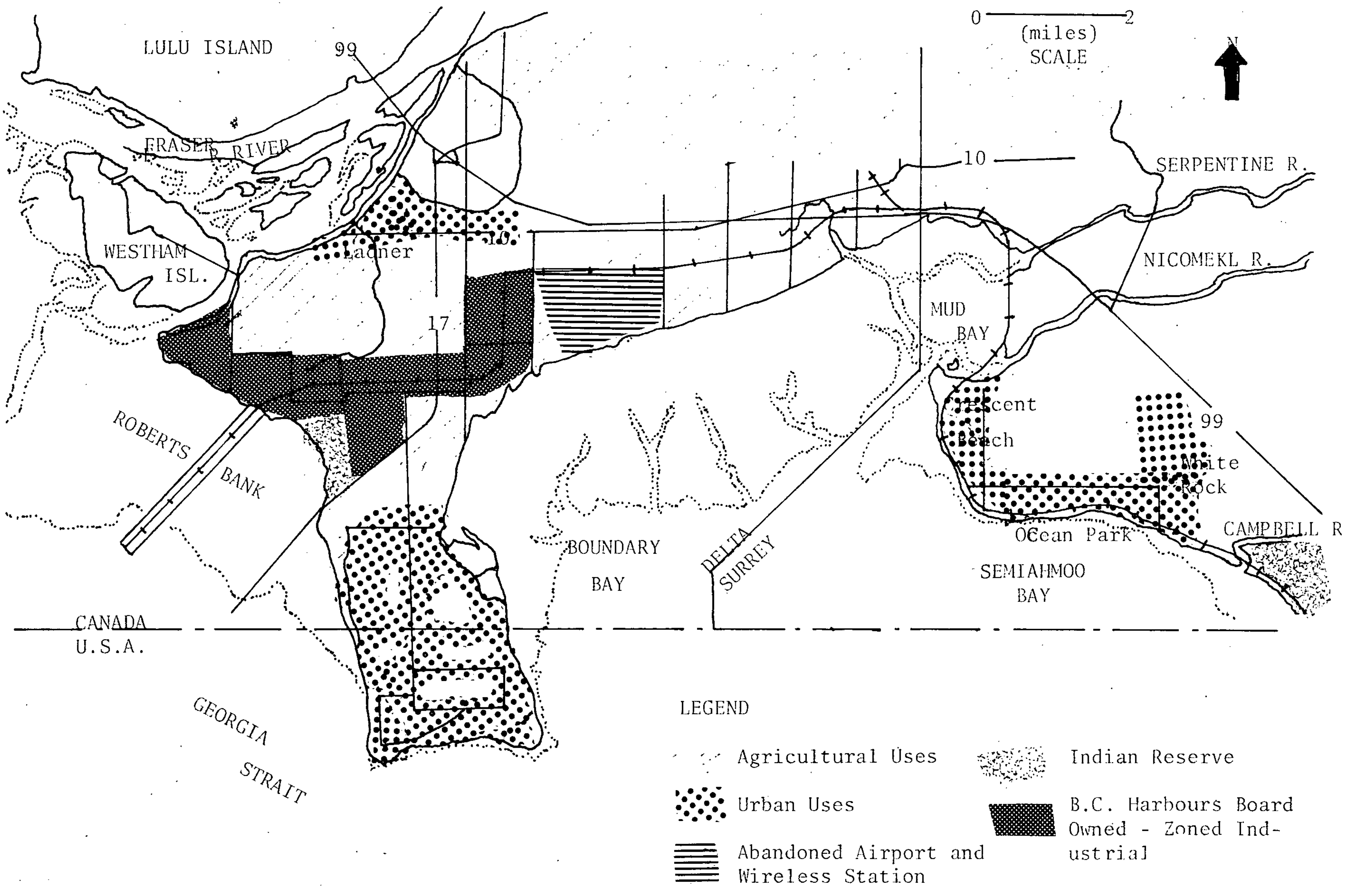
HISTORICAL DEVELOPMENT OF PRESENT LAND USES

Man has used the resources of Boundary Bay for a long time. Indians frequented the area south of the Nicomekl River long before white man was ever in Canada. Evidence of their existence comes from the discovery of primitive artifacts and human remains in the Crescent Beach area and on Blackie spit. However, only within the last seventy-five years has there been extensive modification of the "natural" landscape of the study area.

The large dyke, just north of Boundary Bay, was constructed in 1892 so that adjacent uplands could be drained and used for agricultural purposes. Years later a marsh near Beach Grove was dyked and drained for agricultural purposes. Vegetation in the non-agricultural areas, inland of the marsh, consists primarily of second growth Douglas Fir and Hemlock.

Initially the towns in the study area were settled as summer cottage areas. Changes in structure of these areas occurred with the expansion of metropolitan Vancouver. Transportation and communications facilities were constructed and new land uses developed (see Figure 11 for current predominant land uses).

Figure 11: Current Land Use



MAN/RESOURCE RELATIONSHIPS

Harvest of Resources

The economy of man demands a removable product from the ecosystem. In the case of Boundary Bay a variety of resources have been harvested.

Taylor (1970) shows that annual herring production over a fifteen year period (1954-1971) has been in excess of 3000 tons per year (Table 6). Commercial fishing for starry flounder and yellow shiners occur near the International Boundary. Commercial crabs are annually harvested at the rate of 250 tons. These crabs are also obtained close to the border from White Rock and Crescent Beach bases. The area of Point Roberts to Blaine, Washington, in 1954 produced the largest crab catch in the entire Puget Sound Region (Kincaid, 1954). Approximately 6000 pounds of shrimp are collected annually from the Bay (Taylor, 1970). Residents and visitors to the area collect clams for individual consumption.

The Japanese oyster was introduced into Mud Bay for harvest purposes as early as 1936. Seed oysters were initially planted at Comox on Vancouver Island and then transplanted when mature to Boundary Bay (Kincaid, 1954). After a time other species such as the Olympic Oyster (*Ostera lurida*) and the important east coast oyster (*Ostera virginica*) became dominant. Mud Bay accounted for 50% of the Provincial oyster harvest at an annual commercial value of $1,000,000.00. High coliform bacteria counts of the oyster led to a closure of the area for commercial production in the early 1960's.

TABLE 6.

HERRING PRODUCTION POTENTIAL - BOUNDARY AND MUD BAY
(Source: Taylor, 1970)

Year	Miles of Herring Spawn	Potential (Tons)	Year	Miles of Spawn	Potential (Tons)
1954	--	--	1962	1.7	1,530
1955	15.6	14,040	1963	3.7	3,240
1956	--	--	1964	1.2	1,080
1957	2.1	1,890	1965	1.4	1,260
1958	0.6	540	1966	3.8	3,420
1959	0.2	180	1967	7.3	6,570
1960	2.1	1,890	1968	2.6	2,340
1961	3.0	2,700	1969	3.6	3,240

Recreational consumption of Boundary Bay resources is quite significant. Sport fishing for migrating steelhead, coho, and cutthroat trout is common near the Serpentine and Nicomekl Rivers. Starry flounder, yellow shiners, ling cod, and halibut are also caught in Boundary Bay by the sportsmen.

Boundary Bay accounts for 14% of the Lower Mainland hunting days or approximately 33,600 days in 1965 (Hedlin, Menzies Associates, 1965). A full 70% of the Lower Mainland Pacific Black Brant harvest is accounted for in the Boundary Bay area and the total duck harvest amounted to approximately 40,000 for the 1968 season (Taylor, 1970). The hunting season runs from mid-October until early March and the status of Boundary Bay as a major waterfowl wintering and migration area accounts for its popularity with the hunters.

Depletion of Resources

The Lower Mainland Region is one of the fastest growing areas in Canada. This growth has occurred towards the south and east in the municipalities lying close to Boundary Bay. The southward expansion of metropolitan Vancouver is depleting the fertile farmlands of the Fraser Delta by converting the land to urban uses and indirectly affecting the future quantity and quality of the region's agricultural resources. An earlier mention was made of the dependence of the waterfowl on the adjacent delta farmlands for satisfaction of feeding and nesting requirements. Loss of these farmlands will substantially reduce the wintering waterfowl populations (Russell and Paish, 1968).

Pollution of Resources

Changing land use patterns throughout the years have directly affected the waters of Boundary Bay. The early 1960's saw the commercial oyster fishery brought to a close due to high coliform counts. The high readings were due to sewage wastes from the adjacent upland agricultural areas.

For many years man has taken for granted the water purification aspects of Boundary Bay. This function of Boundary Bay was adequately fulfilled for a long time but as the coliform count increased the system evolved toward a new level of homeostasis. Unfortunately this new level conflicted with man's health requirement prerequisite for food consumption. If this trend of increased nutrient enrichment of the system continues man will no doubt have to initiate more restrictions on human activity.

Expanding metropolitan areas require a vast amount of materials and energy to exist. To supply the needs of these areas industrial centres are expanding in scale and are developing new spatial linkages. An excellent example of this is the new Cherry Point industrial centre located between Lummi Bay and Birch Bay in the shoreline of Puget Sound thirty-five miles south of Boundary Bay. A variety of heavy industries are present at the centre: a petrochemical plant, aluminium smelter, three oil refineries, and a thermal power plant. The character of these industries is such that a variety of potentially dangerous pollutants are present in the form of either the initial resource, or effluents associated with processing and production of the resource, or both.

Dispersal of pollutants dumped into the water is related to the behaviour of the surface current and the dynamics of eddies (Kincaid, 1954). Currents in the region, as was mentioned, flow in a northerly direction through the Georgia Strait and into Boundary Bay. It is almost certain pollutants dumped at Cherry Point will find their way to Boundary Bay via these currents.

FUTURE DEMAND

Community Perspective

Not withstanding the various land use changes the study area has undergone in the past few years, the area to the immediate north and east of Boundary Bay still retains a rural pattern characterized by farms, low residential densities and minimal industry. The low tax base limits the sources of income for the municipalities of Delta and Surrey and services and planning facilities are highly taxed. Developers have cited increased revenue for municipal coffers as a justification for past proposals of industrial, commercial and residential development of the study area. The expansion of metropolitan Vancouver is further pressuring the municipalities of Delta and Surrey and new large-scale land use proposals have arisen.

There has been a variety of proposals in reference to development of Boundary Bay over the years (Table 7). For example, land reclamation of tidal flat land for industrial development was considered. However, a study by the now defunct Lower Mainland Regional Board (whose function has been replaced by the Greater Vancouver Regional District and four other regional districts) revealed that industrial development had only consumed 7,400 acres of the 48,000 available upland acres. So

TABLE 7.

LAND-USE PROPOSALS FOR DEVELOPMENT OF THE BOUNDARY BAY AREA
(Source: Lower Mainland Regional Planning Board Report 1968)

Ref. No.	Year Proposed	Proposed Bay	Nature of Proposal
1	1958	Boultbee-Sweet	Reclamation for industry and port
2	1960	P.F.R.A. (ARDA)	Sea-wall for agricultural land drainage
3	1961	Widgeon Keys	Reclamation for a city of 100,000
4	1963	Boultbee-Sweet	Reclamation for industry, port, parks and housing
5	1963	Surrey Municipality and ARDA	Land drainage for agriculture
6	1964	Maple Beach Tidelands	Residential-recreational complex
7	1964	"Development in Delta"	Recreation
8	1964	Save-the-Beaches Association	Beach, campsite, marina and shoreline
9,10,11	1966	Regional Parks Plan	Beach, campsite, marina and shoreline
12	1967	Surrey Municipality	Marina
13	1967	Surrey Municipality	Pool, picnic area
14	1968	Swan-Wooster	Residential-recreation complex
15	1970	BACM Engineering Ltd.	Residential-recreation complex
16	1971	Spettifore Farm Proposal	Residential-recreational complex, development in South Delta adjacent to Boundary Bay
17	1972	South Surrey Plan Study	Residential development of Sunnysid upland directly east of the Bay

there is no need for reclamation as there is adequate space to meet industrial needs for many years. In the same vein, there is no real need to reclaim land for urban development sites.

General consensus now finds that Boundary Bay itself is more suitable to the exploitation of wildlife and amenity resources of the area due to its waterfowl, fishing, and general recreational attributes (e.g. moderate climate and accessable beach areas). However, consensus is far from complete as to the kind of recreational activities suitable for the study area and the extent (scale, type, etc.) of development on the upland areas.

Recreational Demand

Population trends suggest a doubling of population in the Lower Mainland over the next thirty years (Appendix 1). This increase will no doubt be accompanied by increased participation in recreational activities for a variety of reasons. Man is attracted to open water and the other amenities of foreshore areas and needs to relax and get away from the pressure of modern society. In the future pressure will increase on available parkland and the need for new parkland associated with population growth:

> "In terms of parkland requirements the projected increases will require a shift from the 1966 standards of 65 acres per thousand population to 80 acres per thousand by 1981 and 94 acres per thousand by 2001. In 1966 parkland in the Lower Mainland was 32,140 acres below the level necessary to meeting existing needs which, if fulfilled, would require another 86,000 acres to satisfy the needs of the 1981 and a further 85,800 acres for those of 2001" (Taylor, 1970, p. 30).

The Lower Mainland Region has a shortage of accessable and usable beach areas. As a result, Canadians often frequent the beaches just south of the border. Attendance at Birch Bay, Washington, approximately thirty-five miles south of Vancouver is 90% Canadian and at Larrabee Bay, sixty miles south, approximately 65% of the recreationists are Canadian (Renewable Resources Consulting Service Limited, 1969).

Recreational use of Boundary Bay has been slow in developing. The north central portion of the Bay is virtually untouched but the extreme east and western areas have received some pressure. Intensive recreational use of the Bay is limited to the four month summer period and only three of sixteen miles of beach frontage are utilized. On a sunny summer day Beach Grove can expect 1500 - 2000 people and Crescent Beach in Surrey can expect around 1000 (Taylor, 1970). As population increases, so does beach use and the variety of recreational pursuits.

Many types of recreational demand of substantial economic value will influence the future of Boundary Bay (Table 8).

TABLE 8

ESTIMATED ECONOMIC VALUES OF RECREATIONAL ACTIVITIES IN BOUNDARY BAY
(Source: Hedlin Menzies, 1967)

Activity	Estimated Value 1971	Estimated Value 1985
Waterfowl associated activities	$ 516,000.00	$ 962,000.00
Swimming, picnicking and beach activities	5,880,000.00	12,100,000.00
Boating, fishing and water sports	340,000.00	740,000.00
Overnight and group camping	212,000.00	396,000.00
TOTAL:	$6,948,000.00	$14,198,000.00

The desire for beach footage has already been recognized. Overnight and group camping also have a place in determining demand for recreational facilities although present facilities are quite limited. In addition, recreational harvest of the fish and waterfowl resources gives Boundary Bay a high economic value.

Other recreational pursuits are increasing in popularity and may have a profound effect on the study area. The most important of these appears to be boating. The study area's geographical configuration is well suited for boating activities due to the Bay's proximity to many sheltered inlets, straits, and coves for cruising. In 1965, the boat ownership for the Lower Mainland was estimated at 45,000 boats. The majority of this boating activity continues to be on the salt water areas with a consequent requirement for additional marine moorages, launching facilities, water sports areas and marine parks. The following listing illustrates this need for additional berths as determined by the number of unsatisfied applications for moorage.

TABLE 9

UNSATISFIED APPLICATIONS FOR MOORAGE IN THE VANCOUVER AREA
(Source: Preliminary Report and Financial Feasibility Report, Tsawwassen Marina Development, 1970)

Location	Number
North Shore - Burrard Inlet	650
Coal Harbour	700
Other	520
TOTAL:	1870
Estimates loss of boat sales due to lack of moorage available	250

Because Boundary Bay is a sheltered area, it will be pressured into providing additional facilities. Presently there are 375 boats located at the Crescent Beach Marina at the mouth of the Nicomekl River and sixty boats are moored at Wards Marine up the Nicomekl. Expansion of these facilities or development of new ones would be economically rational but activities associated with marina construction and use may affect the ecosystem of Boundary Bay.

Pressures on the Uplands Areas

Many demands are being made on the upland reaches of the study area. Proposals to increase residential and commercial densities associated with new developments in the Sunnyside area (Crescent Beach to White Rock) of Surrey and in the area just southwest of the town of Boundary Bay are undergoing scrutiny by the public and the respective planning agencies of the two municipalities. As is the trend throughout North America, fertile farmlands in South Delta are being converted to urban uses. Little is known about the future of the abandoned airport site but speculation is that it will be reopened as a private landing strip within ten years. Conservationists express concern over the present legal status of land owned by the British Columbia Harbours Board (a crown corporation) which is zoned industrial (Figure 11). The potential conflicts of these uses with ecosystem processes in Boundary Bay should be self evident from past experience.

UNCERTAINITY

At the present stage our knowledge of man's modification of ecosystems we cannot possibly judge all the effects of a proposed project. Quality and quantity of information regarding immediate effects on ecosystem structure and function is poor. Temporal and spatial dimensions are further complications as ecological impacts show up hundreds of miles and years away from the initial source of the problem. Even current water and air quality criteria are suspect by many ecologists and the level of knowledge that such standards (e.g. "danger" levels of pollutant concentrations) imply does not exist.

The problems of predicting the ecological implications of alternative plans does not negate the use of the ecosystem concept, but it should impress upon one the paucity of knowledge regarding man/environment relationships. Planning should therefore be based on a presumption of ignorance rather than one of knowledge (Holling and Goldberg, 1971). The implications of this planning philosophy associated with the land ethic philosophy discussed in the first chapter will be discussed in the concluding chapter.

CHAPTER V

DEVELOPMENT OF BOUNDARY BAY

SELECTED DEVELOPMENT ALTERNATIVES - A CRITICAL REVIEW

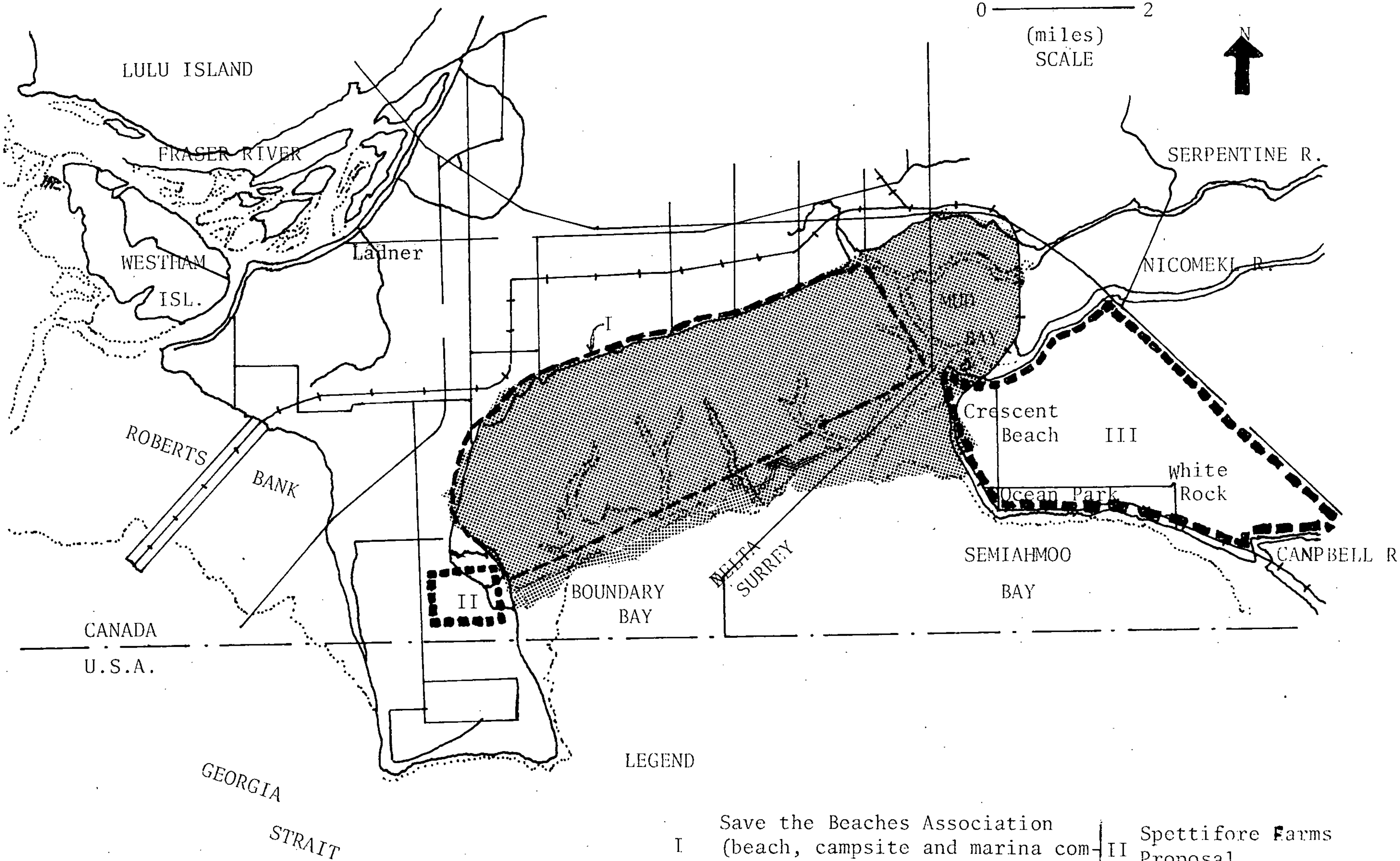
An important stage in the planning process is the evaluation of alternatives. Traditionally this procedure has emphasized economic costs and benefits associated with each plan. Society now appears to realize the additional need for an analysis in terms of costs and benefits to ecosystem structure and function.

The theoretical and practical (as applied to Boundary Bay) ecological concepts that have been dealt with can be used in evaluating development alternatives for the study area. Four alternative proposals from Table 7 have been selected (Figure 12). Two of these directly affect Boundary Bay because large scale alterations of tidal flat areas result. The potential for changes in the ecosystem with these two developments are vast. The ecological implications of two more recent proposals that develop the upland sections of the study area are more obscure due to lack of information.

Development Proposals for the Tide Flats

To save space and unnecessary discussion various types and likely consequences of man induced changes upon the Boundary Bay ecosystem have been listed in Table 10. The chosen examples are the 1964 Save-the-Beaches Association Plan (Appendix 2) and the 1970 BACM

Figure 12: Location of Four Alternative Development Proposals For Boundary Bay



LEGEND

I	Save the Beaches Association (beach, campsite and marina combined with conservation)	II	Spettifore Farms Proposal
	Swan Wooster (recreation on shores of urban area of 200,000 people)	III	South Surrey Development Plan

TABLE 10

VARIOUS TYPES AND LIKELY CONSEQUENCES OF TWO ALTERNATIVE PROPOSALS
ON THE BOUNDARY BAY ECOSYSTEM

Modification: Feature or Activity Changes	Expected Environmental Impacts	Adverse Effects	Beneficial Effects
Features Common To Both Proposals:			
I. Change in Basin Configuration			
a) Filling and Bulkheading	General reduction in acreage of prime habitat; sedimentation traps in shore-zone and marsh habitat; alteration of drainage patterns; creation of basins; change in current velocities and flow; gross change in marine floral communities; loss of nutrient materials from beach areas.	Decreased productivityof many species through destruction of plant cover and food sources (i.e., eel-grass and algae); species dependent on current flow affected (e.g., herring); great uncertainty re: future fishing and shell-fish potential.	Provision of an intensive recreational use area; northern section of the Bay is opened up to pleasure boating.
b) Spits	Current changes, sedimentation processes altered.	Same as above	Access to swimming areas facilitated.
c) Dredging of navigation channels	Deepening of drainage channels; alteration of drainage patterns; increased exchanged of oceanic, bay and marsh water, change in circulation and hence distribution of salinity, temperature; temporary increase in silt load affecting bottom life.	Possible intrusion of greater-than-normal amounts of sea water could decrease carrying capacity of marshes through reduction of plant cover and food sources. Increased turbidity limiting photosynthesis	Increased carrying capacity through provision of access for some species to previously inaccessible estuarine and marsh areas; deepened areas offer haven or routes of escape. Boating access facilitated.

TABLE 10
(continued)

d) Segmentation by spoil banks as well as by rail and highway grades	Lessening of average depth through shoaling due to structures influence on circulation; reduced exchange of fresh and salt water. High salinity of soil dredged up.	Loss of bottom acreage, disruption of flow patterns, and impedance of fish passage would have nominal effect on productivity	Access to northern section improved
II. Protective Works:			
a) Changes in tidal channels	Redistribution of frehhwater discharge; changes in estuarrine salinity regime; changes in ebb tide and flood tide velocity and direction	Depending on species, lower productivity in some areas. Anadromous fish may become confused.	Depending on species increased carrying capacity in some' areas
b) Sea walls, dykes and levees	Impeded exchange of fresh and salt water. Loss of tidal exchange benefits; changein salinity regime	General lowered productivity because of diminished access to tidal flat areas	Limited protection from spring flood flood tides and winter storms.
III Miscellaneous			
a) Changes in basin configuration.	Micro-climatic changes	Lowering of some species chances of survival	Some species chances of survival increased.
IV Pollution	Sediments in dredged areas usually different, silt and clay contrasted to sand and shell - results in habitat changes (Sykes,=1971). Increased turbidity of water during construction; changes in water chenistry; increased BOD demand, presence of toxic compounds in atmosphere from car exhaust; increased sheet runoff; oil and gasoline in water from boating.	Decrease in photosynthesis of primary producers with lowering of productiviyt of dependent species; in case of inadequate o f noxious chemicals decreased productivity of all species.	Increased fertilty limited enhancement of of productivity for a time.

TABLE 10

(continued)

Continuous use of area associated with BACM proposal	Disruption of feeding and nesting patterns of waterfowl; elimination of seal hauling out sites due to proximity of human activity	Reduction in waterfowl numbers; Potential for eliminating seal population very high;restrictions on the the use of the area for many individuals.	Waterfront living and all its attendent amenities; increased tax base for Delta.

Engineering Limited plan (Appendix 3). The effects of these proposals upon the Bay ecosystem are listed together as they are similar in scale and in the extent of direct land use changes. The table shows that both these examples would involve extensive alterations of the natural ecosystem of Boundary Bay.

Ironically, the objective of both plans is the exploitation of the recreational resources of the area. However, the process of developing resource use at this scale would significantly alter some of the amenities the people who frequent Boundary Bay go to enjoy - the fish, waterfowl and seal populations. Additional year round use by a full time residential population (BACM proposal) would destroy the regional recreational value of the area. The extent of alteration of the Boundary Bay ecosystem by the two proposed developments suggests that they are incompatible with the integrity of the Boundary Bay ecosystem.

Two Development Proposals for the Uplands Areas

Two development proposals for the upland areas of the Bay have recently come under public scrutiny. One proposal involves an $80 million community development plan on 616 acres of land in South Delta. A large portion of the land is presently owned by S. Spettifore and Sons Limited (Figure 12). Another proposal (Figure 12) involves the entire Sunnyside Peninsula of South Surrey, excluding the city of White Rock. The effects of these developments on Boundary Bay are much more obscure than the two previous proposals but the possibility of some alteration of the Bay ecosystem is still very real.

Spettifore Farms Proposal

The objective of this proposal is to provide a pleasant mix of high quality housing in a totally planned community featuring many desirable amenities. More than 20% of the land area will be dedicated to recreational use. The development also features cultural and social facilities. Provisions are made for full services including underground utilities and street lighting. Water supply is ample to provide for the proposed development and sewage would be exported from the area.

The completed development will contain a total of 3524 residences housing a population of 9185. Project completion will take approximately ten years with an increase of about 1,000 persons per year. The development would provide an additional $19.5 million tax assessment upon completion and create job opportunities to service the increase in population.

It is necessary that agricultural land be rezoned to residential use. Twenty per cent of the soils are third class agricultural soils limited by stoniness and poor drainage. The rest of the area is unsuitable for farming.

While conversion of land from agricultural to urban uses might be justified on economic grounds the combined factors of:

1) rapid depletion of fertile agricultural areas throughout Canada,

2) the location of most of the development on a flood plain (see Figure 8), and

3) the need for a marine drive arterial along the foreshore of Boundary Bay to service transportation needs in the area suggest that economic criteria is not enough in a benefit-cost appraisal of development.

Experience has shown dangers associated with developments on the floodplain. The developers suggest that "flood proofing" exists through a combination of dyking, pumping, land elevation, and water storage and that this will suffice to alleviate the danger of building on the floodplain. Shanks (1972) has pointed out that flood proofing in these terms may prove to be a falacious "perception" because no area can be given complete flood proofing.

Population increase in the Spettifore farms area would require expansion of the transportation networks. Plans to improve traffic flow with ready access to Highway 17 are already underway. Recent suggestions have been made for a marine drive arterial that would skirt the foreshore area and connect the development to the 499 Freeway. This route proposal along the foreshore of Boundary Bay is tentatively unacceptable barring further studies. A variety of probable impacts upon the ecosystem would ensue with the construction of the foreshore route:

1) alterations of surface drainage conditions.

2) alteration of circulation pattern with resulting changes in (Kutkuhn, 1966):

a) chemical components of the water,

b) physical properties such as temperature,

c) suspended matter, and

d) floral and faunal populations.

3) increased sediment removal in certain areas and sediment deposition in others, and a

4) decrease in primary production by altering conditions suitable for growth of primary producers.

South Surrey Plan Study

The second development proposal (Figure 12) is the South Surrey Plan Study. Following the principle established by the official Surrey Community Plan (1966) which calls for the expansion of the five towns in the municipality, the focus in the study is a town centre which functions as a meeting and market place. Surrounding the town are four smaller villages with a variety of housing types at variable densities. Density ranges from low (3 to 5 dwellings per acre) to medium which allows 5 to 10 dwellings per acre, and includes high densities within the town centre (low rise apartments at 18 and 24 dwellings per acre). The area is expected to accommodate 11,000 persons over the next ten years with an increase in population from 11,000 to 22,300. Recreational features include a system of parks and walkways, notably a riverfront park along the lowlands of the South Bank of the Nicomekl River and a beach front walkway along the western perimeter of the study area. Further emphasis is placed on expansion of the marina facilities at the mouth of the Nicomekl River.

The South Surrey Plan envisages low densities over a major portion of the study area through "... small estate development with large lots." The resulting low density means that sewers will not reach individual estates because of the high cost of their installation. Due to the non-porous nature of the soils and drainage into Boundary Bay from the western slopes on the study area, pollution of the Bay may result. Additionally, increased sediment load runoff resulting from removal of vegetation during construction may affect aquatic production by causing siltation of habitats and a decrease in light penetration. If aquatic plants such as eelgrass are so affected the waterfowl population will probably decrease in numbers.

Expansion of a marina on the south side of the Nicomekl River is a key recreational feature of the Study Plan. Benson has already suggested (1962) that the movement of pleasure boats at the present marina has resulted in some "disturbance" of the waterfowl population. This disturbance would increase with marina development and could become severe because the adjacent Mud Bay area is a prime waterfowl nesting, resting and feeding place.

Expansion of the road network would subject the beaches to pressure but no studies have been undertaken to discover the suitability of beach areas to sustain increased use. No real concern is expressed over a doubling of the density in the area and its attendent technological implications. In fact there is no ecological concept used in the study on which to base the development plan. The study only recommends "that the use of open space be controlled to maintain the natural landscape cover, trees, streams, and drainage courses ... ." All these criticisms may be a bit premature as the plan is up for review and if the public forums are any indication of citizen response the plan will be modified to consider these important points. An example of the questions asked at these forums is provided in Appendix 4.

Summary

The analysis of the four plans shows they did not recognize the important ecological considerations essential before development should take place. Hence the alternatives are not compatible with the integrity of the Boundary Bay ecosystem as presented in Chapter III. Now that proposals for Boundary Bay have been criticized a plan will be presented that recognizes the integrity of the Boundary Bay ecosystem.

A PROPOSAL

Underlying Philosophy and Objectives

The basic objective of the plan and strategies that follow is preservation of diversity of public choice among the different environments in the study area. This orientation arises from a number of points. A serious problem arising from man's alteration of his environment is a restriction in individual choices in the use and "enjoyment" of the environment. Increased choice enables individuals to make combinations for themselves that more closely fit their own views of quality of life (Spilhause, 1972).

Quality of life includes another aspect which is the direct concern of this paper: preservation of those basic life support systems necessary for the survival of marine and terrestrial organisms and growth of vegetational communities. But our knowledge of interactions in the ecosystem is minute in relation to our ignorance. We now need a planning philosophy that recognizes our ignorance and is explicit as to what information is required. A thrust in this direction is the creation of planning strategies that emphasize the maintenance of an ecosystem's "homeostasis" of "resilience." Holling (1971) defines resilience as the capacity of a system to absorb environmental changes. The capacity is defined by the system's tolerance to environmental changes before changes in system structure and function occur.

A COMPARTMENTAL APPROACH TO LANDSCAPE PLANNING

Chapter II suggested an approach to planning in which the landscape is compartmentalized into various spatial units with different planning tactics and objectives applied to each unit. This approach, adapted from Odum (1972), recognizes the desirability of having a variety of characteristics present in young and old ecosystems in a planning region. The plan developed in this Chapter subdivides the study area into compartments emphasizing:

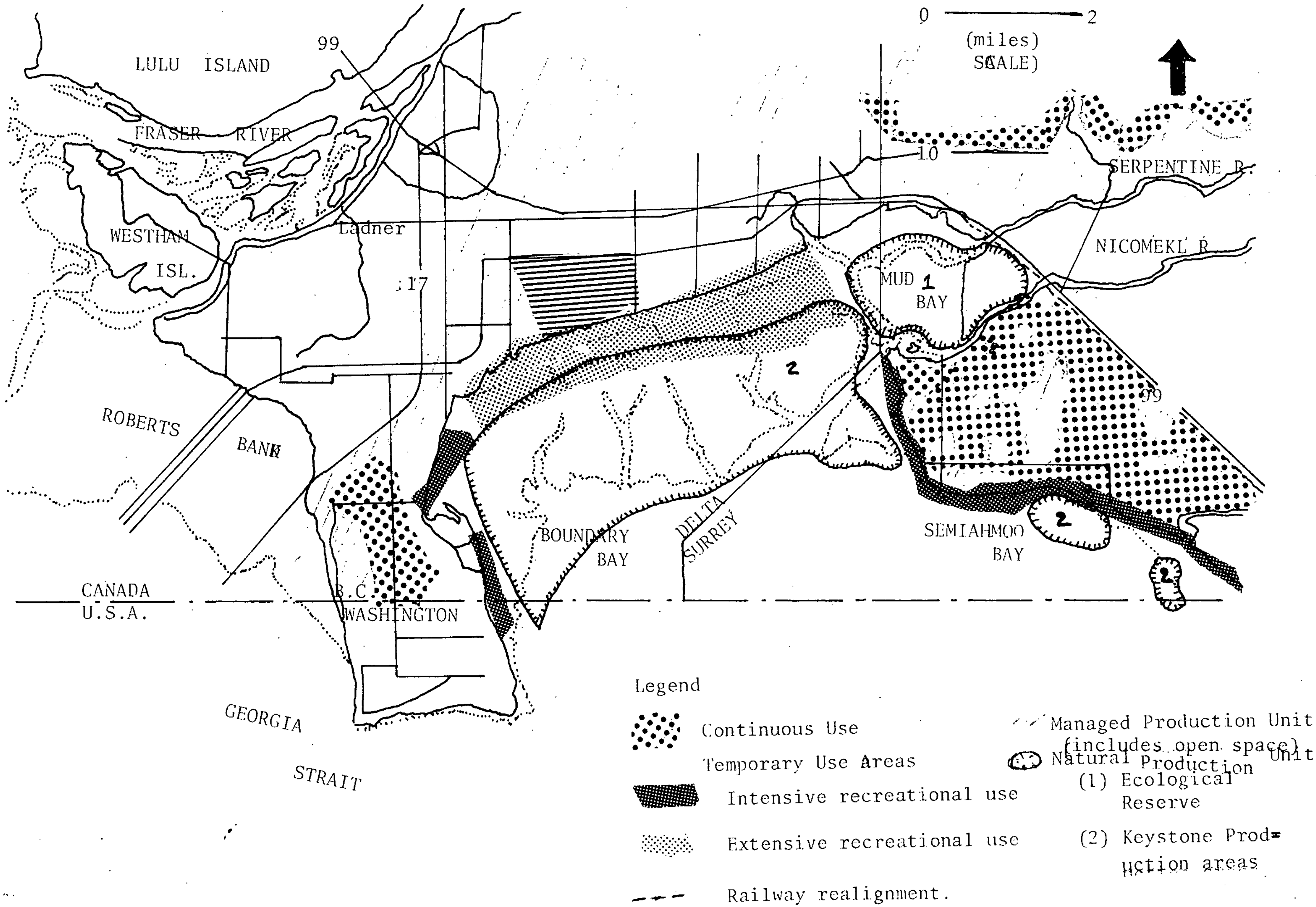
1) continuous use areas, e.g., urbanized areas,
2) temporary use areas, e.g., beach facilities,
3) managed production, i.e. agricultural crops, and
4) natural production, i.e. plant and animal communities.

Figure 13 presents an overview of the plan showing those areas conducive to specific land uses and human activities based on an understanding of the ecological character of the study area. As information from the Point Roberts area is lacking those land uses proposed in that area are very general.

Continuous Use Areas

The procedure for developing the land use plan begins by determining the physiographic limitations to urban uses. This stage is adapted from Ian McHarg (1970) and utilizes information presented earlier on: soils, foundation conditions, slope, floodplain location and drainage characteristics. Past history has shown that urban development on areas of good agricultural soils, excess slope, poor foundation conditions, or

Figure 13: Authors Proposal



those areas lying in a floodplain or experiencing drainage problems have usually resulted in undesirable environmental consequences, such as erosion or flooding. Therefore Figures 5a, 5b, and 8 reveal initial limitations to development. Combining the spatial aspects of these individual limitations we are left with a restricted area suitable to urban development and compatible with the physical environment.

As McHarg (1970) has shown this approach to determining optimum areas for urban development can also be economically attractive as well as physiographically sound. However we must recognize that there are other limitations to development not considered in the approach McHarg takes but recognizable through a knowledge of ecosystem dynamics.

A knowledge of ecosystem dynamics suggests that transportation facilities should not employ the use of a perimeter road system along the beach frontage. Such a road would tend to alter the character of the area at the very least and affect the ecosystem at worst by:

1) increasing sedimentation during road construction and

2) reducing over the long run sediment and detritus flow from the marshes thereby altering habitats and lowering productivity. Utilization of existing roadways perpendicular to the shoreline would adequately preserve beach access.

While increases in density of the South Surrey and South Delta uplands is tentatively acceptable data on the upland environment is poor. Therefore base line studies should commence immediately so reference points are established that monitor changes in the environment. An example of such a study is the analysis of the sediment content of streams to determine future increases in sediment load in streams due to poor construction practices. An increased sediment load would necessitate greater restrictions on construction and these restrictions are much easier to secure if "hard" data is available to support the accusation.

A Potential Use

A section of the area designated as a managed production unit contains an abandoned airport. Due to a dramatic increase in airplane sales over the past few years and an attendent need for hangar facilities in the Lower Mainland Region pressures will be exerted to reopen the airport. The opening is subject to one constraint. A large number of seagulls from Boundary Bay pass right over the airport in the morning and evening hours in their daily visits to a garbage dump north of the study area. Obviously incoming and outgoing airplane flights would not take place during the morning and evening hours (approximately 3 hours duration) due to the dangers of the birds interferring with flight operations.

The possibility of interference with flight operations by the daily movements of waterfowl does not necessarily preclude the reopening of the airport. If an airport can be safely and economically operated on a restricted time and if the dump can be moved to another location so the movement of seagulls does not interfere with flight operations a small scale airport is not necessarily out of the question. However, additional data must also be collected on the flight patterns of other waterfowl species in the area to see if they would present a land/air use conflict. The potential for relating a small regional airport to a regional resource - Boundary Bay is quite intriguing and should be looked into.

Temporary Use Areas

1) Intensive recreational uses on the established beach areas of White Rock, Crescent Beach, Ocean Park, Beach Grove, Centennial Grove on the Canadian side and Maple Beach on the American side.

2) A beach front walkway will run from Peace Arch Park at the Canada/U.S. border to Crescent Beach. Relocation of the present railway is assumed and is essential if any increase in beach use is to occur.

3) An information centre should be established between Crescent Beach and Ocean Park to inform people of marine life in the adjacent rock and tidal pools and the tidal flat areas of Boundary Bay. The centre should also emphasize the cultural history of the area with, for example, a discussion on the Indian artifacts found in the area of Crescent Beach.

4) Overnight and group camping facilities can be provided in the flood plain, providing there are no permanent structures outside of water and sewage facilities. A good location would be just south of the town of Boundary Bay.

5) Hunting season in Boundary Bay does not overlap with summer beach use so the beach areas located away from population centres may be left open to the hunters.

6) Extensive, low density recreational uses should occur on beach areas below the dykes at the northern section of Boundary Bay.

Very little is known about present recreational use of the area. A large portion of the Bay from the north end is unaccessable due to the dangerous nature of the tidal rise over a low gradient of tidal flat. With low tide one has to walk for a long time to get near the water, and longer to get to an adequate swimming area.

Benson (1964) suggested the use of "groins" to increase the area's use for swimming. Groins are small structures that trap sediment in areas while still allowing the water to pass thus creating small depressions in the Bay with time. The use of the area by waterfowl usually increases following groin construction as does eelgrass productivity (Benson, 1964). This combination may make the use of these structures a good management tool.

7) Recreational boating should take place seaward of the lower tidal flats to protect beach users and seal pupping areas from dangerous boaters and noise.

This part of the plan preserves a wide range of choice for a variety of recreational interests. Diversity of opportunity is seen in the provision of hunting, camping, extensive and intensive beach activities, swimming, and boating. Extensive recreational use is compatible with the northern portion of the Bay as little currently is known about its recreational potential. As the hunting season does not overlap with recreational uses of the Bay the two are compatible and revenue from hunting as well as from recreational activities has already proven to be substantial (Table 8). In addition the educational value of the area is tapped with the establishment of an interpretive centre. By providing a variety of recreational and cultural pursuits without extensive modification of the Bay ecosystem the plan allows the public a greater lattitude of choice over decisions regarding the long term (10 years +) future of the Bay. This result has been one of the objectives of this thesis -- to create a framework that results in open ended planning.

Managed Production Unit

1) A large upland section of the study area is set aside as farmland.

The importance of preserving the farmland of Delta and Surrey must be viewed in the context of the total agricultural land in the province. Approximately 2% of the land area of the province is potentially suitable for agriculture, excluding grazing. While Delta and Surrey do not provide an overwhelming percentage of B.C.'s agricultural acreage, a further reduction of prime acreage would be undesirable.

The unique (moderate) climatic conditions and good soils provide (Figure 5a) some of the best conditions in Canada for the production of a variety of vegetable crops including peas, beans, cabbage, and brussel sprouts. Local food costs are reduced with the continued production of vegetable crops from farm areas in the Lower Mainland. The dairy farms in Delta also assist in keeping food costs in line.

In addition to satisfying human demands for food the farmlands also provide food for the waterfowl populations of Boundary Bay. In the event of severe reductions in farmland surrounding Vancouver, people can get their food stuffs elsewhere, but the waterfowl cannot and their chances of survival are affected. At any rate the human system and the waterfowl populations lose more of their resilience to environmental changes and more options are foreclosed with a greater dependence on single food sources.

A substantial reduction in farmland could occur with the development of a section of land owned by the B.C. Harbours Board. The land area is part of 12,000 acres expropriated as backup land for the federally constructed superport at Robert's Bank in 1968-1969. At present the land has been leased back to farmers until the B.C. Harbours Board finds that the land will be required for industrial purposes. No immediate plans exist for the areas and farming leases have recently been extended from two to three years to five years. No one is quite sure (including the Harbours Board) whether the land will actually be converted to industrial uses. Lack of such long range policies by the Provincial and Federal Governments for urban and regional growth (in a floodplain no less) seriously hampers municipal and regional planning. Planning is difficult, at best, when agencies having authority over land assignment do not have stated goals or objectives regarding urban growth, economic development, and environmental quality.

While industrial development on the farmland might increase diversity of economic choice over the short run period the viability of Boundary Bay as a recreational area would be severely affected. Those industries normally associated with port development are not compatible with recreational uses of the Bay. Air pollution from the industrial area would probably blow into the recreational area affecting the recreational experience at the least and if pollution was to continue the waterfowl populations residing in the Bay may become affected.

<u>Natural Production Unit</u>

1) <u>Establishment of the Mud Bay marsh as an Ecological Reserve.</u>

The uniqueness of this area and its importance to waterfowl populations deserves special recognition by the regional planner. The purpose of the Ecological Reserves Act (Chapter 16, B.C. Land Act, 1971) is to reserve crown land for ecological purposes, including:

"(a) areas suitable for scientific research and educational purposes associated with studies in productivity and other aspects of the natural environment,

"(b) areas which are representative of natural ecosystems,

"(c) areas that serve as examples of ecosystems that have been modified by man and that offer an opportunity to study the recovery of the natural ecosystem from such modification,

"(d) areas in which rare or endangered native plants or animals may be preserved in their natural habitat,

"(e) areas that contain unique and rare examples of botanical, zoological or geological phenomena" (B.C., Department of Lands, Forests and Water Resources, 1971).

Areas having the potential for one or more of these purposes are reviewed by an Ecological Committee. If selected by the committee the reserve is set aside on Crown Land. Ecological reserves are not recreational areas but are typical examples of the ecosystems represented in the Province and are to be used for research purposes. Type of research may range from pure science to resource management with people such as educators, natural history societies, and natural and professional environmentalists being involved. The Mud Bay Salt Marsh appears to satisfy a number of the criteria necessary to obtain status as an ecological reserve:

a) the salt marsh is representative of natural ecosystems, and

b) is a unique ecosystem in Canada,

c) as Chapter III pointed out salt marshes are extremely productive units and Mud Bay does not appear to be an exception, and

d) the Mud Bay marsh contains a diversity of flora and fauna eminently suitable for scientific research and educational purposes. However, the marsh is not crown land and is susceptible to development associated with the expansion of the Crescent Beach area. Procedures for establishing the Mud Bay marsh as an ecological reserve must begin immediately, so the critical area will not be further altered by man's conversion of land to more immediately profitable uses. Just as important is the necessity to establish ecological base line studies in the area to have a future indication of man's direct and indirect effects of Mud Bay specifically and ecosystems in general.

2) Other Steps to Ensure Preservation of Keystone Production Areas.

Strategies must be developed that recognize:

a) the flow of sediments and detritus from the marsh areas and the Serpentine and Nicomekl River to the tidal flats and

b) the importance of the eelgrass beds (*Zoestra marina*) as a source of food and habitat.

Placement of structures on the beach areas or tidal flats must be preceeded by studies that would determine the effect of these structures on sedimentation process. In addition flood control and water storage proposals for the Serpentine and Nicomekl Rivers must be preceeded by studies on the effects of removal of river sediments by the reservoir, the effects of flow alteration on marine life and the alteration of anadromous fish habitats and spawning runs.

Eelgrass is critical to the survival of the black brant population. The brant use the Bay for a period of time of their northward migration and are solely dependent on the eelgrass as a food source. Loss of the eelgrass as a food source would make the brant much more susceptible to other changes along the Pacific flyway and would undoubtedly result in a reduction in the population. Thus the brant have no resilience to environmental changes in reference to their food source due to their restricted niche.

The events affecting the survival of species residing briefly in one locality will have effects which extend beyond the boundaries of that locality and reach far into the future. Consequently people of the area should bear a heavy burden of responsibility for conservation of resources they share with others. This responsibility is recognized by the law. As the brant use the Pacific flyway and are an international r resource Federal involvement may provide a measure of protection through the Migratory Birds Act.

In 1916 the United States and Canada signed a treaty for purposes of protecting migratory birds on the North American continent. A result of that treaty was the passage of the Migratory Birds Convention Act (Revised Statutes of Canada, 1930, Sec. 2). The Act, together with the regulations made under it, sets certain limits on hunting season, hunting hours, and bag limits. It also restricts hunting methods and equipment, and provides for the issue of special permits for propagation, scientific purposes and protection of crops. The Federal government using this act should see that the eelgrass beds of Boundary Bay are not altered as they are critical to the maintenance of an international resource.

Pollution considerations are also important as pollutants would have some effect on the Boundary Bay ecosystem. Concern was expressed earlier over the potential problems with the sewage outfall at White Rock. Domestic sewage disposal in small quantities act as fertilizers to the environment and if wisely distributed could increase fertility and value of the resources of Boundary Bay. Excess addition of sewage and agricultural wastes leads to:

1) contamination of resources such as the oyster beds of the area,

2) growth of undesirable species and decline of desirable species (change in community structure and function) and

3) a general decline in the potential for beneficial uses of water.

Ketchum (1967) recognizes that current sewage treatment practices are not satisfactory solutions since fertilizing elements are still discharged even though organic wastes are largely removed. The sewage outfall from White Rock should be monitored for pollution counts of coliform, phosphorus, and nitrogen.

Pollution problems may result from industrial development at Cherry Point in Northwest Washington. The Cherry Point development is disposing of a variety of pollutants that may eventually find their way into Boundary Bay via the northward current flow. It is essential that we examine the nature of the pollutants associated with specific industries at Cherry Point.

A by-product of the Intalco Aluminium smelter is the chemical flouride. Flourides precipitate to form calcium flouride which is a highly toxic biological poison. Specifically the flouride is a denaturant for enzymes. Schneider and Dube (1969) have already recognized changes in community structure near the plant.

Effluents from industrial activities of petro chemical plants are numerous: "These may be organic or inorganic and soluble or non-soluble in water. Many of these materials are extremely toxic to marine organisms." (Church and Rubin, 1970). The possibility of an oil spill during the operation of the Cherry Point oil refineries is very real, with the probable increase in ship traffic over the next few years in Georgia Strait the chances are increased.

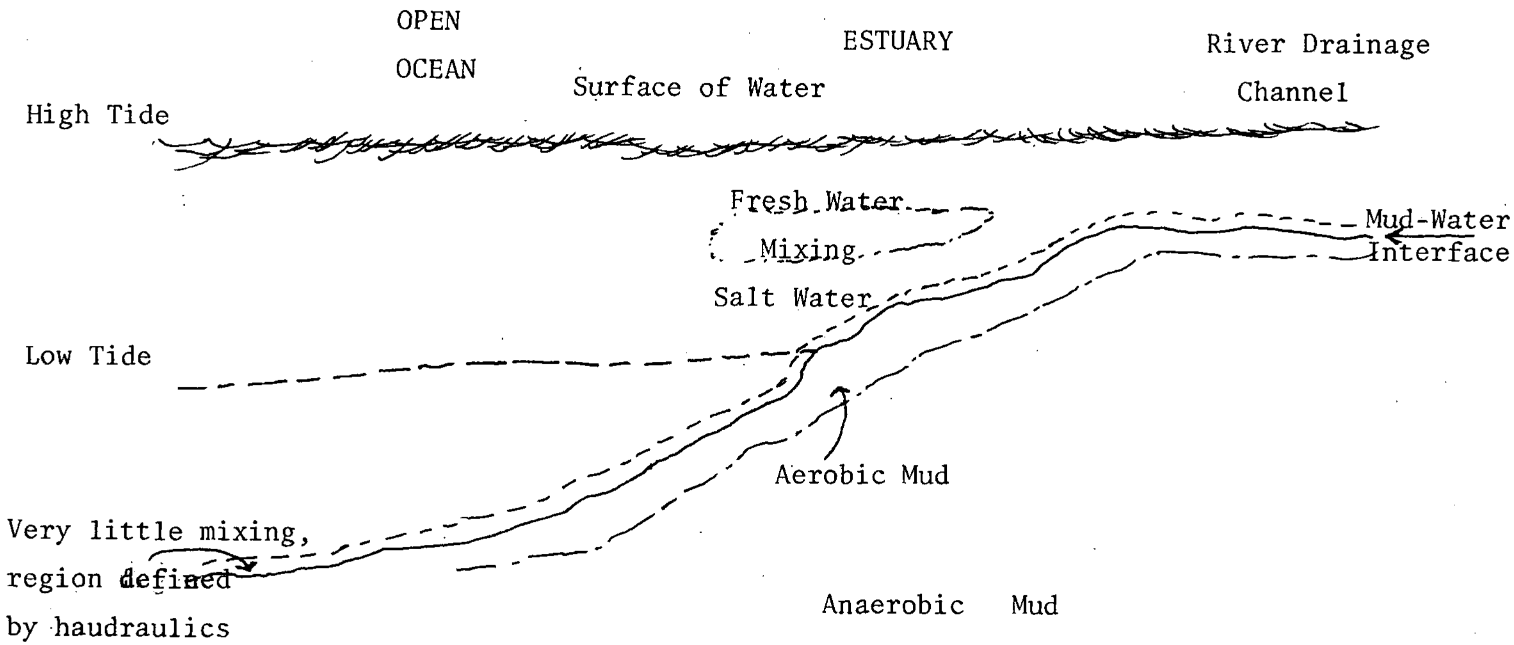
Long term problems are associated with the development of a thermal power plant. The plant may burn fossil fuels which might produce serious air pollution problems if U.S. air quality emission standards are lax. Far more dangerious is the potential of nuclear wastes as an effluent by-product if the plant is to be a nuclear one. These wastes, especially the radioactive isotopes are cumulative biological poisons. The potential that all of these pollutants could be carried into Boundary Bay may be slight but little is known about the effects they might have on marine habitats. Monitoring the aforementioned chemicals must begin now to establish a base line for future comparison. Water quality monitoring procedures must recognize the eight different hydrodynamic areas in an estuary (Figure 14) and should stress the development of biological indices of pollution whenever possible.

Consultation must take place between Canadian and American authorities regarding treatment at the source of the pollutant outfalls. Contingency oil spill plans must be adopted immediately to deal with such disasters.

RESEARCH NEEDS

A number of immediate research needs arise out of this study. The capability of the designated high intensity beach access to sustain continuous use over the years without suffering from erosion is unknown. Very little is known about the specific effects of the construction of piers or jetties out onto tidal flat areas. Before any marina

Figure 14: <u>Eight different hydrodynamic areas in an estuarine sagittal section</u>



construction is allowed to take place on these flats it is necessary that a physical model be built to discover changes in current flow, tidal velocity, sedimentation, etc. caused by construction of such structures. Similarly engineering and ecological studies should preceed dyking and water control proposals. A lot of work needs to be started regarding the classification of biological indicators of pollution and this should commence immediately. In addition development of a computer simulation model, used extensively in ecological research (for a review see Holling, 1972), may be helpful in the determination of a maximum pollution load for Boundary Bay.

SUMMARY CONCLUSION

We cannot isolate each individual land use consideration from the whole, nor can we define our objectives and plans narrowly with a single emphasis, on for example, economic growth. We must maintain a resilience to absorb unexpected changes in the future, since a measure of this resilience determines the domain of ecosystem stability. Thus it is imperative to make small, diverse interventions to provide feasible alternatives of action for system flexibility and maximum diversity of public choice. The economic cost of determining and keeping within the domain of stability may be a little higher in the short run (e.g. cost of base line studies and pollution monitoring) but it will provide us with the greatest amount of environmental security for the future as advance warning is essential to prevent long term alterations of the ecosystem.

CHAPTER VI

DISCUSSION AND CONCLUSIONS

INTRODUCTION

Man has altered his natural environment to suit the demands of his socio-economic system. The result is severe imbalances is some regional ecosystems, such as Lake Erie and, declining stability or resilience in others. Man tends to simplify ecosystems stressing economic gain from the resources present in the system. The trend toward extensive ecosystem modification will continue as long as man perceives himself independentfrom the environment in which he lives. Ironically advances in technology which develop environmental resources in an increasingly intensive fashion increases rather than decreasetthe complexity of man's interrelationships with ecological systems. It is now recognized that the effects of man' s actions on ecological relationships (biological or social) eventually produce unpleasant consequences for man's biological, social and economic well being.

The recent effect of the communication of these problems to the public is an apparent slight shift in values. Concern for "environmental problems" has been translated into action by the passage of legislation such as the Canada Water Act. Nevertheless the real problem continues to beeman's social and political attitudes that do not recognize the interrelationship between the environment and the human community. One aspect of this problem is the general absence of a reasonably holistic approach to land resource planning.

An inventory of resources has usually been one of the first steps in the planning process, but this has not always been approached in a comprehensive manner. Resources have been analyzed as to quantity and quality, current and potential uses, economic value, etc., on an individual basis. To be fully effective, not only should each resource be analyzed for its capacity to sustain uses, but also for its relationship to other uses. Relationships among abiotic and biotic components of the ecosystem must be determined so that resource use does not disrupt these relationships.

INNOVATION

The ecosystem concept developed here provides a framework which recognizes the variety of interrelationships in the environment. It is directly useful in the planning process in exploring the consequences of man's use of the land and the concept assists in suggesting ecologically sensitive land uses. The theoretical possibilities of the ecosystem concept, brought forth in Chapter II, are of course restricted in terms of the practical limitations of essential resources such as time and money. However, any successful plan for a land area must be preceeded by a characterization of the ecosystem involved. Regional planning must take cognisance of the concept of renewable resources being part of interactive systems. The immediately practical aspects of the ecosystem concept, as applied in Chapter III to Boundary Bay is to illuminate the interrelationships among man, other organisms, and the physical environment so at least the consequences of specific actions can be predicted.

A short discussion in Chapter II recognizedthe initial conceptual problems man has in relating his social system to the environment as the goals and strategies (of each system) have tended to oppose each other. The application of this theoretical discussion is seen at the beginning of Chapter V which reviews the impact of four selected development alternatives on the Boundary Bay ecosystem. Two proposals which attempt to open up the northern section of the study area to intensive recreational pursuits, boating and urban use lie in direct contrast to the structure and function of the Bay ecosystem.

A few key factors in the two schemes deserve special mention as they relate to the assessment of alternatives in the planning process. First, the scale of the proposals is quite large and involves extensive ecosystem alterations (Table 10), incompatible with the present desirable structure and function of the Boundary Bay ecosystem. Furthermore the two proposals eliminate a variety of options regarding future use of the area.

The upland development proposals while appearing to have less ecological impact are still naive of the physiographic characteristics of and ecological processes in the study area. Location of a large portion of one proposal on a floodplain is as example of this naivete. In addition neither concept recognizes the purposes of open space apart from serving as a playground and area of visual relief. In addition to these uses, open space in the midst of a development area should; recognize and protect those identifiable areas important for the maintainance of ecological relationships, and if possible be exploited for their educational value (for example those of nature study).

A new approach to the planned development of Boundary Bay was suggested by identifying the physiographic and ecological characteristics conducive or restrictive to specific land uses or human activities. By using the "compartmental approach" to landscape planning different planning tactics and objdctives were applied to different parts of the landscape. This approach delimits areas of human settlement in the environment where the man/environment relationship is a compatible one.

A number of reasons make the plan developed out of the compartmental model superior to the other development proposals:

1)The approach directly evaluates long term (previously) hidden costs. Planners must recognize preservation of the structure and function of ecosystems in order to insure that the net benefits for man from his interventions are more than just temporary benefits for some vested interests. Thus ecological values share a place with traditional economic and social concerns re: the long term implication of planning options.

2)The plan recognizes man's desires to live in the area but the ecosystem imposes initial limitations on where he specifically locates by recognizing the processes of energy flow and material cycling and the restrictions associated with physiographic limitations, for example, excess slope and occurance of a floodplain.

3)The plan also recognizes the necessity of preserving key areas for scientific study as in the case of the ecological reserve proposal.

4)The concept of resilience in ecological and social systems is directly incorporated into the plan. The setting aside of a large area of land for farmland recognizes a lack of farmland on a provincial and national scale to serve Canada's future food requirements. This farmland is also an important source of food for the waterfowl that frequent the area.

5)Emphasis on continuous monitoring procedures recognizes the importance of internal stability in ecosystems. Establishment of ecological base line studies and adequate monitoring procedures for potential pollutants are two examples of the basic type of technical infrastructure required to specify man's impacts on ecosystems. Monitoring specificly refers to the "systematic observation of parameters related to a specific problem, designed to give information on the characteristics of the problem and their change over time" (SCEP, 1971, p. 68).

6)There is greater predictibility of systems parameters over time as a basic grasp of Boundary Bay ecosystem structure and function was obtained in Chapter III. Uncertainty is quite higher with the other proposals. This is especially true with the development proposals on the tidal flats as species would be radically reassorted if the plans were carried out.

7)Diversity of choice is preserved with a variety of recreational activities available. Urban development is allowed to continue as specified recognizing a basic lack of data on the upland areas and very little data for Pt. Roberts.

IMPLICATIONS OF THIS APPROACH FOR THE PLANNING PROCESS

1)A "comprehensive" plan must begin with a comprehensive ecosystem analysis emphasizing relationships between organisms and their environment.

2)The ultimate objective of this analysis is not a static environmental description but: a) the predictions of system responses to alterations, and b)specific location of physiographic and ecological opportunities and limitations for development.

3)Information on ecological processes should assist the decision making process through:

> a)additional information on both the positive and negative consequences of decisions,
>
> b)more comprehensive evaluation of alternatives, and
>
> c)identification of those who stand to be significantly affected by a plan or project under consideration.

4)Through time the ecosystem concept provides the framework for assessing on a case by case basis the capability of the ecosystem to accomodate suggested changes in land use.

5)Regulatory controls (e.g., monitoring) must be built into the planning process. The results of these controls must "feed back" into plans and policies altering them when necessary. Flexibility of institutional arrangements in adapting to these necessary changes is critical in this case.

6)Planners must recognize the need to orientate society towards internal stabiltiy rather than expansive growth (Caldwell, 1969). For example, the process of urbanization which builds over productive farmland must be redirected, as it permanently forecloses an option for the future and increases ones dependence on a restricted number of producers.

7)Finally there is a need to adopt a general planning strategy involving small yet diverse interventions to provide a variety of alternatives of action, maximum diversity of public choice, and increased chances of systems stability.

In conclusion, the ecosystem concept can be useful in planning for a compatible man/environment relationship and it thus represents a theoretical model of the land ethic. However, not until everyone assumes a personal responsibility for the land will planners be successful in integrating urban society with the natural environment.

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APPENDIX I

TABLE 1A Population growth, Delta Municipality

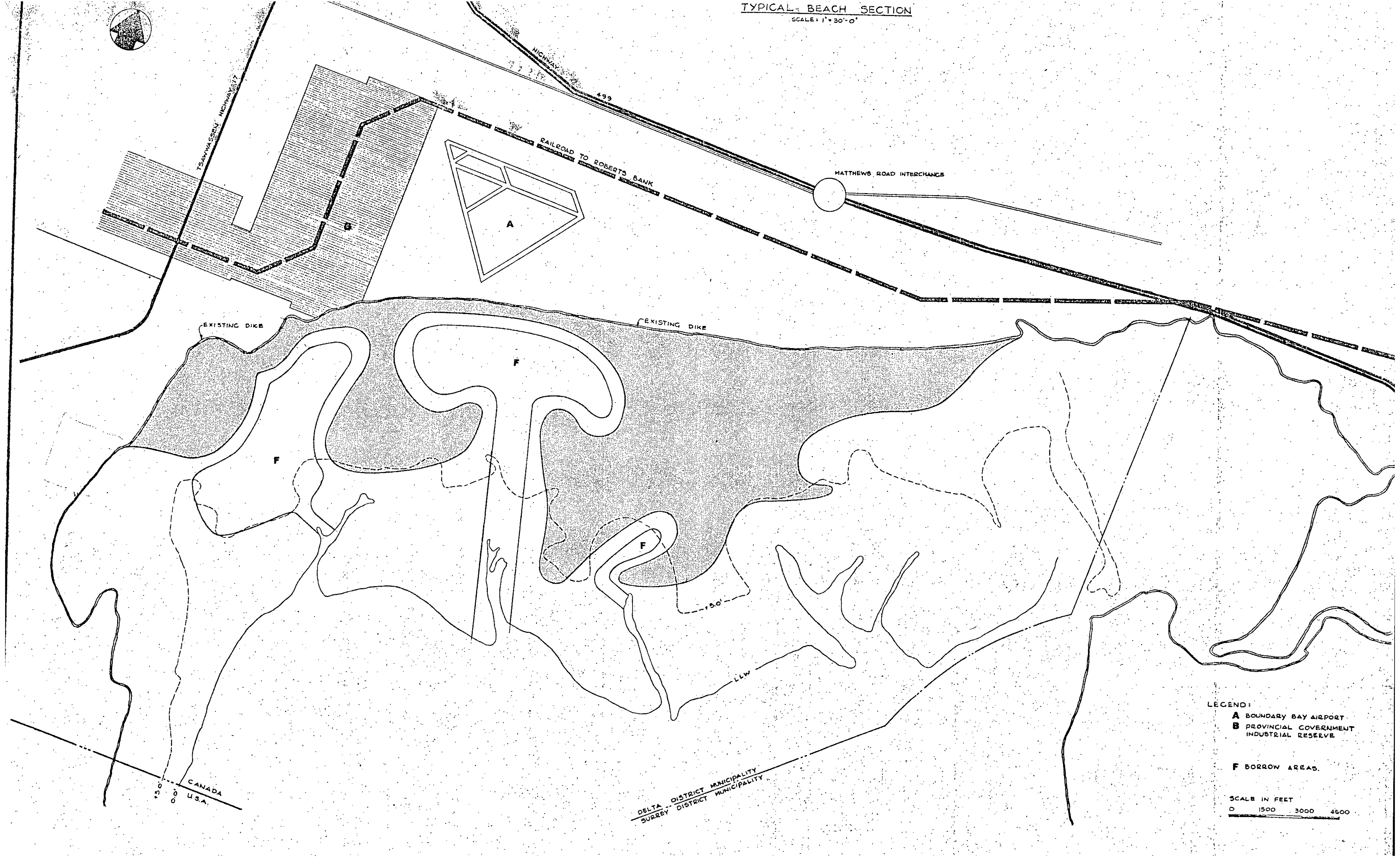
Year	Population	Year	Population	Year	Population
1961	14,597	1965	18,715	1969	36,537
1962	*	1966	22,011	1970	39,111**
1963	16,187	1967	24,488		
1964	17,382	1968	29,801		

* No data ** Population as at 28 August, 1970

Table 2A Population trend & forecast for British Columbia & the Lower Mainland Region, 1921 to 2001

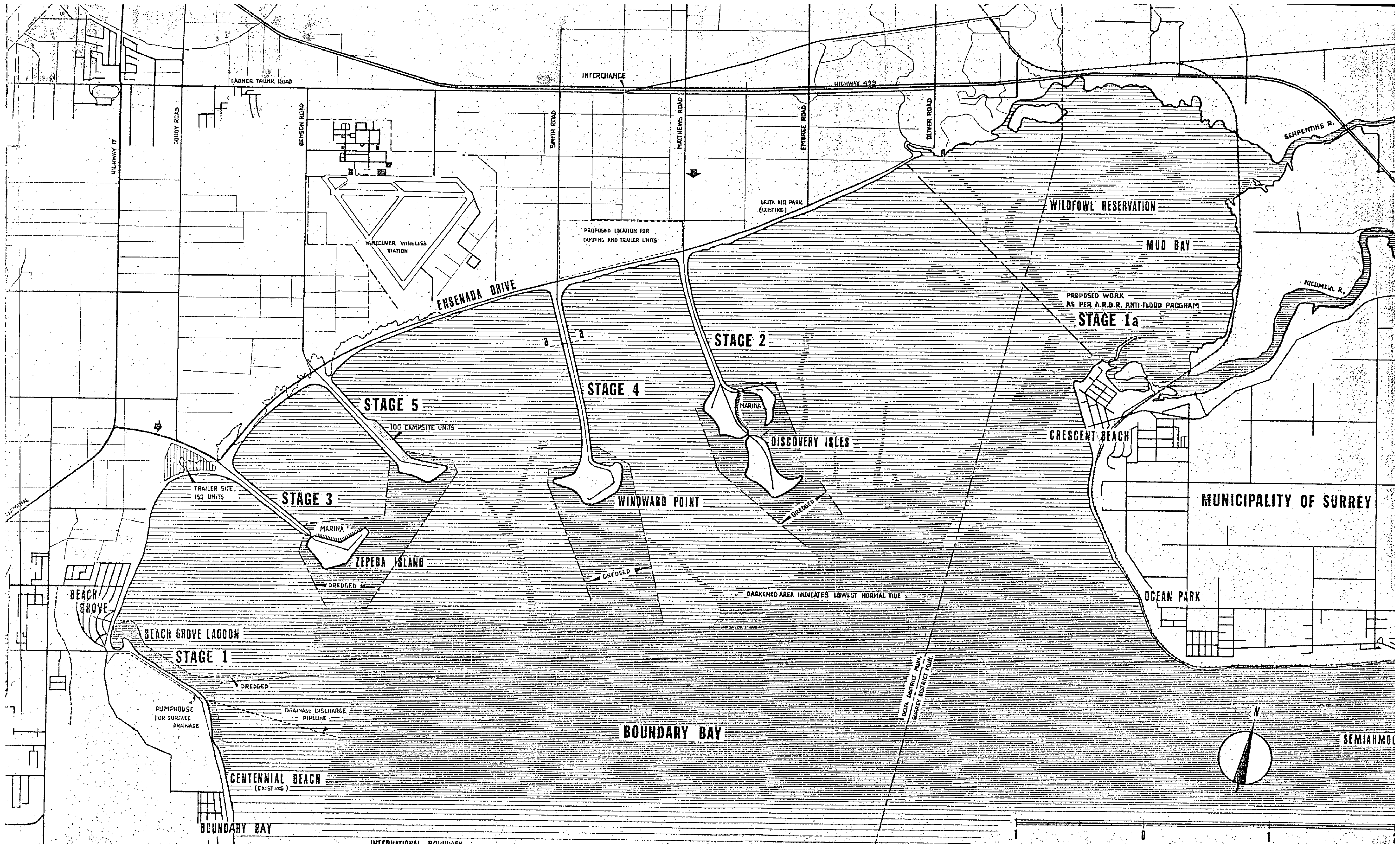
	Year	B.C. total	Lower Mainland Region % of B.C.	Lower Mainland Region Number
	1921	524,582	47.5	249,331
Actual	1931	694,263	53.5	371,319
	1941	817,861	53.8	440,052
	1951	1,165,210	54.6	636,548
	1956	1,398,464	53.8	752,983
	1961	1,629,082	54.9	893,619
	1966	1,873,674	53.7	1,005,824
	1971	2,144,000	54.0	1,158,000
	1976	2,447,000	54.0	1,321,000
Forecast	1981	2,793,000	54.0	1,508,000
	1986	3,188,000	54.0	1,722,000
	2001	4,500,000	53.0	2,400,000

From Lower Mainland Regional Planning Board estimates



TYPICAL BEACH SECTION
SCALE: 1"=30'-0"
HIGHWAY
499
TSAWWASSEN HIGHWAY 17
RAILROAD TO ROBERTS BANK
MATTHEWS ROAD INTERCHANGE
A
B
EXISTING DIKE
EXISTING DIKE
F
F
F
+5.0'
LLW
CANADA
U.S.A.
+5.0 0 0
DELTA DISTRICT MUNICIPALITY
SURREY DISTRICT MUNICIPALITY
LEGEND:
A BOUNDARY BAY AIRPORT
B PROVINCIAL GOVERNMENT INDUSTRIAL RESERVE
F BORROW AREAS.
SCALE IN FEET
0 1500 3000 4500

Appendix III



LADNER TRUNK ROAD
INTERCHANGE
HIGHWAY 499
HIGHWAY 17
GOUDY ROAD
BENSON ROAD
SMITH ROAD
MATHEWS ROAD
EMBREE ROAD
OLIVER ROAD
SERPENTINE R.
NICOMEKL R.
VANCOUVER WIRELESS STATION
PROPOSED LOCATION FOR CAMPING AND TRAILER UNITS
DELTA AIR PARK (EXISTING)
WILDFOWL RESERVATION
MUD BAY
PROPOSED WORK AS PER A.R.D.R. ANTI-FLOOD PROGRAM
STAGE 1a
ENSENADA DRIVE
STAGE 2
STAGE 4
STAGE 5
100 CAMPSITE UNITS
MARINA
DISCOVERY ISLES
CRESCENT BEACH
TRAILER SITE, 150 UNITS
STAGE 3
WINDWARD POINT
MUNICIPALITY OF SURREY
DREDGED
MARINA
ZEPEDA ISLAND
DREDGED
DREDGED
DARKENED AREA INDICATES LOWEST NORMAL TIDE
BEACH GROVE
OCEAN PARK
BEACH GROVE LAGOON
STAGE 1
DREDGED
PUMPHOUSE FOR SURFACE DRAINAGE
DRAINAGE DISCHARGE PIPELINE
DELTA DISTRICT MUN.
SURREY DISTRICT MUN.
BOUNDARY BAY
N
SEMIAHMOO
CENTENNIAL BEACH (EXISTING)
BOUNDARY BAY
INTERNATIONAL BOUNDARY
1
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1

Appendix IV

Appendix IV

UESTIONS FOR AUDIO-VISUAL PRESENTATION -
PREPARED BY SOUTH SURREY PLAN/STUDY GROUP

. Why is it necessary to have some 120,000 to 125,000 people in the White Rock-
outh Surrey area?
. Do you believe that a trunk sewer line of a certain capacity is adequate
stification for a certain population density?
. If this plan is a "peoples' plan" why were "people" not involved in formulating
he basic assumptions upon which this plan was based?
. How many of the school sites required for this plan have been acquired? What is
he estimated cost of these additional school sites if they are acquired now? What
ill the cost be if they are acquired 10-20 years from now? What portion of this cost
ust be borne by ratepayers?
. What is the estimated capital cost of new schools for the area at first cycle
aturation? What portion of this cost must be borne by ratepayers?
. Will storm sewers be necessary if the proposed density occurs? What will be the
ost to ratepayers?
. Why have no additional hospitals been included in the plan? What will be the cost
f adequate hospital facilities at first cycle saturation? What portion of this cost
ust be borne by ratepayers?
. Why has the Mayor established a committee to "review by-laws, policies and
rocedures and to recommend to Council any changes deemed necessary for greater
fficiency"? Why is 50% of this committee made up of representatives of large
evelopment companies? Are any of the principals of these companies members of the
iberal Party?
As Stan McKinnon has said of this committee, "Incredible. When wolves are appointed
e sheperds, you can guess who gets shorn".
Some changes seem to have been made in the Audio-Visual presentation. If so, what
these changes? Has the plan been accordingly modified?
Reliable sources indicate that a race track will be established near Mud Bay on
old Kelly farm within a few years. Does this fit into the plan?
. Without increased access to the Deas freeway how will the first cycle saturation
opulation move to and from Vancouver?
2. One of the reasons suggested for the need to adopt a plan as quickly as possible
s that there is a freeze on zoning? Is there a freeze on rezoning?
3. What will it cost the ratepayers of Surrey to establish and service the town centre?
4. Are the definitions of the various areas on page 1 of the $25 version of the Plan/
tudy correct?
5. The Plan proposes the widening of Crescent Road to 4 lanes. Will increased parking
e developed at Crescent Beach to handle additional vehichles? If so, where?
6. The Mayor has suggested that the proposed system of 4-lane parkways are envisaged
s handling about 10,000 to 40,000 vehichles per day. Is this the load on each parkway?
7. Is there a section of the Plan/Study dealing with the ecological effects of the plan?
as an ecological inventory of the area been completed by the consultants or by any
ther persons?
8. The report suggests a population of 118,500 at first cycle saturation. What is
he projected population for second cycle saturation and when will this occur?
9. When will the financial section of this Plan/Study be released? Can you inform
he ratepayers of Surrey now how much implementation of this plan will cost them?
0. Are the Mayor and Council amenable to in-depth study of the plan by the citizens
f the area?