

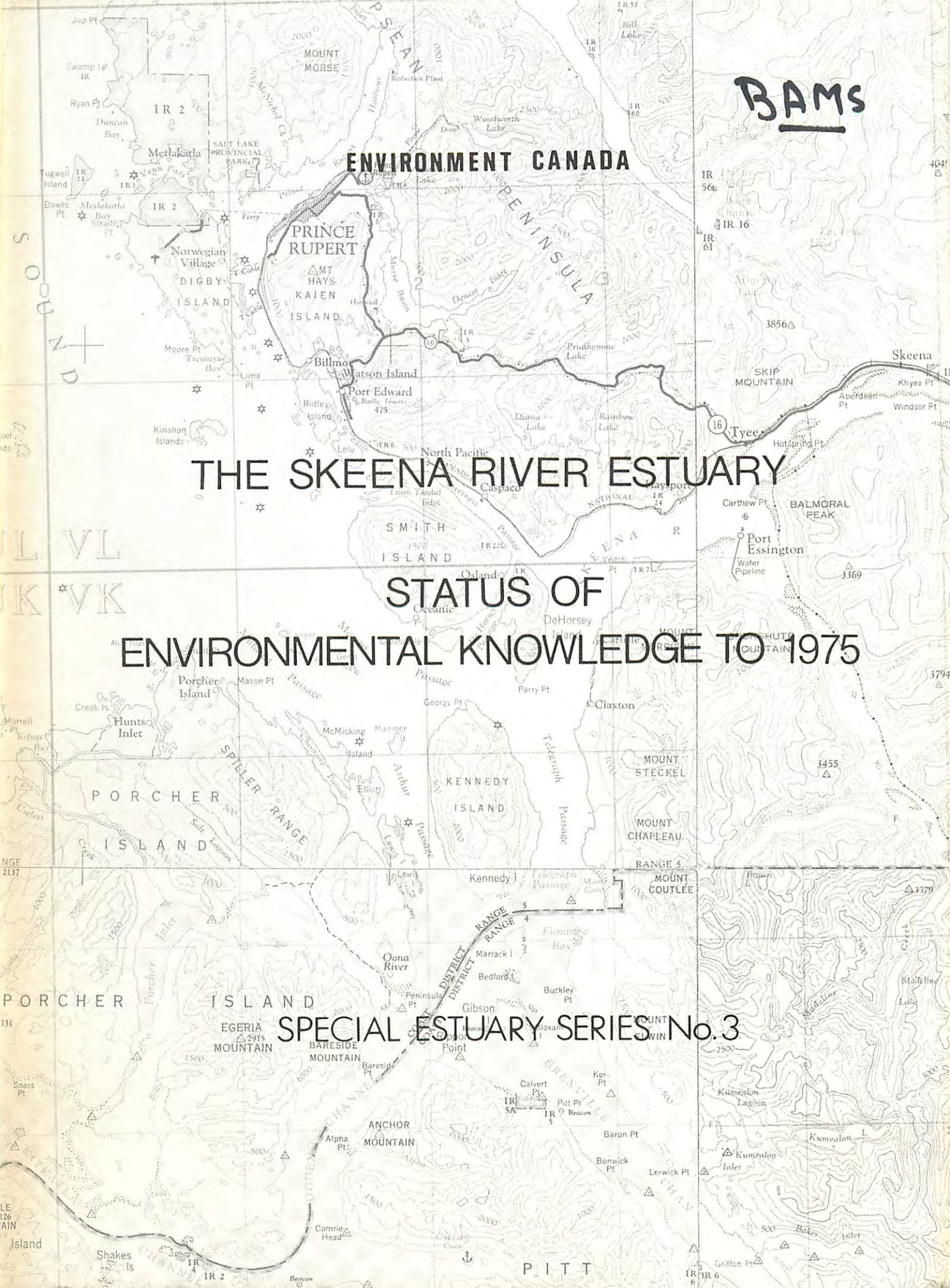
BAMS

ENVIRONMENT CANADA

THE SKEENA RIVER ESTUARY

STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1975

SPECIAL ESTUARY SERIES No. 3



ENVIRONMENT CANADA

R.A. Bams.

THE SKEENA RIVER ESTUARY
STATUS OF
ENVIRONMENTAL KNOWLEDGE TO 1975

REPORT OF THE ESTUARY WORKING GROUP
DEPARTMENT OF THE ENVIRONMENT
REGIONAL BOARD PACIFIC REGION

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Special Estuary Series No.3



Aerial photo of the Skeena River estuary showing De Horsey Island on the right (B.C. Government Air Photo).

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ABBREVIATIONS AND SYMBOLS

asl	above sea level
ADTON	air dry ton
CH	alcohol group
Cd	cadmium
CaO ₂	calcium dioxide
CaO	calcium oxide
carb.	carbon
CO ₂	carbon dioxide
CO	carbon monoxide
C	Celsius (or centigrade)
cm	centimeters
cm/sec	centimeters per second
Cl ₂	chlorine
ClO ₂	chlorine dioxide
Cu	copper
cfs	cubic feet per second
m ³	cubic meters
o	degrees
δ _T	density (sigma t)
EPS	Environmental Protection Service
e.g.	example
F	Fahrenheit
fm	fathoms
ft	feet
BOD ₅	five day biochemical oxygen demand
Au	gold
>	greater than
H ₂ S	hydrogen sulphide
IGD	Imperial gallons per day
km	kilometers
kts	knots
Pb	lead
<	less than

ABBREVIATIONS AND SYMBOLS (cont'd).

Me_2S	metallic sulphide
Me_2S_2	metalous sulphide
MeSH	metal sulphydryl compound
m	meters
	(8m2 = 8.2 meters
	5m8 = 5.8 meters
	4m0 = 4.0 meters
	4m6 = 4.6 meters)
CH_3SH	methyl sulphydryl compound
mi.	miles
M.P.H.	miles per hour
meq/l	milliequivalents per liter
mg/l	milligrams per liter
mill.	million
M/100ml.	million per 100 milliliters
'	minutes
min.	minutes
mpn	most probable number
n.mi.	nautical miles
TLM 96	ninty-six hour median lethal tolerance level
NO_3	nitrate
NO_2	nitrite
N	north
#	number
oz.	ounces
P.E.I.	Pacific Environment Institute
ppm	parts per million
‰	parts per thousand
°/o	percent
PO_4	phosphate
PCB	Pollution Control Branch
lb.	pounds

ABBREVIATIONS AND SYMBOLS (cont'd).

NaCl	salt or sodium chloride
sat.	saturation
Ag	silver
Na ₂ SO ₄	sodium sulphate
sp.	species (singular)
spp.	species (plural)
SSL	spent sulphite liquor
sq. ft.	square feet
SO ₂	sulphur dioxide
S.S.	suspended solids
T	temperature
temp.	temperature
i.e.	that is
T.O.C.	total organic carbon
T.S.	total solids
T.O.	type of operation
var.	variety
W	west
yr.	year
Zn	zinc

PREFACE

This third volume in the special estuary series was preceded by similar treatises on the Fraser and Squamish estuaries. It will be followed by volumes covering 15 other British Columbia estuaries, considered critical from the point of view of natural living resources, vulnerability to man's encroachment and potential development. These include estuaries of the Indian, Homathko, Bella Coola, Kitimat, Nanaimo, Courtenay, Campbell, Quatse, Wannock, Nimpkish, Gold, Somass, Cowichan, Chemainus and Salmon rivers. The next volume will deal with the Cowichan and Chemainus, estuaries having high priority in terms of fisheries resources, recreation potential and threats from future development.

As noted in the earlier volumes, this series inventories available information on the environmental aspects of the estuaries. It is intended to provide a full bibliography of published and available unpublished information on scientific studies, and to summarize knowledge in particular fields relevant to preservation, utilization and possible restoration of estuaries. The inventory was initiated by the Estuary Working Group (see Preface Table i) of the Regional Board Pacific Region of Environment Canada. Members and/or their colleagues review the contents of the reports prepared under contract. Subsequent to initiation of the project, a provincial representative was invited to participate, so that the work could benefit from a suitable liaison with provincial activities in estuaries.

The Skeena River estuary is of great importance because of the sockeye salmon runs, which rank second only to those of the Fraser, in British Columbia. The Skeena sockeye fishery has contributed greatly to the economy of Prince Rupert, and to the fishing industry of British Columbia. It is carefully managed for a maximum sustained yield by the Fisheries and Marine Service

of Environment Canada, as was done for decades by its predecessor, the Department of Fisheries.

During the 1960's, the Skeena sockeye became the subject of the first major salmon enhancement program in British Columbia. Preceded by some successful, pilot-scale, artificial spawning channels on Jones Creek of the lower British Columbia mainland and at Big Qualicum River on Vancouver Island, the Babine Development Project on artificial spawning channels on the Fulton River and Pinkut Creek, tributaries to the main basin of Babine Lake, was a 10-million dollar, 5 year program (1965-1970) in salmon enhancement. It was meant to increase the utilization of Babine Lake, by sockeye smolts, to near capacity, and, in particular, to increase the use of southern Babine Lake's main basin as a nursery area. This spawning channel development has succeeded beyond all expectations. During 1974, the influx of adult salmon was so great that they had to be captured at the counting fence and sold by auction, for fear of overloading the spawning grounds. Because of this valuable resource, which has been substantially enhanced by government investment, the Skeena River and its estuary merit the highest degree of environmental protection that can be afforded.

The city of Prince Rupert has always had some prominence as a transportation centre for the northwestern part of British Columbia. From the outset, it became the Pacific terminus of the Canadian National Railway (CNR). Periodically this has led to consideration of major port development. Originally, the city itself was the focus of attention. Then, since the CNR skirts along the seashore for some distance before it reaches Prince Rupert, alternative sites on the Tsimpsean peninsula were examined.

One of these sites was Flora Bank. It has some protection from the open ocean, but is readily accessible to deep-sea ships on one side and the railway on the other. Environmental

studies were conducted in this area by Fisheries Operations of Environment Canada. It was found to be a rich intertidal area, vital as a nursery and feeding ground for fishes, and vulnerable to development. Because port development on Flora Bank would result in the loss of limited, ecologically vital delta area, the proposal was eventually abandoned.

Around 1950, a sulphite pulp mill was built on Watson Island, adjacent to the fishing community of Port Edward, some five miles south of Prince Rupert and 10 miles northwest of the mouth of the Skeena River. The effluent from this mill was discharged via a small inlet into Wainwright Basin, a semiconfined body of water, separated from Porpoise Harbour by the constricted Zanardi Rapids on one side, and from Morse Basin, by Galloway Rapids, on the other. By 1960, it was found that, notwithstanding the large tidal range and vigorous tidal mixing, oxygen depletion (arising from decomposition of the spent sulphite liquor) was causing nearly anoxic conditions in both Wainwright Basin and Porpoise Harbour, and herring kills were reported by the fishermen.

Remedial measures had to be instituted. The "red liquor" from the sulphite mill, which has the highest proportion of the biochemical oxygen demand in the effluent, was piped into Chatham Sound west of Ridley Island. Before this was done in the late 1960's, a Kraft mill was added to the sulphite mill on Watson Island. In spite of various problems with pipeline breaks and leakages, the improved disposal system was finally put into operation by the spring of 1969. Needless to say, as a result of pulp mill wastes and other industrial operations associated with the forest products industry, degradation has occurred not only in Wainwright Basin and Porpoise Harbour, but also on the west side of Ridley Island.

An obvious choice of an alternative port site, to that of Flora Bank, was Ridley Island. It has rail and deep-water

access, and its shores are already degraded by pulpmill effluent. The site received renewed interest in late 1972 when the Minister of Environment Canada suggested Prince Rupert as an alternative to Squamish as a coal port.

The above proposal prompted further studies, on behalf of the provincial government, by Howard Paish and Associates Limited. Not satisfied with the conclusions drawn by the consultant's report, the federal government, on the advice of its DOE "Prince Rupert Steering Committee", proposed that a federal-provincial committee be established to deal with the subject of alternative bulk-loading sites at Prince Rupert.

As a result, a four member Joint Federal-Provincial Committee on Prince Rupert Port Study (sometimes referred to as the Tsimpsean Peninsula Federal-Provincial Joint Committee) was established, with equal representation from both levels of government. A contract was awarded to Swan Wooster Engineering Company Limited, Vancouver, British Columbia, for Phase I, dealing with engineering aspects of alternative sites for bulk loading in the Prince Rupert area. Their report, "Phase I. Bulk Marine Terminal Sites in the Prince Rupert Area of British Columbia (Engineering Aspects)", was issued in November, 1974. The study on Phase II, dealing with the biological/ecological aspects of the problem, was contracted to B.R. Hinton and Associates Limited, Vancouver, British Columbia, and was completed in March, 1975. It is anticipated that these studies will provide definitive answers for appropriate site selection for a bulk-loading terminal, from both the engineering and ecological points of view.

Because of the proximity of the Prince Rupert area to coal deposits in the interior of British Columbia, and the availability of transportation for this raw material, as well as iron ore, Prince Rupert has recently received attention as one of the alternative locations for a major steel mill, backed by Japanese

interests (Vancouver Sun, February 5, 1975). Of some 12 sites considered as possibilities, three were in the Prince Rupert area (Port Simpson, Digby Island and Ridley-Kaien islands). To gain some appreciation of the environmental impact of this proposed steel mill, it has a planned production of 4 million metric tons of steel per year, or about 2/3 of the output of Canada's largest mill, located in Ontario. Six million tons of coal would be burned per year in the smelting of the iron ore, equivalent to the amount handled annually at Roberts Bank. It should also be noted that steel mills are one of the heaviest water users of all industries.

Feasibility studies have been undertaken by a joint group representing the provincial government and the Japanese company Nippon Kokan K.K. for an integrated steel mill in the province. These will include investigations of the economic, sociological and environmental impacts, and are scheduled for completion by October 31, 1975.

A federal-provincial General Development Agreement was signed by the federal government with British Columbia on March 28, 1974. As a possible subsidiary agreement within terms of the foregoing, a joint federal-provincial program for development of environment and resource inventories in British Columbia is being developed. A high priority under such a proposed agreement is being given to the northwestern portion of the province. Among studies proposed is one on estuaries, including the Skeena as a critical rearing area for anadromous salmonids.

In compiling and summarizing knowledge on the Skeena River estuary, it was our desire that the resulting report would serve to provide useful background information for those concerned with environmental impacts of these and other contemplated developments. Most proposed developments initiate studies of one kind and another, and part of the purpose of this volume is to provide the essential background information on what is already

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known, so that costly duplication of effort is avoided. We hope that this objective has been met.

M. Waldichuk

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Preface Table (i).

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Acknowledgements

The author would like to thank all agencies and individuals that supplied reports and data, particularly unpublished material.

I am also grateful for the helpful advice and criticism received in the preparation of this report.

Finally, I would like to express my appreciation to Mrs. Rose Dawson for preparing the manuscripts.

SUMMARY

The Skeena River estuary receives the drainage of approximately 20,000 square miles. River runoff is highly seasonal, averaging a mean monthly flow rate of 32,600 cubic feet per second at Usk, and is characterized by a spring freshet between May 19 and June 29.

Fresh water enters Chatham Sound, Dixon Entrance, and Hecate Strait via a series of passages and channels between several islands lying off the river mouth. About 1/4 of the Skeena's flow moves through Inverness Passage (separating Smith and De Horsey islands from the mainland), while the remaining 3/4 of the flow is divided nearly equally between Marcus Passage (separating Smith and De Horsey islands from Kennedy Island) and Telegraph Passage (separating Kennedy Island from the mainland).

Like that of many other estuaries, the water of the Skeena estuary is very turbid, particularly during the spring freshet and heavy autumn rains. This is due to suspended "glacial flour" and silt, picked up by the river during its movement from the headwaters to the sea. However, unlike most other estuaries, there is no distinct delta formed by the Skeena River. Rather, the suspended particles are deposited in banks or shoals along or in the lower river and/or the various channels connecting the estuary with the open ocean.

The lower reaches of the Skeena River estuary channels cut across plutonic, metamorphic and sedimentary rocks, and are floored with medium-to coarse-grained sand. The margins of the channels are floored with organic rich, silty or plastic clay. Along the delta front there is a sharp transition from sandy, channel sediment to muddy, deeper ocean basin sediment. However, at the mouth of the river between Kennedy and Marrack islands, sandy sediment extends into deeper water, suggesting that sediment

deposition there is relatively great.

The Skeena River estuary experiences a modified maritime climate, being significantly cooler and wetter than estuaries of the Strait of Georgia. The main climatic controls are the large scale circulation pattern and the topography. During most of the autumn, winter, and spring, the prevailing southwesterly winds aloft bring storms to the coast, with accompanying precipitation. Fewer storms reach the coast during the summer. At all times of the year, the mountains cause the moisture-laden winds to be lifted, and subsequent cooling thus augments precipitation. Also, the Skeena River valley permits direct access of cold winter winds to the coast, and frequent periods of strong northeasterlies are experienced during most winters.

The Skeena estuary tides are of the typical mixed type, with large diurnal inequalities, and characterized by large tidal ranges with associated strong tidal currents and vigorous mixing. These are modified by the flow of fresh water, accelerating the current on the ebb tide and retarding it on the flood, and introducing some stratification at certain periods. As a result of the strong tidal action, the waters are generally well mixed from top to bottom, although there is seasonal variation, particularly with varying river discharge and tidal range.

Wave action is considerably lessened by the islands, shoals, and banks in front of the Skeena River mouth, which serve to break any oceanic waves or swells. Shoals submerged at all times may cause amplified wave heights in some areas. Local winds and the restricted fetch of open "inside" waters would only allow relatively small waves, with steep crests, to develop.

Because of the constricted passages connecting some bodies of water to the open sea, various confined basins are not flushed by tidal action. However, this does not seem to be the case in the main channels serving the mouth of the Skeena.

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Freshwater invertebrate studies have been conducted in relation to fish feeding habits in several lakes of the Skeena drainage. The dominant benthic organisms found are bivalves, snails, amphipods, oligochaetes, stonefly nymphs, mayfly nymphs, lace wing nymphs, chironomids, caddisflies, and fly larvae. Zooplankters consumed by fish are mainly copepods, cladocerans, ostracods, and mysids.

Most marine and estuarine invertebrate research has been done in relation to pollution from the Canadian Cellulose pulp mills on Watson Island. Recent studies indicate that the benthic faunas of Wainwright Basin, Porpoise Harbour, and the Ridley Island red liquor discharge cove are being adversely affected by mill wastes.

One of the most abundant organisms in rocky, moderately polluted areas is the amphipod *Anisogammarus confervicolus*. Other areas have varied faunas, the species and abundance depending on the degree of pollution stress. Soft-bottom organisms found include bivalves, polychaetes, and mud shrimp.

The red liquor cove on Ridley Island contains no intertidal benthic life at all. For approximately the first quarter mile past the cove there is a zone of transition which contains a few typical intertidal organisms. However, the calcareous-shelled animals present are extremely fragile, and will crush under the slightest pressure. Beyond this zone, a relatively normal intertidal community, consisting of *Thais* sp., *Katherina tunicata*, *Mytilus* sp., *Acmaea* sp., *Littorina* sp., *Balanus cariosus*, and *B. glandula*, is found.

Zooplanktonic invertebrates recorded in Skeena estuary waters include amphipods (*Allorchestes angustus* and *Anisogammarus pugettensis*), copepods, various decapod larvae, euphausids, chaetognaths, larvaceans, and polychaetes, among other less common forms.

xxiii. Summary

The waters in, and adjacent to, the Skeena estuary support a substantial shrimp and crab fishery. Oysters, clams, and scallops are also taken locally, although they do not form a commercial fishery.

The Skeena River ranks second only to the Fraser River as a producer of salmon. The most productive region of the Skeena drainage for salmon is the Babine tributary system. Over the past decade, this area has been the subject of intensive fisheries management and experimentation to enhance production. In 1969, the commercial salmon catch at Prince Rupert was valued at \$4 million, the troll fishery of the area providing 4 to 8 million pounds annually.

In addition to salmon, the Skeena River, its estuary, and/or adjacent waters are noted for their steelhead, trout, whitefish, rock sole, Pacific cod, halibut, smelt, and Pacific herring. Commercial fishing forms the single most important source of income to the residents of Prince Rupert. In 1970, nearly 42% of its basic employment and 36% of its basic income were attributable to this industry. In addition, many more people are employed in a growing tourist trade related to sports fishing, not to mention the jobs supplied by the fish processing plants of the region.

Recent Fisheries Service studies have found that the many banks formed by deposited sediment from Skeena runoff are important nursery areas for juvenile fish species. Researchers have stressed the necessity of retaining these habitats in order to maintain the fish populations of the Skeena system.

Like the invertebrate populations of the Skeena estuary, the benthic algae have only been studied in relation to pollution from the pulp mills on Watson Island. In general, there is an inverse relationship between the degree of pollution and the number of algal species present. Red and brown algae are

xxiv. Summary

more abundant in unpolluted locations, while green species are more common in moderately to heavily polluted areas. The most tolerant species are *Enteromorpha* spp., *Rhodomela larix*, *Gigartina papillata*, and *Fucus distichus*.

Flora Bank supports 50 to 60 percent of the total eelgrass found in the Skeena estuary, and as such, is a vital fish-rearing area. Marsh vegetation, characterized by horsetails, cattails, bulrushes, and sedges, is not noted in the estuary area, but is recorded as occurring around the margins of some Skeena drainage lakes.

The Skeena River estuary lies within the coastal western hemlock biogeoclimatic zone, and is characterized by western hemlock, western red cedar, amabilis fir, Douglas fir, salmonberry, and salal. Other common species known to occur in the region include red alder, huckleberry, juniper, willow and labrador tea.

Approximately 30 species of waterfowl are listed as occurring in the Skeena estuary area. However, due to the rugged topography, lack of marsh vegetation and flooding, few nest here. Those that do include Canada geese, mallard ducks, and common mergansers. Common winter residents are snow geese, pintail, harlequin ducks, white-winged scoters, surf scoters, greater scaup, common goldeneye, Barrow's goldeneye, bufflehead, oldsquaw, and red-breasted mergansers.

The spotted sandpiper and sandhill crane are the only shorebirds that nest on the estuary, while black turnstones, rock sandpipers, and dunlin over-winter there. The only resident gull species is the glaucous-winged gull, but glaucous, herring, mew, and Bonaparte's are migrant or over-wintering forms. Other water birds recorded for the estuary region include loons, grebes, cormorants, pigeon guillemots, murrelets, and auklets. Another bird species reported to be abundant in the Skeena area is the

bald eagle, which nests in the tall trees along the river and estuary.

Other notable wildlife recorded for the Skeena region are black bear, grizzly bear, caribou, moose, deer, sheep, beavers, wolves, coyotes, mink, and marten. Hair seals are commonly found in the estuary, as well as upriver, where they feed on eulachon. The wildlife of the Skeena drainage system is a valuable recreational resource, dependent upon the preservation of natural habitats for its existence, as are the other biotic components of the estuary.

Compared to more southern British Columbia estuaries, the Skeena River estuary has not been excessively exploited. This is more the result of inaccessibility than lack of interest. Although some recent land use studies have tried to emphasize the value of the region's resources in recreational and/or non-consumptive ways, the north is just beginning to feel the push towards industrialization. Despite pollution studies which would indicate otherwise, urbanization, with its attendant industries such as lumbering (including pulp mill operations), mining, and fish processing, is relatively new to the region. With the opening of the general cargo terminal at Fairview, and the probable construction of a bulk-loading facility somewhere on the estuary, development will proceed at an increasing rate for several years to come.

In order for sound decisions to be made regarding any further alterations to the Skeena estuary, it would seem necessary to obtain baseline data on several topics found to be lacking in the research to date. In the field of biology, there is a general lack of data on all aspects of the floras and faunas, be they terrestrial, freshwater, estuarine, or marine; vascular or non-vascular; vertebrate or invertebrate. The only possible exception to this is salmon fisheries research, which, because of the Babine program, has been studied in some detail.

This is not, however, true of the other fish resources of the system. Other fields requiring increased research are geology (all aspects), hydrology (flow and sediment data taken at the river mouth), water quality (all aspects), land use (landscape suitability studies for development other than for a bulk-loading port, including such things as urbanization, housing, recreation, etc.), and pollution (particularly industries other than the pulp mill). Oceanographic processes, although better studied than the preceding subjects, are not well understood. Current and wave data, particularly, are lacking.

1. INTRODUCTION

The Skeena River system drains an area of about 20,000 square miles, and empties into Chatham Sound at approximately $54^{\circ}08'$ north latitude and $130^{\circ}10'$ west longitude (Figure 1.1), at an average mean monthly flow rate of 32,600 cubic feet per second (cfs), at Usk (Water Survey of Canada, 1973). The estuary formed at the mouth of the river is unusual in that it does not occur at the head of an inlet or open into a large body of water. Instead, the fresh water enters Chatham Sound, Dixon Entrance, and Hecate Strait through a series of channels which separate several islands, particularly Smith, De Horsey, Kennedy, and Porcher. The main channels receiving this influx of Skeena River water are Inverness Passage (separating Smith and De Horsey islands from the mainland, or Tsimpsean peninsula), Marcus Passage (separating Smith and De Horsey islands from Kennedy Island), and Telegraph Passage (separating Kennedy Island from the mainland) (see Figure 1.2).

There are no extensive, continuous tide flats forming a distinct Skeena River delta. Rather, there is a series of pockets of shallow water where sediments have built up to form shoals and sand banks.

The largest deltaic deposit occurs between Smith and De Horsey islands. This takes the form of a broad bank, 2 to 3 miles wide, between Parry Point (at the south end of De Horsey Island) and Croosdaile Island (off the southern tip of Smith Island).

Another band of deltaic deposit can be found at the north side of the entrance to the Skeena River, from Mowitch Point on the mainland around to Gust Point at the river entrance, and continuing for about 2.6 mi. on the northeast side of Inverness Passage as far as Caspaco PO. This deposit has

2. INTRODUCTION

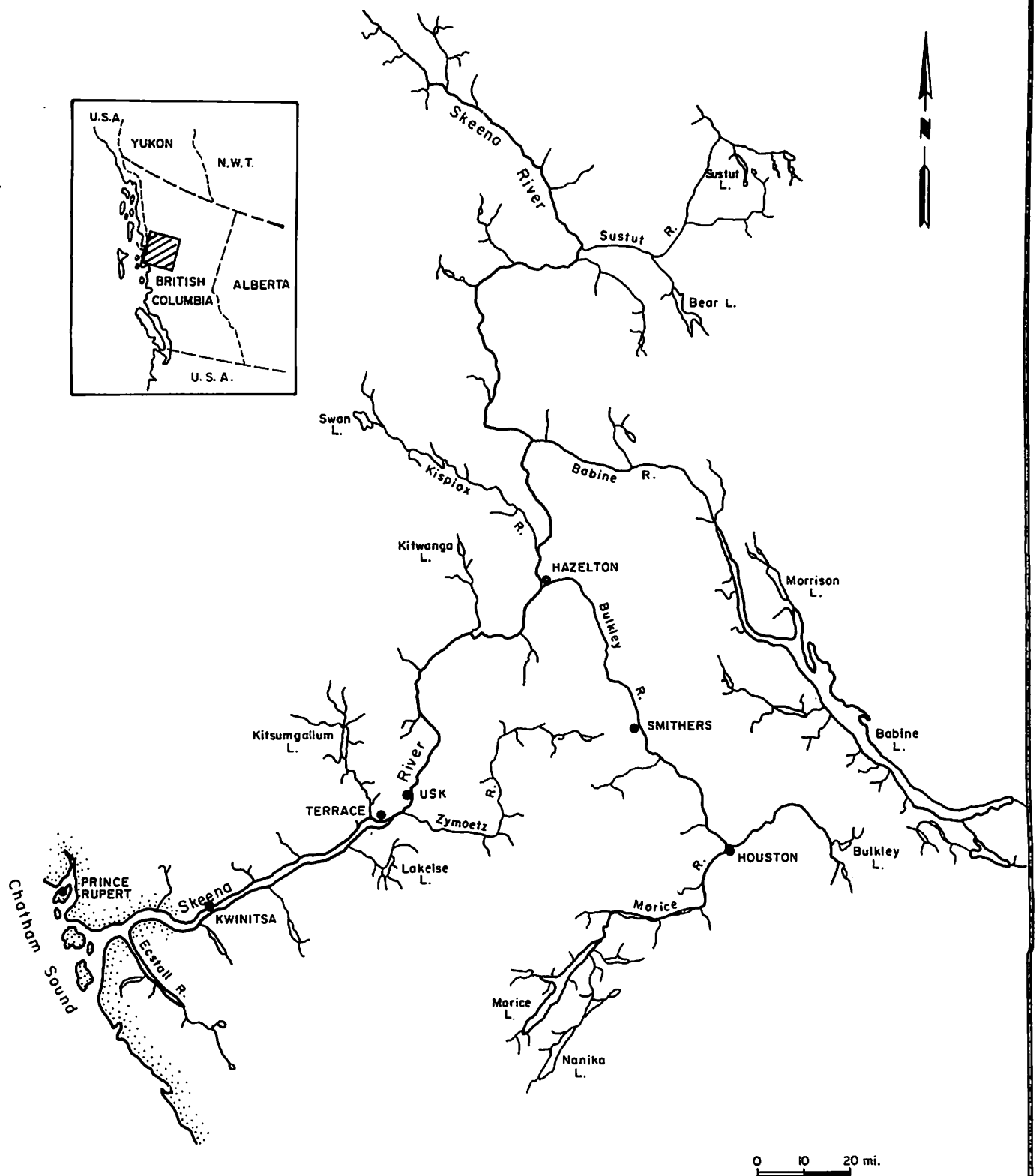
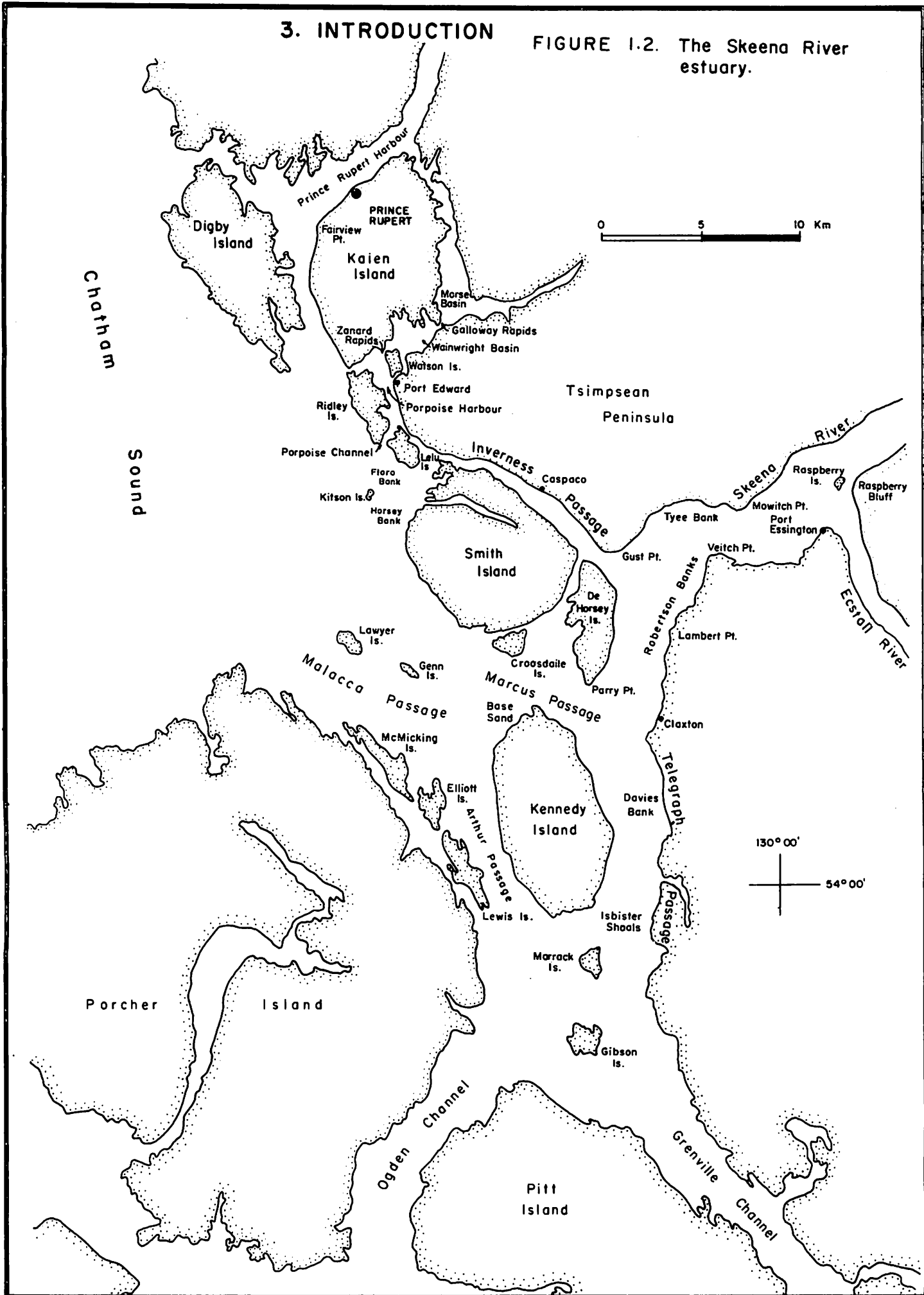


FIGURE 1.1. Skeena River drainage basin
(after Brett, 1950)

3. INTRODUCTION

FIGURE 1.2. The Skeena River estuary.



4. Introduction

an average width of approximately 0.4 mi., and extends for a distance of 6.1 mi.

Other major sedimentary deposits from the Skeena include Flora Bank, located between Lelu and Kitson islands at the western end of Inverness Passage, and "Base Sand", between the north ends of Kennedy and Genn islands and separating Marcus Passage from Malacca Passage. Robertson Banks seem to have grown in the channel, quite removed from any land. They are located at the entrance to the Skeena River, in the lee of Veitch Point on the mainland.

Davies Bank, located in the middle of tide-swept Telegraph Passage (between Kennedy Island and the mainland), is a deltaic deposit measuring about 0.4 mi. wide by 0.7 mi. long. It would appear that this is the beginning of an extensive bank which is gradually forming on the east side of Kennedy Island, approximately three-quarters of the way across Telegraph Passage.

Upstream in the Skeena River, various other banks have formed from the sediment carried by the fresh water. One strip, about 2 mi. long by 0.75 mi. wide, occurs in the lee of Port Essington, just west of the confluence of the Ecstall River with the Skeena. Almost directly north of this is Tyee Bank, having almost the same dimensions as the first. Between Raspberry Island and Raspberry Bluff, east of the confluence of the Ecstall and Skeena rivers, there is a deposit (measuring about 3 mi. long by 0.5 mi. wide) extending northeastward into the banks of the Skeena. Further upstream, Carnation Bank has formed where the Scotia River meets the Skeena.

All of these deltaic deposits, together with the foreshores of the many islands lying just off the river mouth, form an extensive estuary area which covers nearly 20 square miles, and projects almost 5 mi. seaward (Environ. Prot. Serv., 1975).

5. Introduction

Because the largest population of the region is located at Prince Rupert, and the main industries of the area are centred in and around this city, for the purposes of this discussion, the "Skeena estuary" will include Kaien Island and the surrounding bodies of water, such as Wainwright Basin and Porpoise Harbour (Figure 1.2). It will be seen that these areas exert a substantial influence on the ecosystems of the estuary.

Being the most northern and western of the estuaries of the British Columbia mainland, that of the Skeena has played an important role in the economy of the province's northland. Prior to the mid-1800's, the region was inhabited primarily by native peoples, who relied on the river and estuary salmon and herring fisheries for their existence. With the coming of the whiteman, settlements sprang up along the river banks, the economies of which were based on fur trading and fishing. Fish processing plants were built along the river and estuary channels. Sawmills began cutting timber, thus beginning an industry which continues to grow in the region today. A small gold rush in the 1870's started the search for mineral wealth in the Skeena drainage.

In time, steamboats replaced the canoes on the river, only to later be replaced, themselves, by the coming of the railroad, via which, in 1903, the city of Prince Rupert was established. This was the western terminus of the Grand Trunk Pacific Railway, and, with the settlement's incorporation, the move of the north coast towards an industrialized civilization really began.

After many years of uncertainty, the region has finally become economically viable. Highways and ferries now link this area with the more populated southern and interior parts of the province, and new industries have brought greater prosperity to the people. The most notable of these industries is the Canadian Cellulose pulp mill operation on Watson Island, south of Prince

6. Introduction

Rupert.

As far back as 1903, the idea of building deep-sea port facilities in the Skeena estuary area has been expounded. A variety of proposals, made over the past fifty or more years, have been shelved for various reasons, both ecological and economic. However, a general cargo terminal was eventually approved for Fairview Point, on Kaien Island, and this is now under construction. At present, a federal-provincial committee is examining alternative sites for a bulk-loading terminal in the Skeena estuary area, and it would appear to be only a matter of time until this facility will also become a reality.

These developments, and others planned for the Skeena estuary, should only be approved after careful study. Environmental research has shown that pollution from the pulp mills on Watson Island is already having substantial deleterious effects on the water quality and biota of the receiving waters. As the extensive deltaic deposits, particularly Flora Bank, support various life stages of the valuable fisheries resource of the Skeena River, it is vitally important that these estuarine habitats be maintained.

2. GEOLOGY AND SOILS

Extremely little is known of the geology of the Skeena River drainage basin and, in particular, the Skeena estuary. The first sub-section of this chapter provides the general geological setting of the region, and relies heavily on early map-area studies. The second sub-section was written by Dr. J.L. Luternauer (Geological Survey of Canada) and describes the most recent geological investigations being undertaken on the Skeena River estuary. The bibliography for these two sub-sections was compiled by Mr. K. Ricker (Geological Survey of Canada). The final sub-section, concerning soils of the region, was compiled from the sources indicated.

2 (i) GENERAL GEOLOGICAL SETTING

Two Geological Survey of Canada publication abstracts (Duffell and Souther, 1964; Hutchison, 1967) serve to introduce the general geological characteristics of the Skeena region, and the reader is referred to the original reports and bibliography for more detailed information. The glossary provides definitions of many of the geological terms quoted below.

Duffell and Souther (1964) analyzed the geology of the Terrace map-area of British Columbia, a zone which covers 2,800 square miles of the Coast and Hazelton mountains of west-central British Columbia. For our purposes, this region can be considered representative of the headwaters area of the Skeena drainage.

Duffell and Souther indicated that "The Coast Mountains are composed largely of rocks of the coastal intrusions, which cut sedimentary and volcanic rocks from Permian and Cretaceous age. The main contact runs, generally, northwesterly, but large

8. Geology

apophyses extend eastward. Granodiorite and adamellite predominate in the main mass, and quartz-diorite, diorite, gabbro, and minor syenite in the apophyses and stocks; true granite forms a minor component of both. These rocks may be divided into four main facies on the basis of type and proportion of mafic content: gabbro, pyroxene-quartz diorite, inner, and border facies. Each facies may be subdivided again on a basis of textural and colour variation."

"Dykes fall into four main groups and are instrumental in the location of mineralized quartz veins."

"The Hazelton Mountains to the north are composed largely of sedimentary strata of Upper Jurassic - Lower Cretaceous age, here named the Bower Group. These rocks, previously included with the Hazelton Group, or referred to as the Skeena formation, are now known to underlie thousands of square miles of north-central British Columbia, and are sufficiently distinctive to be classed as a group."

"The Pleistocene period produced the wide, flat, gravel-and clay-filled Kitimat-Kitsumkalum valley...."

"Occurrences of gold, silver, lead, zinc, and copper minerals are common" (the possible environmental effects of mining such ores are discussed in the Pollution section of this report).

Hutchison's report (1967) deals with the geology of the Skeena estuary area. In his paper on the Prince Rupert and Skeena map-area, British Columbia, he states that "Prince Rupert (east half) and Skeena map-areas cross the Coast Mountains of British Columbia between latitudes 54° and 55° N, and abut the Alaska Panhandle. They are underlain mainly by a northwest-trending zone of gneiss and migmatite, that is flanked and penetrated by large bodies of plutonic rock. Sediments and volcanics

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in the western half of the area are of uncertain age, but are thought to be Late Palaeozoic or Early Mesozoic. They are regionally metamorphosed to gneisses and schists."

"Sediments in the eastern half are unmetamorphosed, and are of Late Jurassic and Early Cretaceous age. The plutonic rocks, which constitute almost half the exposed rock in the area, are mainly diorite, quartz diorite, granodiorite, and quartz monzonite, and are regarded as post-early Cretaceous in age. They commonly grade into the Palaeozoic gneiss complex. Major faults probably underlie some of the pronounced northwest-trending channels."

"Several old prospects of gold, copper, silver, zinc, iron, limestone, and salt occur within the area".

The general geology of potential bulk terminal sites in the vicinity of the Skeena River estuary was described in three of the many reports published concerning site location (C.B.A. Engineering, 1969; Slaney, *et al.*, 1973; Tera Environ. Resource Analysts, 1975). The following information was derived from those by F.F. Slaney and Company (1973), regarding the ecological effects of port development, and Tera Environment Resource Analysts (1975), regarding the terrestrial environments of possible bulk loading sites.

Prince Rupert lies on the boundary between the Kitimat Range of the Coast Mountains and the Hecate lowland. The offshore islands of the Hecate lowland are separated from the mainland by deep channels carved by glaciation. The islands rarely exceed 2500 feet in elevation, and consist of metasediments and metavolcanics, protected by plutonic rocks (Ridley, Lelu, and Kaien islands are examples). The topography consists of rounded landforms and dome-shaped hills, less than 1500 feet high.

Despite glaciation by valley glaciers and at least one

10. Geology

ice sheet from the Quaternary Period, there are few glacial deposits in the area. Most of the glacial deposits have since been masked by resorted river deposits.

Near Fairview Point, metamorphosed schists of Mount Hays form a steep, 1200-foot high ridge. The topography just behind the point is hummocky, with a 50-foot relief, owing to bedrock-cored hillocks and organic deposits in intervening depressions.

The islands of Ridley, Lelu, and Kitson have a local relief of about 50 feet. The highest elevations on the hummocky topography are about 115 feet above sea level (asl). The small hills and ridges on the islands are bedrock-cored, being generally elongate in a northwesterly direction, parallel to the strike of the bedrock. No bedrock outcrops occur except along the beaches and foreshore area.

The two reports (Slaney, *et al.*, 1973; Tera Environ. Resource Analysts, 1975) also included some information on the bedrock geology of the port sites. In general, the area is entirely underlain by metamorphic rocks equivalent to the Vancouver Group of Jurassic-Triassic age. The rocks are layered metasediments of the almadine amphibolite facies, consisting mainly of hornblende and hornblende biotite schists, with minor quartzite, graphite schist and amphibolite.

The rocks are tightly or isoclinally folded, with a northwest strike (generally parallel to the coastline of the proposed port sites), and the general dip is to the east, varying gradually from gentle to moderate (40°). Major planes of weakness have created fault zones such as the Skeena River, and smaller secondary fault and fracture patterns are common on the Tsimpsean peninsula. One deep fault is that of the Ecstall pluton, resulting in a northward and upward movement of the rocks. The Ecstall pluton lies southeast of the port sites, and consists

11. Geology

of poorly foliated or massive quartz diorite or granodiorite.

Prince Rupert Harbour lies within a maximal possibility zone for incidence of earthquakes. Only one quake has occurred in the area, that being in May, 1929, with an intensity of 7 on the Richter scale, and epicentered in Hecate Strait. The same earthquake measured an intensity of 4 on Digby Island, and caused a local tsunami.

Surficial deposits of the region include colluvial, organic, and alluvial deposits of nonglacial origin, and a small amount of glacio-marine till of glacial origin (in the Casey Point region).

Colluvial deposits of bedrock rubble, loose silt and sand, minor slump and organic deposits are found extensively throughout the study area on the slopes of low erosional scarps overlying bedrock. These deposits cover a total area of about 200 square miles on the peninsula, and are generally less than five feet thick, except at the base of mountain slopes where deeper layers have formed.

The second most common surficial material is exposed rock with less than three feet of overburden. These areas (a total of 132 square miles) are associated with oversteepened valley walls of glaciated valleys or with mountain tops in excess of 2,000 feet asl.

The third most extensive deposit in the area (32 square miles) is organic deposits, which vary greatly in thickness. Shallow deposits (2 to 3 ft. thick) occur on bedrock knobs and slopes. A considerable amount of silt, clay, and organic muck is also found.

A small alluvial fan occurs near Fairview Point on Kaien Island. It is reported to consist of silt, sand, and

12. Geology

schist fragments up to boulder size, and to have been formed by a small north-flowing stream.

Extensive floodplain and deltaic deposits are found along the Skeena River channel. Since the flow is generally confined by steep mountains, such deposits are relatively coarse. The only areas containing deltaic silts and fine sands are protected embayments, such as occur at the mouth of the Khyex River, in Inverness Passage, and on Flora Bank. The delta front of the Skeena River is located at Kitson Island (derived from Inverness Passage sediments), and between Kennedy and Smith islands (derived from Marcus Passage sediments). These fine deposits have poor foundation and bearing strength, as well as poor stability and internal cohesion, and would not be suitable locations for port development.

As was indicated in the two previous reports of this estuary series (Hoos and Packman, 1974; Hoos and Vold, 1975), the geology of an estuary is extremely important in relation to the biological populations able to inhabit the area. The sediment stability and composition dictate, to a large degree, whether or not benthos (both floral and faunal) will be able to survive there, and if so, whether they will be infaunal organisms, epifaunal organisms, or both. As well, sediments and, in particular, organic deposits are important in estuary food chains.

It should also be noted that geological information is essential when undertaking developments such as the bulk-loading facilities proposed for the Prince Rupert region. It would seem necessary for one to know the foundation conditions and, thus, the engineering requirements, for each possible site. In view of these facts, it seems unusual that so few of the studies related to environmental impact of possible port development in the Skeena estuary vicinity have included work on the geology of the region.

13. Geology

2 (ii) ON-GOING GEOLOGICAL STUDIES

The Geological Survey of Canada initiated a preliminary marine geological research program of the Skeena estuary and delta in 1974, to acquire data which could be applied to studies of sediment dispersal routes, past and present sites of sediment deposition, the influence of river discharge/wave climates on delta front erosion-accretion rates, trace metal base levels, etc. A total of 210 sediment samples were collected from the sea-floor off the delta-front, from the lower reaches of the Skeena River channels, and from small beaches and basins in the vicinity of Ridley Island (Figure 2.1). In addition, approximately 50km of continuous seismic profiles were obtained along Grenville and Ogden channels, and Arthur and Malacca passages (Figure 2.1).

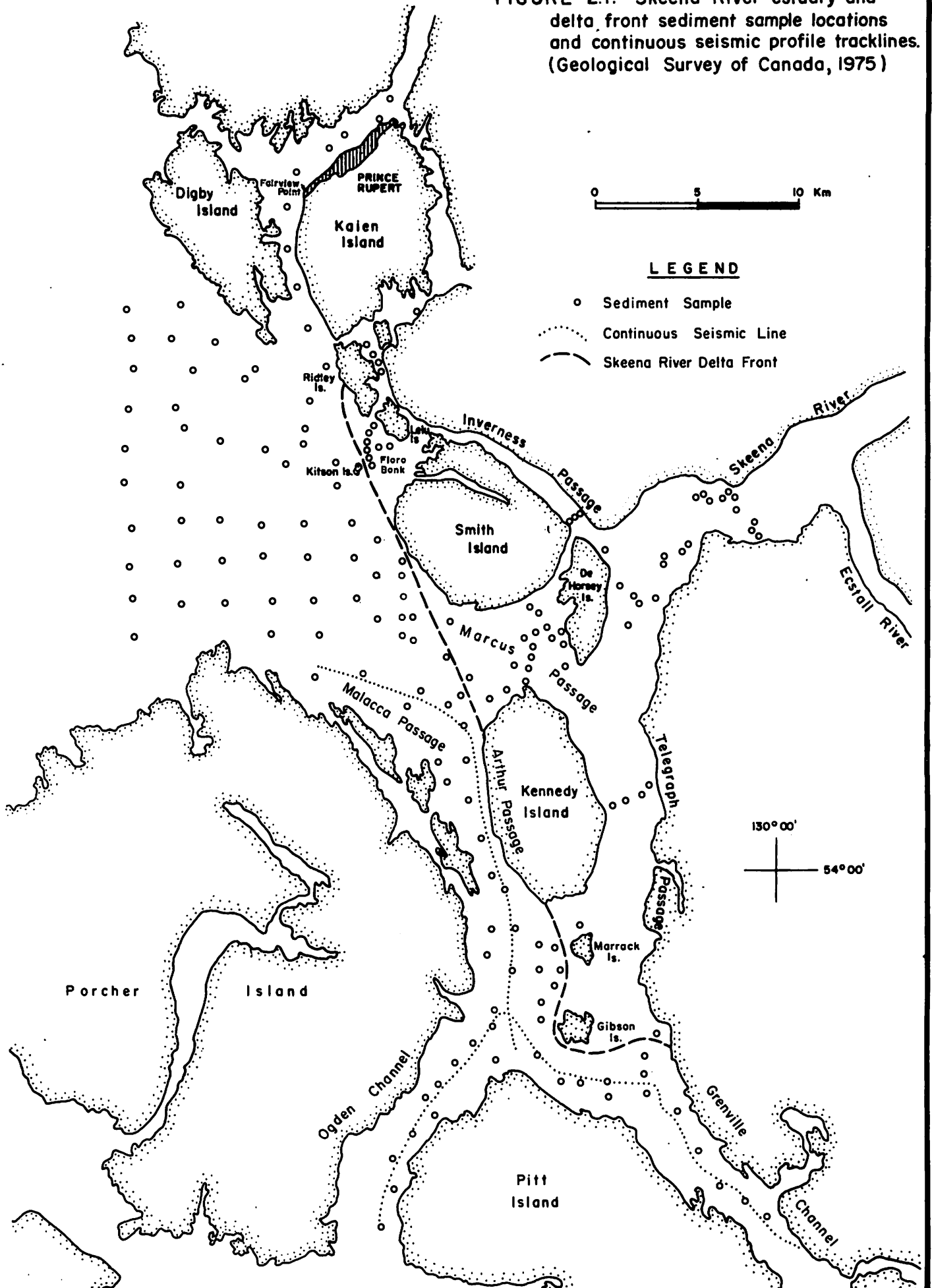
Operations were carried out from the C.S.S. *William J. Stewart* (June 17 to 23) during a Canadian Hydrographic Service survey of the Skeena River, from the C.S.S. *Laymore* (August 12 to 24) during a biological survey of various estuaries (under the direction of Dr. C. Levings of the Pacific Environment Institute), and from the C.F.A.V. *Endeavour* (August 25 to 30).

At this stage in the analysis of the accumulated data, only a few remarks can be made about the marine geological environment of the Skeena estuary, based primarily on field observations, and the gross characteristics of samples and seismic lines obtained.

The lower reaches of the Skeena River channels cut across plutonic, metamorphic and sedimentary rocks (Duffel and Souther, 1964; Hutchison, 1967, 1970; Roddick, 1970; Hutchison and Okulitch, 1973). In general, they are floored by medium to coarse sand, which accumulates in places to form extensive bars. Megaripples, commonly having amplitudes and wave lengths as great as 0.5m and 10m, respectively, are produced on the surface of these bars by currents which can attain velocities in

14. GEOLOGY

FIGURE 2.1. Skeena River estuary and delta front sediment sample locations and continuous seismic profile tracklines. (Geological Survey of Canada, 1975)



15. Geology and Soils

excess of 3kts (150 cm/sec).

The margins of the river channels, particularly the little pocket beaches, generally are floored by organic rich, silty or plastic clay. Broad, sandy flats lie at the edge of the Skeena delta, which extends in a discontinuous fashion for approximately 30km, from Ridley Island to Gibson Island (Figure 2.1). Along the delta front, there is a generally sharp transition from sandy, channel sediment to muddy, deeper ocean basin sediment. However, at the mouth of the river between Kennedy Island and Marrack Island, sandy sediment extends into deeper water, suggesting that sediment discharge there is relatively high. This agrees with evidence from seismic profiles, which indicates that massive deposition has occurred all along Ogden Channel.

Considerably more will be learned about the geologic setting of port sites, as well as the Skeena estuary, when the Geological Survey initiates, in 1975, more detailed studies of terrestrial sediment distribution and landslide potential along the Skeena River and environs.

2 (iii) SOILS

The following information regarding soils of the Skeena estuary area was summarized from the reports by F.F. Slaney and Company (1973), on the ecological effects of port development, and by Tera Environment Resource Analysts (1975), regarding terrestrial environments of proposed port sites. Other general information can be obtained from vegetation studies of the coastal western hemlock zone (Orloci, 1961, 1964; Krajina, 1965). Definitions of the terminology employed can be found in the Glossary.

The soils of the Tsimpsean peninsula are approximately

16. Soils

8,000 years old, having formed as a function of climate, topography, parent material, and time. Climate has played an especially important role in this region of year-round heavy rains and cool temperatures. Drainage and slope are also particularly important here. Podzols are predominant where internal drainage is moderately good to imperfect, as on colluvium; while folisols are more common where internal drainage is more restricted (e.g. on bedrock). In both cases, surface drainage must be good.

Regosols (drained, oxidized mineral soils) occur in association with major stream courses; while the finer sediments of the Skeena River have chemically-reduced gleysols, which occur beneath marsh vegetation.

Areas having poor surface and internal drainage are generally flat or depressed, and are characterized by having extensive organic soils varying from three to fifteen or more feet in depth. Shallower soils (<3 ft.) are normally lithic fibrisols, while the deeper ones (>10 ft.) would be mesic fibrisols. Lithic fibrisols have undecomposed top and bottom horizons, and are associated with forest bog associations (such as lodgepole pine-yellow cedar, and blanket bogs of higher elevations). Mesic fibrisols are open bog soils composed of undecomposed sphagnum in the top layer and partially decomposed organics in the lower horizons..

Soils of Kaien Island, Ridley Island, Lelu Island, Kitson Island, and Flora Bank include podzols, folisols, lithic fibrisols, and mesic fibrisols. In general, podzols and folisols predominate on Kaien Island. Folisols and lithic fibrisols are found on the perimeter of Ridley and Lelu islands, while they completely cover Kitson Island. The remainder of Lelu Island and a circumferencial band (inside the folisol-lithic fibrisol ring) on Ridley Island consist of lithic fibrisols and mesic fibrisols. The center of Ridley Island is boggy, and is characterized by mesic fibrisols.

3. CLIMATOLOGY

3 (i) GENERAL DESCRIPTION

The climate of the Skeena River estuary may be classified as modified maritime, although it is significantly cooler and wetter than that of the estuaries of the Strait of Georgia (Hoos and Packman, 1974; Hoos and Vold, 1975). The climatic controls on the estuary are the large scale circulation pattern and the topography.

During the greater part of the autumn, winter and spring, the prevailing southwesterly winds aloft bring storms to the coast with accompanying winds and precipitation. The northern mainland coast is well exposed to these storms, since the Queen Charlottte Islands are too far away to afford much protection. Fewer storms reach the coast in the summer, and, therefore, this season is drier and less windy.

The mountains, which parallel the coastline, give the necessary lift to the moisture-laden winds, and, hence, augment the precipitation. The Skeena River valley permits direct access of cold winter winds to the coast, and frequent periods of strong northeasterlies are experienced during most winters.

3 (ii) CLIMATOLOGICAL RECORDS

No climatological records are available from the estuary itself, but long-term records have been kept at several sites close enough to allow reasonable extrapolation (see Table 3.1 and Figure 3.1). A short-term station was operated at Port Essington near the turn of the century. Detailed recording of weather parameters really began in 1914 at the Prince Rupert Marine Station, located on the east side of Digby Island, and, until the opening of the airport office in 1961, these constituted

18. Climatology

Table 3.1. Skeena River estuary - available weather data
(Atmospheric Environment Service, 1973).

1. Prince Rupert $54^{\circ}17'N$ $130^{\circ}23'W$ $170'$
 - 1.1. Temperature & Precipitation. August 1908 - January 1963.
 - 1.2. Wind. Sept. 1921 - Oct. 1936; April 1938 - May 1962.
 - 1.3. Sunshine. Sept. 1921 - July 1936; April 1938 - March 1962.

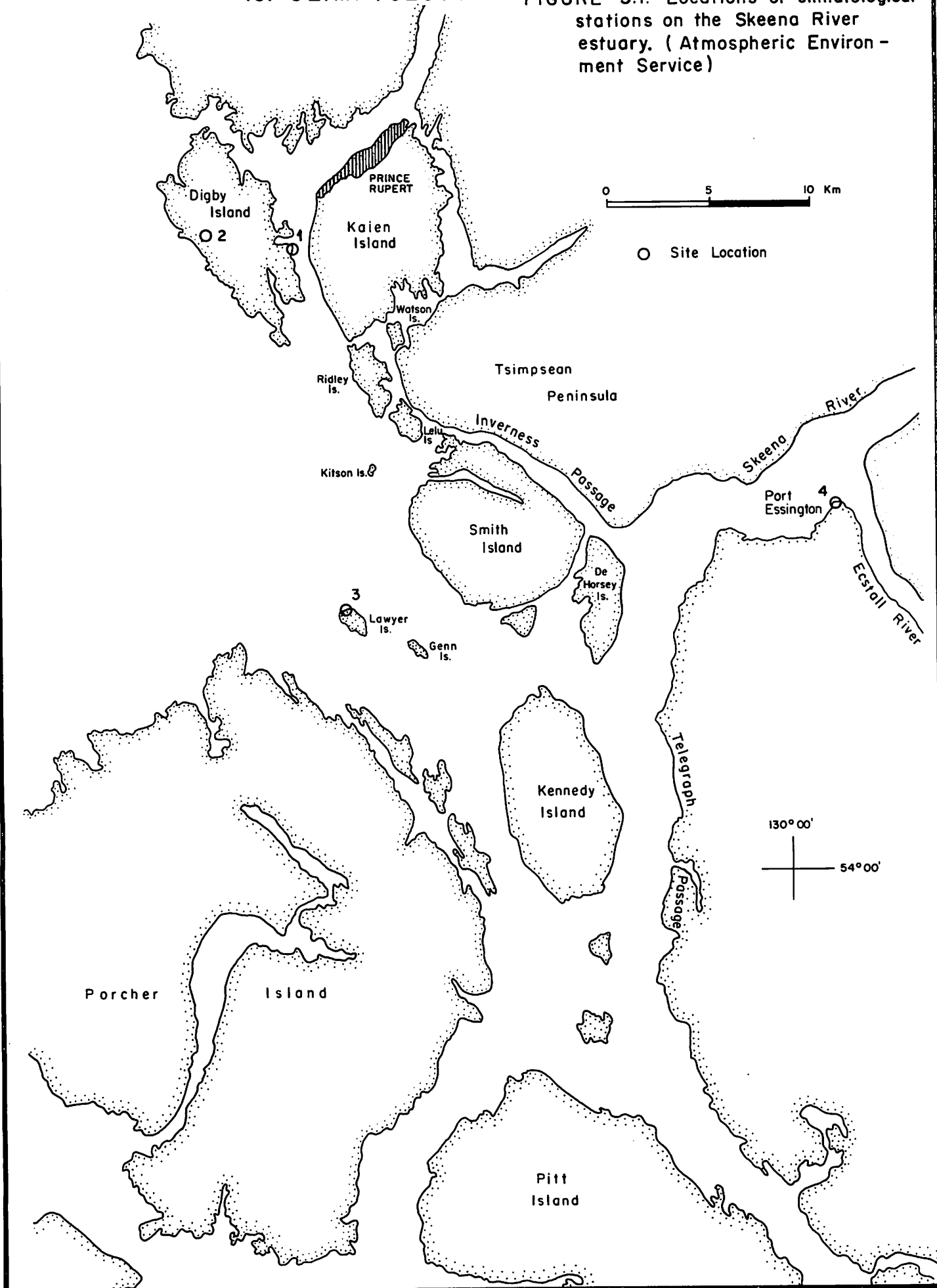
2. Prince Rupert Airport $54^{\circ}18'N$ $130^{\circ}26'W$ $110'$
 - 2.1. Temperature & Precipitation. May 1962 - Continuing.
 - 2.2. Wind. April 1962 - December 1966.
 - 2.3. Rate of Rainfall. October 1969 - Continuing.
 - 2.4. Sunshine. April 1962 - Continuing.

3. Lawyer Island $54^{\circ}07'N$ $130^{\circ}21'W$ $25'$
 - 3.1. Wind. Sept. 1969 - Continuing.

4. Port Essington $54^{\circ}09'N$ $129^{\circ}55'W$ $10'$
 - 4.1. Precipitation. March 1900 - November 1905.

19. CLIMATOLOGY

FIGURE 3.1. Locations of climatological stations on the Skeena River estuary. (Atmospheric Environment Service)



20. Climatology

the official Prince Rupert records. With the move to the airport, a more complete observation program was instituted. As well, Lawyer Island is included, because its wind is representative of the conditions over the exposed waters just off the coast (see Table 3.2 for a summary of available data).

The records from these stations are adequate to portray the general characteristics of the estuary climate. However, any detailed study, or an environmental impact assessment, would necessitate further monitoring on, or reasonably close to, the estuary. In particular, a station would be required that would intercept the strong winter outflow winds which blow down the Skeena valley, since neither the Prince Rupert airport nor the Lawyer Island station are suitably exposed.

3 (iii) TEMPERATURE

The maritime nature of the climate is shown by the annual mean temperature of 45.8°F (7.6°C), the monthly mean range of which is from 35.3°F (1.8°C) in January, to 56.4°F (13.5°C) in July. Temperature extremes vary from -6°F (-21.1°C) in January, to 90°F (32.2°C) in July.

3 (iv) PRECIPITATION

The effect of the local topography on precipitation is exemplified at Prince Rupert. The mean annual precipitation is 95.06 inches, with precipitation occurring on an average of 227 days of the year.

Prince Rupert lacks a dry season. Minimum average precipitation occurs in June, and that exceeds 4 inches. The wettest month is October, averaging over 14 inches. It is noteworthy that the seasonal progression of the mean storm track down the British Columbia coast produces peak rainfall on the

21. Climatology

Table 3.2. Skeena River estuary - climate summary (Atmospheric Environment Service, 1973).

1. Prince Rupert

1.1. Temperature

Mean temperature annual	45.8°F
Mean temperature January	35.3°F
Mean temperature July	56.4°F
Extreme maximum temperature	90°F
Extreme minimum temperature	-6°F

1.2. Precipitation

Mean annual total precipitation	95.06"
Mean annual total rainfall	90.61"
Mean annual total snowfall	44.5"

1.3. Wind

Prevailing wind direction by hours	Southeast
Prevailing wind direction by miles	Southeast
Mean annual wind speed	7.1 M.P.H.

1.4. Annual Number of Days with:

Frost	71 days
Measurable precipitation	227 days
Thunder	1.0 days

1.5. Average Annual Hours of Bright Sunshine 1036 hours

1.6. Cloud Cover

Mean annual cloud cover	7.5 tenths
Month with lowest cloud cover - January	6.8 tenths
Month with highest cloud cover - June	8.1 tenths

1.7. Frost-Free Period

May 8 - October 20 (Airport)	164 days
April 19 - November 5 (Marine Station)	199 days

22. Climatology

Table 3.2. (cont'd).

2. Prince Rupert Airport

2.1. Fog - Visibility Less than 5/8 of a Mile

Annual number of days with fog	27.7 days
Month with greatest average - August	6.5 days
Month with least average - April	0.4 days

3. Lawyer Island

3.1. Wind

Prevailing wind direction by hours	Southeast
Mean annual wind speed	11.5 M.P.H.

23. Climatology

north coast about two to three months earlier than the December-January peak experienced over the south coast.

A fall of 44.5 inches of snow, on the average, can be expected, occurring on 21 days. The worst month for snow is January, with an average of 13.5 inches, and a 24 hour fall, on one occasion, of 15 inches.

3 (v) WIND

As noted previously, wind roses for Prince Rupert airport and Lawyer Island (Figures 3.2 and 3.3) probably are not representative of all estuary winds. The prevailing, strong southeasterlies occur over most of the north coast in advance of Pacific storms. The winter outflow easterlies or northeasterlies are not as frequent, but are likely to be equally strong, and perhaps stronger, down the Skeena valley and over the estuary.

3 (vi) FOG

Fog conditions, with a visibility equal to, or less than, one kilometer, are common in July and August, associated with the cold water of the coast. Ten years of records from the Prince Rupert Marine Station show an average of 4 days of fog per month for July and August, and 18 days for the entire year. Prince Rupert airport records a higher fog frequency - 6.5 days in August, and 27.7 days for the year.

3 (vii) OTHER PARAMETERS

The average annual number of hours of bright sunshine totals 1036, a very low figure, and a result of the frequency of coast storms and the rugged terrain. The mean annual amount of sky cover is 7.5 tenths, the brightest month being January,

24. CLIMATOLOGY

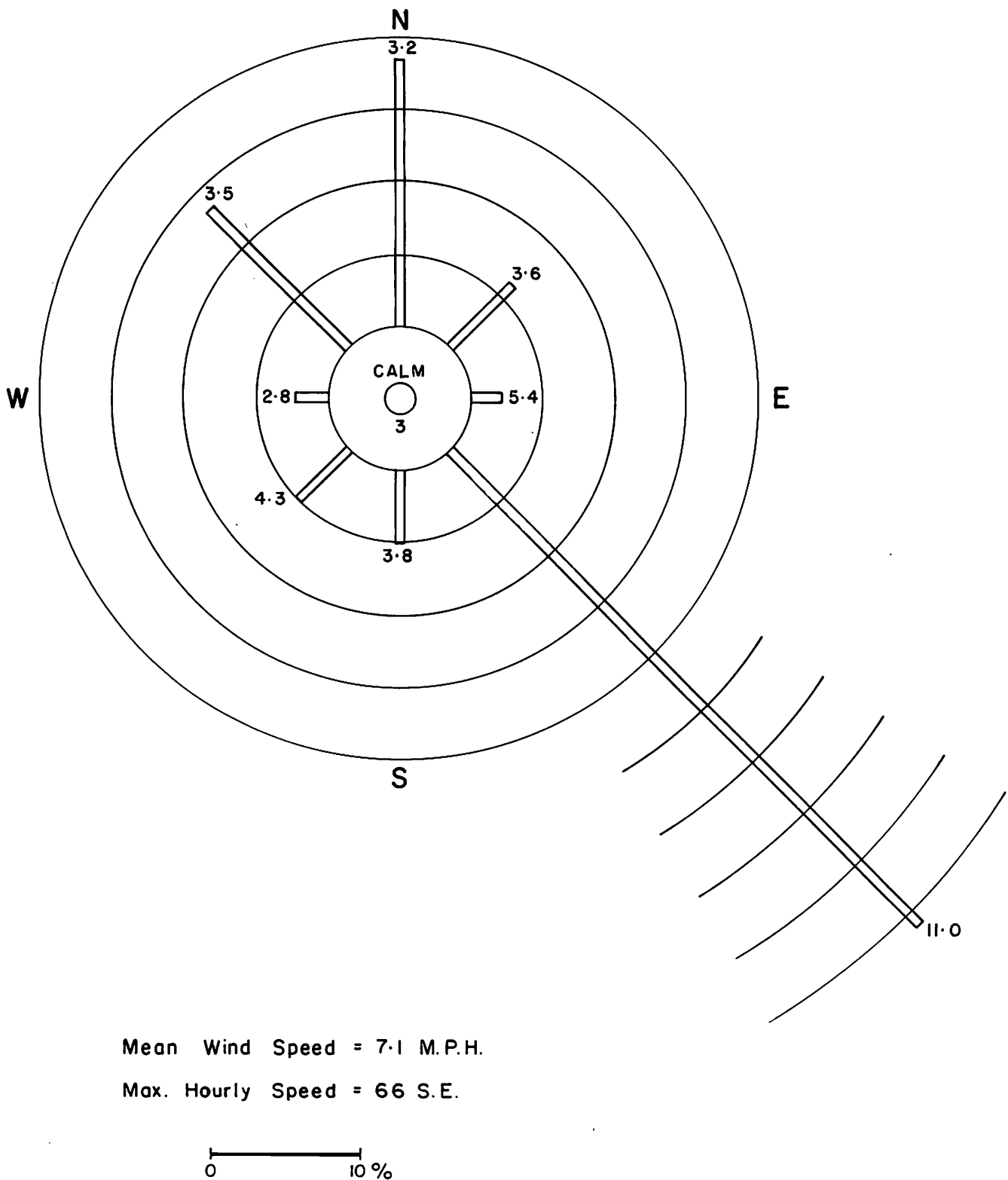


Fig. 3-2 Prince Rupert, B.C.
(1955 - 1962) wind rose -
percentage frequency by direction
(Atmosphere Environment Service).

A horizontal number line with three tick marks. The first tick mark is labeled '0', the second is labeled '10', and the third is labeled '20 %'.

Fig. 3-3 Lawyer Island, B.C.
(Oct. 1969 - Nov. 1972)
wind rose - percentage frequency
by direction
(Atmospheric Environment Service).

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with an average of 6.8 tenths covered. No information is available on evaporation or radiation.

3 (viii) AIR POLLUTION POTENTIAL

The wind roses illustrated in Figures 3.2 and 3.3 show a fairly low frequency of calms, but a higher frequency of light winds. Due to the complexity of the wind patterns associated with topographical features, it is difficult to extrapolate the air pollution potential with any degree of reliability.

Deep inversions are fairly common and persistent, owing to the cold waters of the Pacific and cold-air drainage from the interior. The following table shows the seasonal percentage frequency of ground-based inversions at two times of day:

	<u>Winter</u>	<u>Spring</u>	<u>Summer</u>	<u>Fall</u>
A.M.	60	65	65	60
P.M.	40	35	30	25

In all seasons, ground-based inversions are fairly frequent overnight and in the early morning, and only about half as frequent in the afternoon.

Due to the high frequency and the intensity of precipitation, washout of pollutants should be a favourable factor, particularly in autumn and winter.

To summarize, during the late spring, summer and early autumn, calm winds are quite frequent overnight and in the early morning, as are occurrences of ground-based inversions. During these hours, emitted air pollutants would remain in the local area at low elevations. Later in the day, during this period, stronger westerly winds would promote good horizontal mixing of emitted air pollutants. In all seasons, the very frequent southeasterly winds would carry pollutants and odours towards the city of Prince Rupert. However, since these winds are generally

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stronger than those from other directions, concentrations would not build up. As well, southeast winds are frequently associated with the approach of Pacific storms, so extended periods of precipitation would wash out much of the pollutants.

4. HYDROLOGY AND WATER QUALITY

4 (i) HYDROLOGY

The Skeena River, together with its major tributaries, drains an area of approximately 20,000 square miles. The furthest downstream flow gauge is located at Usk (85 miles from the mouth), and has been in operation, with only minor interruptions, since 1928. Other stations important in the estimation of flow of the Skeena are those on the Zymoetz River above O.K. Creek, the Khtada River near Kwinitza, and the Zymagotitz, Exchansiks, and Kitsumkalum rivers all near Terrace. A complete list of streamflow stations of the Skeena system, and their period of record, can be found in Appendix 4.1 (Water Survey of Canada, 1973).

The long-term (30 years) average of the mean monthly flow at Usk is 32,600 cfs (Water Survey of Canada, 1973). Figure 4.1 shows a typical hydrograph of a year's streamflow data. Flow varies seasonally depending on the amount of stored runoff (ice and snow) which accumulates in the headwaters during the winter and then melts in the spring, and depending on the local precipitation, in the form of rain, during the spring and autumn. Large-scale climatological factors may cause year-to-year flow changes as well. As the hydrograph illustrates, peak flows occur in the spring, with smaller peaks, owing to heavy rainfall floods, occurring in the autumn. Over the forty years of record, the spring freshet has occurred between May 19th and June 29th (Water Survey of Canada, 1973). Other flow data, recorded at Usk, can be found in Table 4.1. It should be noted that considerable runoff is added to the Skeena below Usk, and information presented here does not reflect the flow characteristics at the estuary itself.

The upstream effects of tides are not well documented for the Skeena River. Old data collected by the Pacific Oceanographic Group in 1948, but which were never published, record a salt wedge at the Ecstall River, or further, while similar data

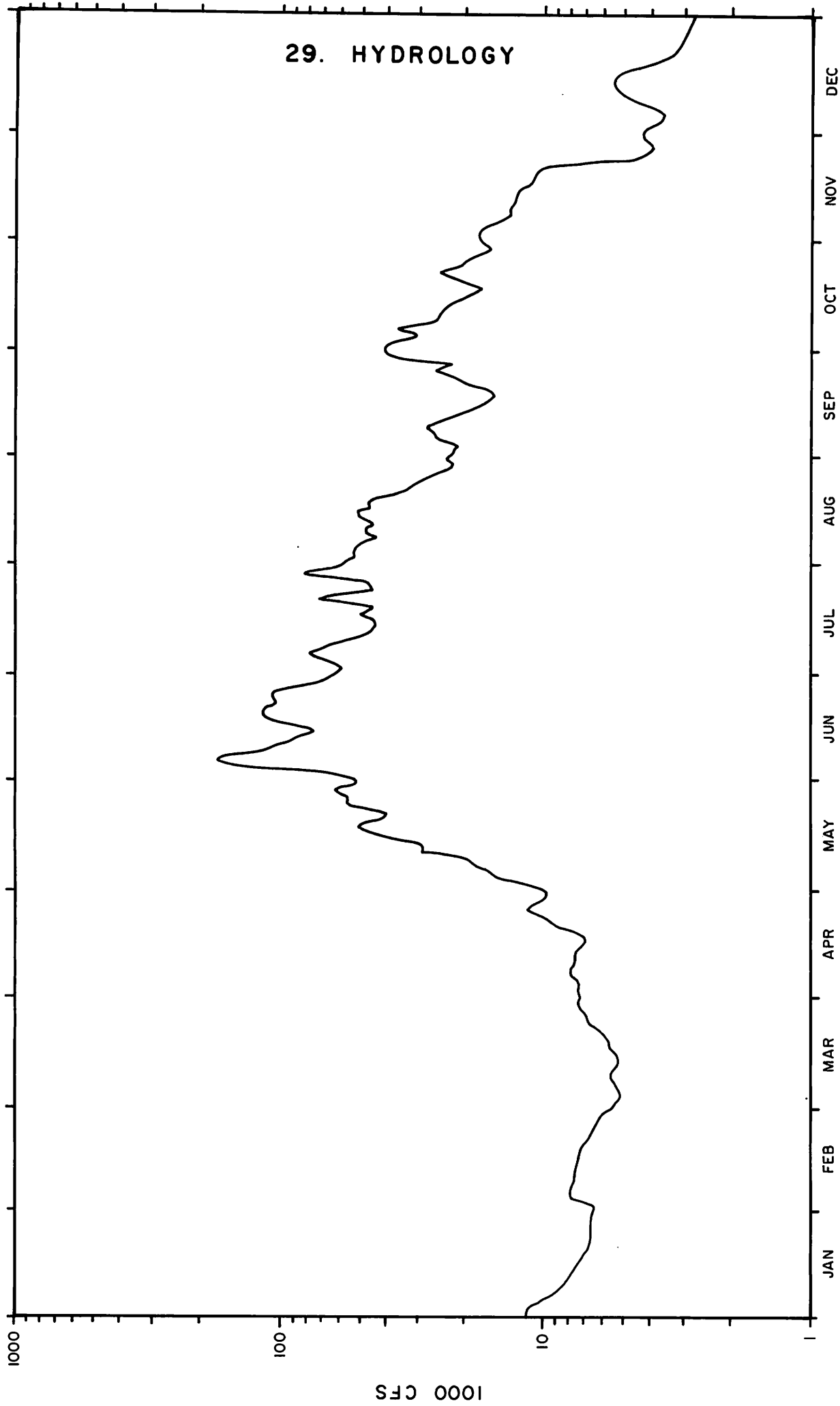


FIGURE 4.1. Discharge hydrograph for 1970, Skeena River at Usk
(Stat. No. 08E F001).

30. Hydrology

Table 4.1. Other Skeena River flow records measured at Usk,
British Columbia (Water Survey of Canada, 1973).

<u>Record</u>	<u>cfs</u>	<u>Date</u>
maximum daily flow	330,000	May 26, 1948
minimum peak daily flow	102,000	May 29, 1944
minimum daily flow	1,830	March 1-4, 1950
largest mean annual flow	42,100	1954
smallest mean annual flow	24,800	1929
maximum mean monthly flow	155,000	June, 1972
minimum mean monthly flow	1,990	February, 1950

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collected by the Water Survey of Canada note the presence of saline water as far upstream as Terrace (Anonymous, 1974). Little else is known of the salinity regime of the lower Skeena River.

Water temperatures of the Skeena River at Usk have varied between a maximum of 63°F (17.2°C) and a minimum of 32°F (0°C) (1951-1972) (Water Survey of Canada, 1973). Records of the history of settlement of the Skeena River valley indicate that much of the river is frozen during the winter months (O'Neill, 1960). Quoting the British Columbia Pilot (Canadian Hydrographic Service, 1969): "the upper part of the Skeena is frozen-over during the winter, and in severe winters the whole river as far as Port Essington has also been frozen.....the greater part of the loose ice which encumbers the Skeena in the cold season comes from the Ecstall River. Strong northeast gales in winter interrupt communications with the shore, and, though not frozen over, there is much loose ice, also quantities of heavy driftwood".

Like the Fraser and Squamish rivers (Hoos and Packman, 1974; Hoos and Vold, 1975), the Skeena water is very turbid, particularly during the spring freshet and heavy autumn rains. Part of the turbidity arises from glacial flour scoured from the glaciated regions of the river headwaters, while some of it is derived from suspended particulates (silt, etc.) from the lower sections of the drainage basin. Although no records of the exact quantity of sediment carried by the Skeena are available, photos of the estuary during the freshet, showing a greyish-brown plume extending from the river mouth, would indicate that the load is at least as large as those of the Fraser and Squamish rivers.

It might be worthwhile here to mention the navigability of the Skeena. Quoting again from the British Columbia Pilot (Canadian Hydrographic Service, 1969): "The Skeena River is the largest river on the coast of British Columbia northward of the

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Fraser River. About 120 miles above Port Essington the river divides into three branches, known as forks of the Skeena, the principal branch taking a northward direction [the Skeena River], the others running northwestward [the Kitsumkalum River] and southeastward [the Zymoetz River], respectively.....About 2 miles above Port Essington, electric power cables are carried across the river on five pylons, with a clearance of 60 feet (18 m3) at high water. The Department of Public Works of Canada maintains the snagboat *Essington* for the purpose of removing snags from the Skeena and Ecstall rivers". However, because of the many bars and sand banks scattered throughout its lower reaches and often extending almost fully across the river, the Skeena River has a very limited range for navigation.

4 (ii) WATER QUALITY

Inland Waters Directorate operates a water quality station at the Highway #16 bridge at Terrace, British Columbia, to routinely analyze the Skeena River for various chemical substances, as well as temperature, pH, colour, turbidity, dissolved solids, etc. Despite the fact that records are somewhat patchy for certain analyses and sampling has been disrupted periodically, recent data on the period from 1961 to 1967, published by the Inland Waters Directorate (1974), and unpublished data compiled in 1973 and 1974, in relation to data collection for the Estuary Working Group (Anon., 1974), are interesting, although interpretations are difficult under these conditions. It should be noted here that spot sampling without, or with only one or two, replications makes analysis of these, or any, water quality data very difficult. Values for substances measured can vary substantially within one sample alone, and, therefore, attempting to relate several samples taken at different places at various times can become an exercise in futility. The data presented here are purely qualitative, cursory appraisals of the water quality of the Skeena region, and one should be aware of

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this before attempting to draw any conclusions regarding the over-all water quality of the system.

In general, the following statements can be made regarding the data collected between 1961 and 1967. PH was almost neutral throughout the samples (range of 6.8 in May, 1962 to 8.0 in March, 1963). Colour and turbidity values were greatest in May and June samples, as would be expected since the river is in freshet during these months. Total dissolved solids' levels were greatest in the fall and winter months (October - February). The remaining analyses, and those carried out in 1973 and 1974 (Anon., 1974), were so infrequently done that no trends could be distinguished, or the results were so similar at each sampling, and values normal enough, that results are not worth describing here. A copy of the former data can be obtained from the Inland Waters Directorate, Water Quality Branch, Ottawa through the NAQUADAT computer system.

A few other notes on fresh water quality of the Skeena drainage system can be obtained from recent reports by Hallam *et al.* (1975) and Lee Doran Associates Ltd. (1975). Hallam *et al.* (1975) studied the aquatic environment of Cronin Creek (a Skeena tributary) in relation to possible mining pollution. While highly qualitative, their results indicated that turbidity, total residues, and filterable fractions were very low. Dissolved oxygen concentrations were above 100% saturation at all stations. Total calcium and magnesium values were low, and, therefore, the water was considered "soft" in terms of total hardness (100 ppm CaCO_3). Iron, chromium, molybdenum, and nickel were below detectable levels, while concentrations of zinc and lead were slightly greater than the usual government standards (0.04 ppm and 0.03 mg/l, respectively). PH values were between 6.0 and 9.0 throughout the study.

In relation to their assessment of aquatic environments proposed for possible port development, Lee Doran Associates Ltd.

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(1975) included a small amount of information on fresh water quality of the Tsimpsean peninsula. As much of the region is covered in bog and muskeg, the waters of many streams are brown and slightly foamy owing to large concentrations of natural humic acids. Water quality analyses of Stumaun Creek and Neaxtoalk Lake by the above researchers in 1974, and of Prudhomme and Rainbow lakes, done in 1952 and 1972 by the British Columbia Fish and Wildlife Branch, indicated low to moderate dissolved solids concentrations (14 to 112 ppm for the former case, 4 to 40 ppm for the latter) and low pH (4.5 to 6.2 and 5.5 to 6.8, respectively). The Fish and Wildlife Branch data (in Lee Doran Assoc., 1975) indicate a Secchi disc transparency reading of about 10 feet for Prudhomme Lake, with that for Rainbow Lake being 24 feet. Organic matter ranged from 8.1 to 22.1 ppm in the Lee Doran Associates Ltd. (1975) study.

The above data are all the information on the Skeena freshwater environs. The remaining literature dealing with water quality is concerned with the estuary, and, in particular, with the effects of the Cancel pulp mill on it. Since much of the water quality impairment owing to the pulp mill is the result of toxic chemicals and fibre, most of the discussion of this literature will be done in the Pollution Section of this report. However, some of this information is concerned with dissolved oxygen values and water temperature, and, as such, are discussed here.

Stokes (1953) analyzed the dissolved oxygen levels of the water adjacent to the pulp mill on Watson Island. In general, it is necessary to maintain dissolved oxygen levels of 5.0 ppm for normal life processes in the water column to continue. Stokes found, however, that levels in Porpoise Harbour were less than 5.0 ppm on a low tide, although they increased to 8.7 ppm when the tide rose. In Wainwright Basin, a level of 4.4 ppm (at low tide) was recorded. Chatham Sound dissolved oxygen levels, at low water, averaged 8.4 ppm.

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Waldichuk (1962) found that the water quality in the mill vicinity had deteriorated substantially in the 8 years between his and Stokes' work. Dissolved oxygen levels were low from Porpoise Channel to the north end of Porpoise Harbour, the worst conditions being found just off the mill wharf, where oxygen values ranged from less than 0.5 mg/l to 4.0 mg/l at 20 m. Studies showed that the surface and bottom waters were being replaced (the bottom layer more quickly than the top), but that intermediate layers were not being replenished.

Water samples from Porpoise Harbour had lower pH values (7.1 to 7.5) than did those taken in Chatham Sound (around 8.0), and bottom samples were usually higher in pH than those obtained from the top 15 meters of the water column.

Alkalinities were almost constant from top to bottom in Porpoise Harbour (about 2.0 milliequivalents per litre), and similar to those found in Chatham Sound (1.9 meq/l at 0 depth to 2.3 meq/l at 100 m).

In Wainwright Basin, all dissolved oxygen values were below 5.0 mg/l, even at the surface, and bottom levels fell to less than 0.5 mg/l. PH values were lower than those of normal sea water, ranging from 6.9 to 7.2.

Goyette *et al.* (1970) summarized the dissolved oxygen data collected by the federal Fisheries Service between Waldichuk's 1961 survey and their own work in 1969. The general result showed that dissolved oxygen values had not improved over the eight year period, with average values in Porpoise Harbour and Wainwright Basin being, in general, lower than the necessary 5.0 mg/l.

The most recent work on water quality of the pulp mill site and outfall cove has been done by the federal Environmental Protection Service (EPS) and the provincial Pollution Control

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Branch (PCB). These agencies carried out independent studies during 1973, and EPS continued its surveys through the summer of 1974.

The PCB report (Drinnan and Webster, 1974) was one of several based on a provincial inter-agency study of the overall environment in the vicinity of the pulp mill. A large number of analyses were done for each station, and the survey was repeated three times - in April, July, and October. The following results were obtained.

Water temperatures responded to prevailing weather conditions, with a thermocline being found only in July. Temperatures were somewhat higher, in July, in the more isolated Porpoise Harbour, Wainwright Basin, and Morse Basin.

The pH was nearly constant and normal at all stations during the entire study, generally falling between 7.8 and 8.5 units. Levels were slightly higher in July at all stations, perhaps due to phytoplankton production. Lower readings were found in Wainwright Basin, and, in particular, over the red liquor line.

Dissolved oxygen concentrations were nearly constant (8 to 10 mg/l) throughout the study, in Prince Rupert Harbour and Chatham Sound. However, there was a general decrease in oxygen from the southern end of Porpoise Harbour to Wainwright Basin. During April and July, all values dropped to, or below, the 5.0 mg/l level, while in October levels were somewhat higher (6.5 mg/l). At the autumn sampling, the pulp mill was not operating.

In July, low concentrations of phosphate and nitrate were found in surface waters of Prince Rupert Harbour and, to a lesser extent, in Chatham Sound. This was probably due to phytoplankton activity. At deeper depths, values were higher (0.04

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and 0.05 mg/l for phosphorus; 0.20 and 0.25 mg/l for nitrate). The results from April and October samples were comparable to those found in the deeper waters in July.

During each of the three sampling periods, there was a general decrease in phosphate and nitrate, at all depths through Porpoise Harbour to a minimum in Wainwright Basin. Increased phytoplankton activity as a cause was ruled out, as waters were turbid and highly coloured, and dissolved oxygen levels were low - all factors which would inhibit photosynthesis.

Ammonia values were generally low (0.05 mg/l or less), a level of 0.5 mg/l being toxic to fish. However, one sample taken at the red liquor outfall contained a concentration of 1.0 mg/l.

Total organic carbon values ranged close to the limits of analytical uncertainty. However, in general, higher levels were found in Wainwright Basin and Porpoise Harbour, and particularly high values were found directly above the red liquor outfall.

Oil and grease concentrations were consistently very low at all stations during the study period.

Tannin, lignin, the Pearl-Benson index (for lignin sulphonates), and colour are analyses which reflect the concentration of pulp mill wastes, and which are used as measures of the aesthetic and health properties of the water. In general, all tests showed low values at most stations, but the concentrations did tend to increase through Porpoise Harbour to maximum values in Wainwright Basin. The same was found for turbidity values. It should be remembered that such factors as freshwater runoff, wood debris, natural "cedar" water (dissolved tannin and humic acids), etc., would affect the results of these tests.

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Faecal coliform counts were generally low. Highest values were found off the Prince Rupert waterfront where several municipal sewage outfalls are located. Slightly higher values were found in July than during the other two sampling periods, probably due to increased boating activity.

Aesthetically, Wainwright Basin and northern Porpoise Harbour were described as "very unappealing". Large amounts of wood debris were found floating in the water and deposited on the beaches, while the water itself had a deep brown colour and was often layered in foam. Gases from decomposing benthic deposits, smelling of hydrogen sulphide, were seen bubbling to the surface.

Visual debris was practically unnoticeable in Chatham Sound, while small amounts of seaweed, pieces of wood, and foam accumulated on the tide line in Prince Rupert Harbour. Some fish offal was seen off the fish processing plants on the waterfront.

A preliminary water quality survey conducted by EPS in November, 1973, prior to their more detailed work of the following summer, indicated that dissolved oxygen levels were very low (2.2 mg/l) in the vicinity of the Ridley Island discharge cove, while normal values of 6.8 to 8.5 mg/l were found in Chatham Sound, 1½ miles offshore of Ridley Island (Holman, 1973). Dissolved oxygen values in Wainwright Basin ranged from 5.4 mg/l at the surface, to 4.05 mg/l at 20 meters. Values throughout Porpoise Harbour and Porpoise Channel were somewhat higher, with levels of 5.1 mg/l to 6.1 mg/l in surface and 5 meter samples, and slightly higher values near the bottom.

The results of the EPS summer, 1974, survey have yet to be analyzed. Raw data indicate that the dissolved oxygen concentration was lowest in Wainwright Basin, with slightly higher levels being found in Porpoise Harbour.

5. OCEANOGRAPHY

5 (i) INTRODUCTION

Like many of the other estuaries along the British Columbia coast, the Skeena River estuary has not been intensively studied oceanographically. However, in connection with fisheries research and management studies, there have been incidental observations of physical and chemical characteristics of the estuarine waters. Access to these data can only be achieved through field records of Fisheries Research Board investigators involved in the Skeena River Salmon Management Program (1955-1965), and subsequently, from Fisheries Operations.

Daily seawater observations have been made since 1934 at a number of lighthouse stations (Cape St. James, Triple Island, Langara Island, and Bonilla Island) on the northern British Columbia coast, but at some distance from the Skeena River estuary (Tully, 1952; Pacific Oceanographic Group, 1956b; Canadian Oceanographic Data Centre, 1968; Hollister, 1952, 1971a, 1971b, 1972, 1974; Giovando and Hollister, 1974). These data have proven valuable, at both inshore and offshore stations, for examination of seasonal and year-to-year variations of salinity and temperature (Tabata, 1958), which have environmental significance to coastal fisheries. The daily seawater data from the entire British Columbia coast, from 1914 to 1970 (including 1935 and 1940-42 data for Prince Rupert), have been summarized by Hollister and Sandnes (1972).

Most of the relevant oceanographic studies of waters adjacent to the Skeena River estuary have been done either from the point of view of research interest in coastal oceanography, or because of the pollution from the Canadian Cellulose pulp mill on Watson Island, or both. A number of early oceanographic studies were conducted in Chatham Sound to determine if the

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behaviour of waters from the Nass and Skeena rivers affected the migration routes of salmon. Included in this pioneering work were investigations by the Pacific Oceanographic Group of the Fisheries Research Board, during 1948 (Cameron, 1948a and b, 1951; Tully, 1952; Trites, 1952, 1956; Pacific Oceanographic Group, 1955-56). In these studies, Chatham Sound was considered an estuary "in the modern sense of the word" (Trites, 1956), but complicated by irregular boundaries and the freshwater influx from two rivers.

Because of the interest in fisheries of the waters of Hecate Strait, oceanographic studies were subsequently conducted in this body of water, between the Queen Charlotte Islands, and the British Columbia mainland (MacKay, 1954; Barber and Tabata, 1954; Barber and Groll, 1955; Barber, 1957a, 1958a). Some of these studies were also extended southward into Queen Charlotte Sound (Barber, 1956, 1957a, 1958b).

Research was also extended northward into Dixon Entrance, for a better understanding of the water exchange between Chatham Sound and the open ocean. In conjunction with field work on Hecate Strait and Dixon Entrance, a model study was conducted at the Biological Station in Nanaimo from 1954 to 1964 (Bell and Boston, 1962; Bell, 1962, 1963a, 1963b; Terhune, 1963). The study on Dixon Entrance ultimately culminated in a well-developed treatise on the subject (Crean, 1967).

Because of the apparent pollution from the sulphite pulp mill on Watson Island, some of these studies moved closer inshore after 1960. Although a preliminary survey (Stokes, 1953) had suggested that no serious effect from the pulp mill was occurring in either Wainwright Basin or in Porpoise Harbour, herring fishermen reported fish kills in Wainwright Basin during the 1960-1961 fishing season. This prompted oceanographic research to examine in more detail the conditions of the water in both Wainwright Basin and Porpoise Harbour, as well as at the

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approaches in Chatham Sound (see Figure 5.1) (Waldichuk, 1962b, 1966b).

A number of changes to the pollution control facilities at the pulp mill, and the construction of a Kraft mill at the same site, prompted further observations to measure the effectiveness of pollution control measures, and to assess the effects of the wastes from the new mill. This information and the early observations are reported in a data record (Waldichuk, *et al.*, 1968).

5 (ii) EFFECTS OF DELTA PHYSIOGRAPHY ON WATER-FLOW PATTERNS

The physiography of an estuary can very much determine its behaviour. As noted in the Introduction, the Skeena River estuary is not typical of those found on the British Columbia coast. Fresh water enters Chatham Sound through a series of channels separating the mainland from several islands, particularly Smith, De Horsey, Kennedy, and Porcher, and via a series of passages between these islands.

Although the waterflow of the Skeena River has not been measured, it is roughly estimated that about one-quarter of its flow moves into Inverness Passage (separating Smith and De Horsey islands from the mainland), while the other three-quarters of the flow is divided nearly equally between Marcus Passage (separating Smith and De Horsey islands from Kennedy Island), and Telegraph Passage (separating Kennedy Island from the mainland). The main impact of the Skeena River water (70%) occurs in the north in Chatham Sound and Dixon Entrance, rather than to the south (Trites, 1956), and this is partly due to the effect of Coriolis force, which diverts water to the right of the direction of flow in the northern hemisphere. However, probably about a quarter of the flow from the Skeena River passes through Ogden Channel (separating Porcher Island and Pitt

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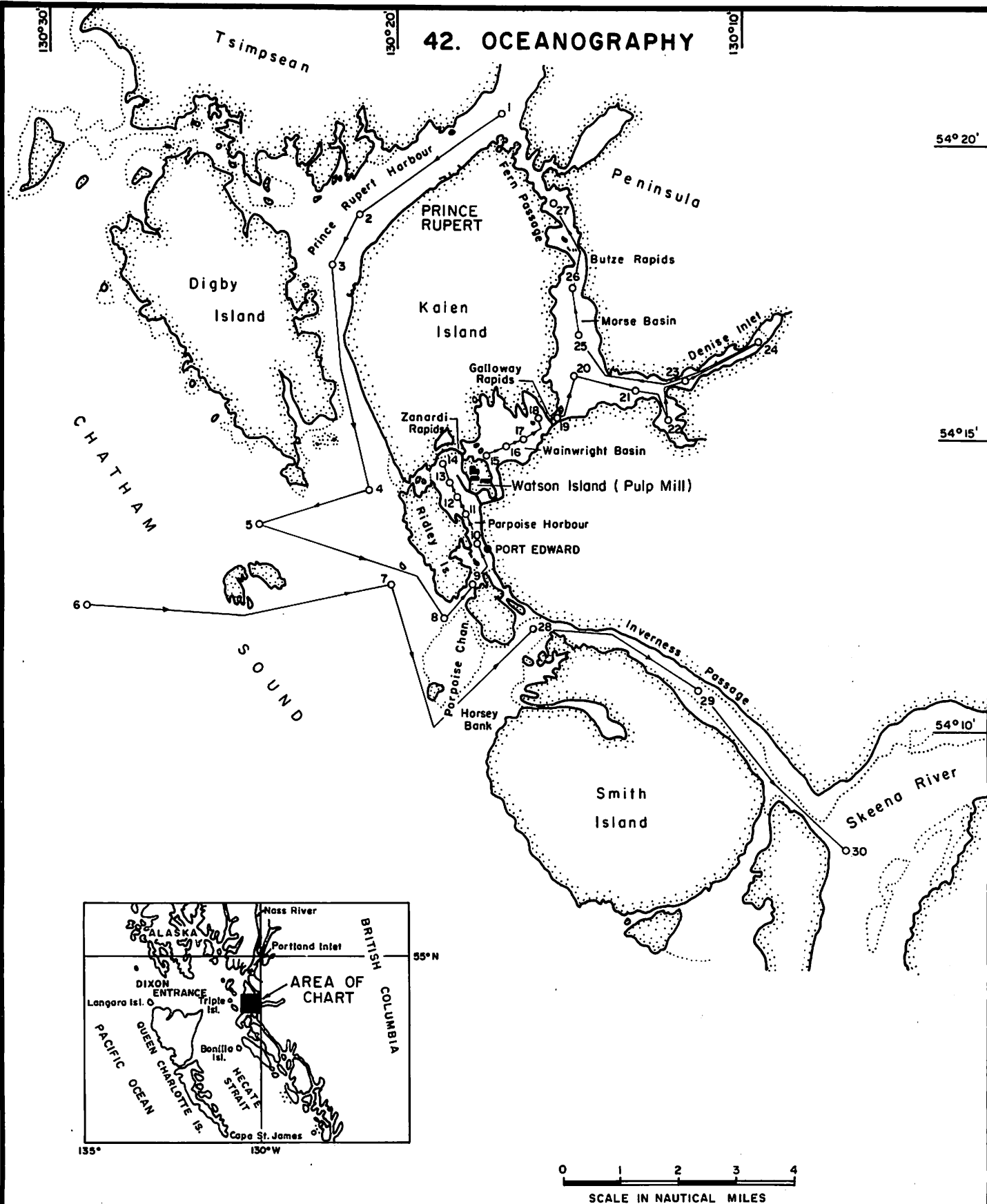


FIGURE 5.1. Chart of the Prince Rupert area showing locations of stations occupied during September, 1961 (Nos. 1-18), and during April, 1962 (Nos. 1-30).

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Island), on its way to Browning Entrance, which opens into the northern part of Hecate Strait. Trites (1956) pointed out that Nass River water, coming from Portland Inlet to the north, acts as a barrier to prevent Skeena River water from moving extensively northward of Tugwell Island, located west of Prince Rupert.

There are no large-scale, continuous tide flats at the Skeena River delta, as there are in the Fraser River estuary (Hoos and Packman, 1974). Instead, there is a series of pockets of shallow, sheltered water, where water currents are minimal and sedimentation has occurred. Part of this pattern is due to the strong tidal currents that pass through the passages, preventing sedimentation along the broad delta-front of the Skeena River estuary.

As indicated in the discussion of the Skeena delta found in the Introduction of this report, some of the banks are dissected by channels of deeper water, where there is probably a good mixture of fresh water with sea water. However, depths are nowhere very great (<20fm or 37m), even in the deepest channels within the confines of the three main passages of the estuary.

The Skeena River estuary cannot be considered in a simple straight-line fashion, as is possible with the inlet estuaries. Rather, one must examine water flow through each of the main connecting passages, that is, Inverness, Marcus, and Telegraph. Intuitively, one would expect the major flow from the Skeena River to pass through Marcus Passage, into the southern end of Chatham Sound. However, neither Inverness Passage nor Telegraph Passage should be ignored, inasmuch as they may contribute significantly to the water exchange, sedimentation processes, and hence, the ecological regime of the estuary as a whole.

5 (iii) EFFECTS OF RIVER RUNOFF

The section on Hydrology has dealt with the flow regime of the Skeena River, both on a seasonal and daily basis. It is clear that, like the Fraser River, the Skeena River undergoes wide seasonal fluctuations in discharge, although the effect of "stored runoff" has its main impact on the Skeena slightly earlier in the year than occurs on the Fraser (Hoos and Packman, 1974). Like that of other large British Columbia rivers, the Skeena discharge may undergo significant year-to-year changes related to certain large-scale climatological factors. These factors, in turn, can be translated into year-to-year changes in oceanographic processes in the estuary.

1. SALINITY:

As occurs in all estuaries, the Skeena River water has a certain diluting influence on the salinity of waters in the estuary and in the more distant waters of Chatham Sound, Dixon Entrance and Hecate Strait. The effect of the Skeena discharge varies seasonally, from low-runoff periods of late summer and early autumn, to freshet conditions in May and June.

Typical of most estuaries, the Skeena River water flows over the surface of the coastal sea water. The surface salinity at the approaches to the Skeena River during normal river flow is shown in Figure 5.2. In terms of percentage of fresh water in the upper 60 ft., Figure 5.3 shows the effect of runoff from normal river flow. A freshet results in a substantial increase in the percentage of fresh water in the vicinity of the Skeena River, as well as in the outflow of Portland Canal, receiving the discharge of the Nass River (Figure 5.4).

However, the mechanism of this freshwater dilution occurs somewhat differently here than in other Pacific coast estuaries. This is partly related to the geographical

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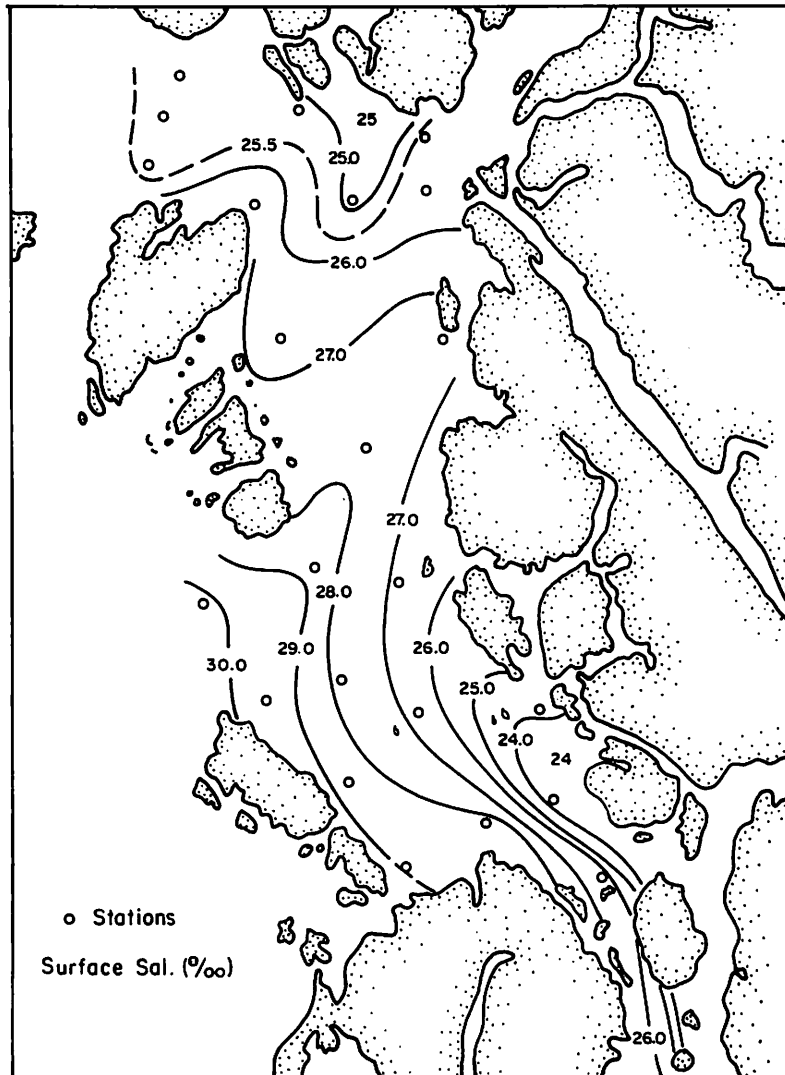


FIGURE 5.2. Surface salinity pattern (‰) in the Skeena River estuary during normal river conditions, August 10-19, 1948. (from Trites, 1956).

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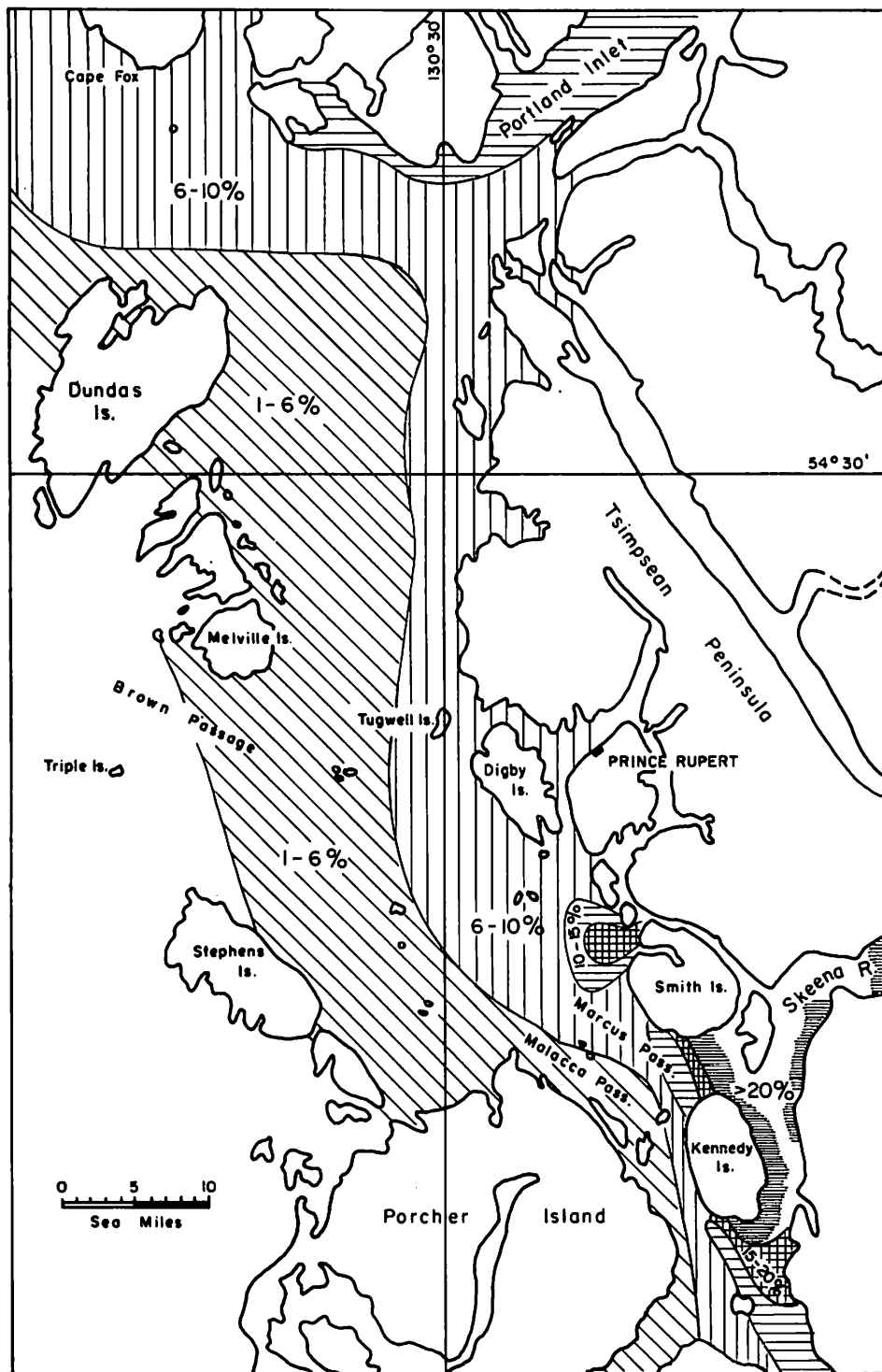


FIGURE 5.3. Percentage of fresh water in upper 60 feet during normal river conditions, Skeena River estuary, August 10-19, 1948. (from Cameron, 1948 a).

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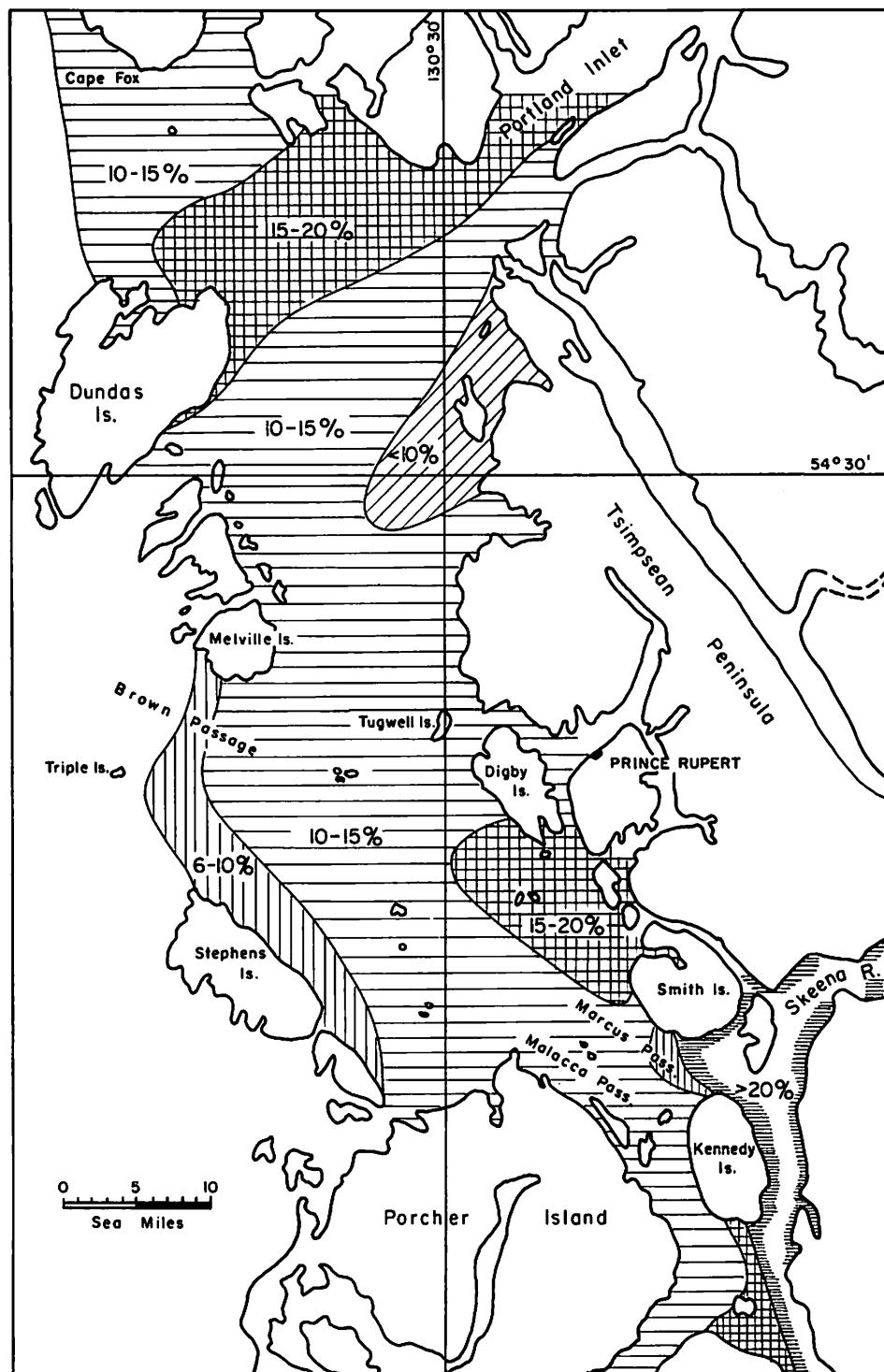


FIGURE 5.4. Percentage of fresh water in upper 60 feet during freshet conditions, Skeena River estuary, June 8-18, 1948. (from Cameron, 1948 a).

configuration of the estuarine system, and partly to the large tidal range off the northern coast of British Columbia. The net effect of these factors is that mixing proceeds much more rapidly as one goes from the river itself into the coastal bodies of water receiving Skeena River runoff. This means that salinity stratification does not extend as far seaward as observed, for example, in the Fraser or Squamish River estuaries (Hoos and Packman, 1974; Hoos and Vold, 1975). The "salt wedge" does not penetrate into the Skeena River as far as in the other river systems, partly because of the foregoing factors, and partly because of comparatively shallow waters in the lower reaches of the Skeena River.

Nevertheless, most of the Skeena River estuary still exhibits a certain degree of vertical stratification. This condition prompted Cameron (1948b) to remark, "From the visual observation of the numerous eddies and rips that are present in the Skeena, near its mouth, one might conclude that in this locality at least, the water would be fairly uniform from top to bottom. But examination of the vertical distribution of salinity shows that this is not the case." A vertical section of the percentage of fresh water from Telegraph Passage into the Skeena River is shown in Figure 5.5. Although the lines of constant percent fresh water are not vertical, they are certainly far from horizontal, as found in the Fraser River (Hoos and Packman, 1974), and in most inlets, suggesting comparatively vigorous vertical mixing.

Certain areas, however, exhibit almost vertical homogeneity because of vigorous local mixing. A vertical section of salinity through Porpoise Harbour and Wainwright Basin, shown in Figure 5.6, gives an indication of the vertical mixing caused by the turbulence in Zanardi Rapids, as shown in the uniform salinity from top to bottom at Stations P-11 to P-13. The effect on density, which is closely related to salinity in these waters, is depicted in the σ_t distribution shown in the same figure.

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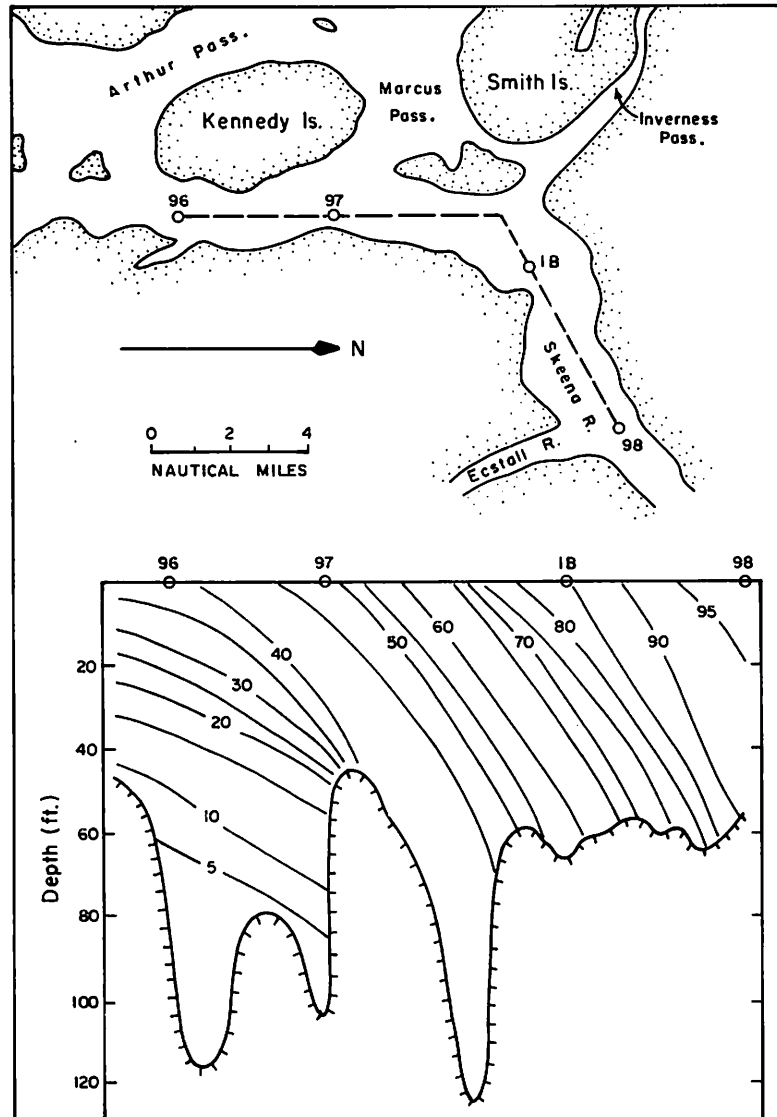


FIGURE 5.5. Fresh water concentration (%) in section through main channel of Skeena River, September 7, 1948 (from Trites, 1956)

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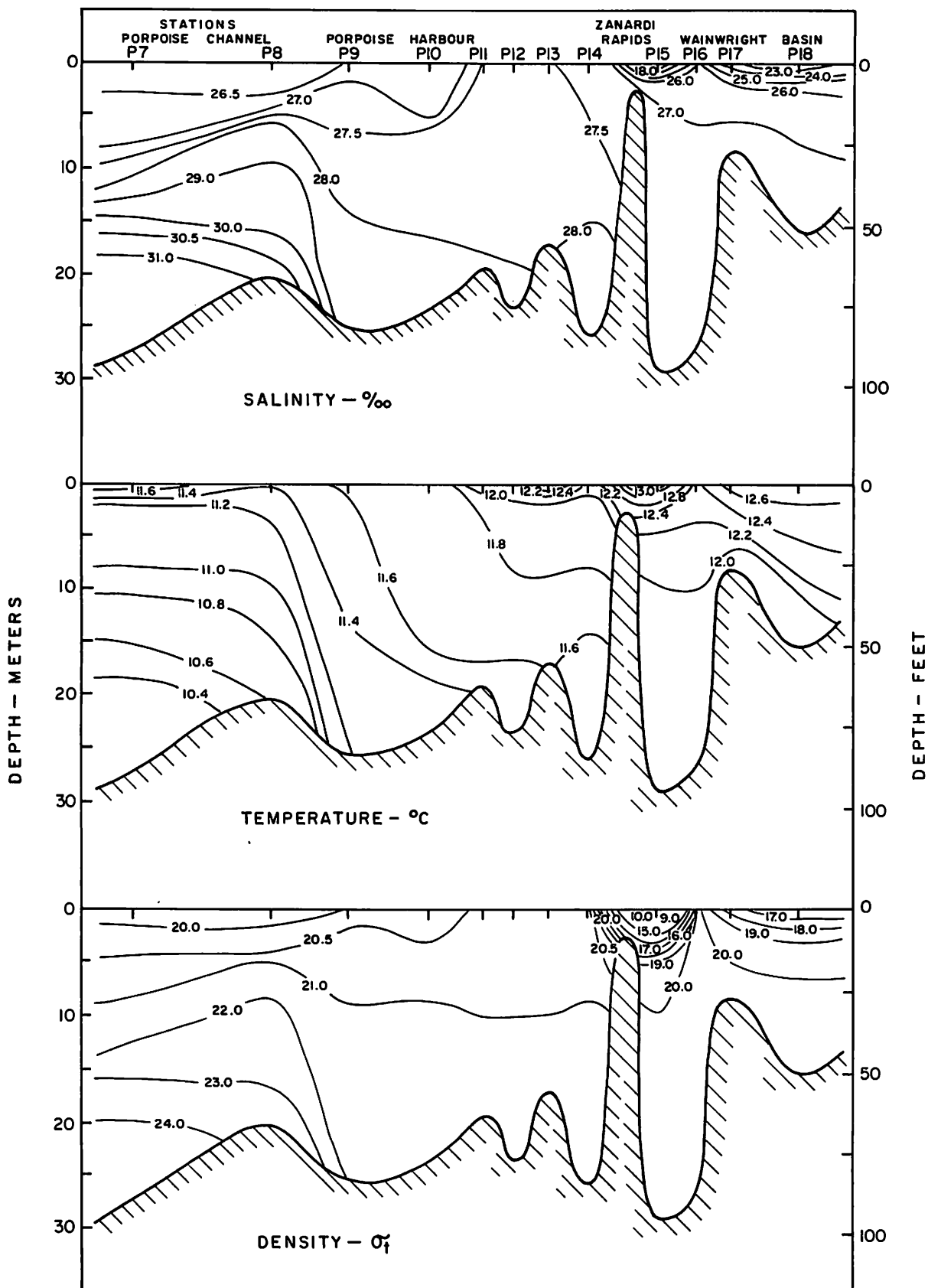


FIGURE 5.6. Sections through Porpoise Harbour and Wainwright Basin showing vertical distribution of salinity, temperature, and density (σ_t) during September, 1961. (from Waldichuk, 1966).

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There is comparatively little information on the salinity within the Skeena River estuary, as bounded by a line from the west side of Kitson Island to Seabreeze Point, at the southeast tip of Kennedy Island. One set of observations (Appendix 5.1) made in mid-April, 1962 (Waldichuk, *et al.*, 1968), showed that the salinity ranged from $25.2^{\circ}/_{\text{oo}}$ (at the surface) to $30.1^{\circ}/_{\text{oo}}$ (near the bottom at 25 m) on station P-28, at the western end of Inverness Passage. At station P-29, mid-way along Inverness Passage, taken on the same day at high tide (April 18, 1962), the salinity ranged from $25.1^{\circ}/_{\text{oo}}$ at the surface to $27.6^{\circ}/_{\text{oo}}$ near the bottom, at 10 m depth. In the deepest channel of the entrance to the Skeena River, just east of the eastern entrance to Inverness Passage (station P-30, occupied at the beginning of a falling tide), salinity values of $20.2^{\circ}/_{\text{oo}}$ at the surface and $30.0^{\circ}/_{\text{oo}}$ near the bottom, at 20 m, were found. There was generally a gradual increase in salinity from top to bottom, although the largest increase occurred near the surface (from $20.2^{\circ}/_{\text{oo}}$ at the surface, to $23.1^{\circ}/_{\text{oo}}$ at 4 m depth, with an increase to $24.0^{\circ}/_{\text{oo}}$ at 6 m depth). There was also an increase from $24.8^{\circ}/_{\text{oo}}$ at 15 m to $30.0^{\circ}/_{\text{oo}}$ at 20 m, suggesting the presence of a rather diffuse salt wedge.

A similar set of data is available for the period 20-26 October, 1964 (Appendix 5.2) (Waldichuk, *et al.*, 1968). This was characterized by considerably lower salinity than observed during April, 1962. At station P-28 (west end of Inverness Passage), the surface salinity was $4.1^{\circ}/_{\text{oo}}$, while near the bottom (at 8 m) it was $10.5^{\circ}/_{\text{oo}}$. At station P-29 (mid-way along Inverness Passage), the surface salinity was $2.9^{\circ}/_{\text{oo}}$ and that at 6 m depth, near bottom, was $5.6^{\circ}/_{\text{oo}}$. A distinct fresh-water environment was observed at station P-30 (off the east end of Inverness Passage). The salinity at that time was found to be $0.3^{\circ}/_{\text{oo}}$ at the surface and $0.9^{\circ}/_{\text{oo}}$ near bottom (at 8 m depth). These data show the intensive vertical mixing that must have been occurring at the time. Such an effect could be expected since the station was occupied near the end of a 20 ft. rising

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tide. The Skeena River discharge was recorded as 83,500 cfs on that day (October 22, 1964), 124,000 cfs on the day before (October 21) and 134,000 cfs on October 20, with only 52,500 cfs on October 19 and 40,400 cfs on October 18. The 27-year mean discharge of the Skeena River up to that time was 31,700 cfs. This illustrates the large day-to-day changes in runoff that can occur.

2. TEMPERATURE:

The seasonal effect of runoff temperature on the Skeena River estuary is similar to that in the Fraser (Hoos and Packman, 1974), considering that both rivers acquire some of the temperature characteristics of the province's interior during their long journey to the sea. In the winter months, temperatures are generally depressed in the estuary by the Skeena River water. During the summer months, on the other hand, the temperatures of the Skeena River water are elevated by insolation and the generally high atmospheric temperatures in the interior of the province. However, the impact of temperature from the Skeena River is rather small, in that mixing tends to distribute the effects over the water column, and minimizes any large changes which could be manifested in a highly stratified system. A vertical temperature distribution through Porpoise Harbour and Wainwright Basin is shown in Figure 5.6. The water is quite uniform in temperature from top to bottom in regions (stations P-12 and P-13) affected by vigorous vertical mixing, such as Zanardi Rapids.

Considering the three stations occupied during April, 1962 (Appendix 5.1), temperatures ranged from 7.2°C at the surface to 6.1°C near bottom at station P-28, compared to 7.1°C and 6.1°C at the respective corresponding depths on station P-30, at the entrance to the Skeena River. These data show that temperatures were not only low at this time of year, but that they were also quite uniform from top to bottom, in this part of the

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Skeena estuary.

For the same three stations occupied on October 22, 1964 (Appendix 5.2), temperatures were only slightly higher, ranging from 7.5°C at surface to 8.0°C near bottom at P-28, and 6.8°C and 6.7°C at the same depths at P-30.

Unfortunately, there are no data from these surveys to provide temperature information during the temperature extremes of the year, that is, in mid-winter and in mid-summer.

3. TURBIDITY:

The water of the Skeena River, like that of the Fraser and the Squamish rivers (Hoos and Packman, 1974; Hoos and Vold, 1975), is highly turbid, especially during freshet. Part of the turbidity arises from the glacial flour scoured from the glaciated headwaters of some of the tributaries, while some of it is derived from runoff eroding particulate materials in the lower sections of the drainage basin. Skeena River water increases the turbidity of the estuarine waters, although the effects are not as noticeable or as wide-spread as those in the Fraser River and Squamish River estuaries. This again is related to the effects of mixing, where the sea water flocculates the silt in the fresh water, leading to rapid deposition in the deltaic areas of the estuary.

An indication of the effects of the silt from the Skeena River can be provided by Secchi disc readings at a number of points in the estuary and in contiguous waters. Choosing the stations used in the section on salinity and temperature, and comparing these with a station in Chatham Sound, some 10 n. mi. from the mouth of the Skeena River, the changes in water transparency caused by the Skeena River silt are apparent. During the period April 14-21, 1962, the Secchi disc readings at station P-6 in Chatham Sound (Figure 5.1) and at stations

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P-28, P-29 and P-30 were 23, 6.5, 6.5, and 3 ft., respectively. At station P-8, at the entrance to Porpoise Channel, the Secchi disc reading was 10 ft., obviously still exhibiting the substantial effect of the Skeena River water.

At the same stations, during the period October 20-26, 1964, the Secchi disc readings at stations P-6, P-8, P-28, P-29 and P-30 were 11.5, 3, 1, 0.8, and 0.8 ft., respectively. The reduced transparency during this survey was clearly associated with the autumn freshet of the Skeena River. These readings correspond to the salinities described earlier, with very low Secchi disc readings matching low salinities, both arising from dilution by the early autumn freshet, the heavy runoff carrying much of the particulate material which had accumulated during the summer months in the drainage basin.

4. CURRENTS:

Skeena River water introduces a seaward current component into the waters of the estuary. However, the effects of runoff are largely masked by the strong tidal currents. Nevertheless, within the entrance to the Skeena River, the ebbing currents during the falling tide can be substantially increased by the river flow, while in the other direction, the flooding tidal current can be appreciably retarded.

There have been no long-term observations on currents in the Skeena estuary. However, the Canadian Hydrographic Service has conducted some general driftpole observations during spring tides, and these are shown on hydrographic charts of the area. Within the entrance to the Skeena River, currents of 3.5 knots have been measured, on the ebb, during spring tides. Maximum currents of 3 to 4 knots, on the ebb, are also shown for the deeper channels of Telegraph and Marcus passages.

Flood tides move in from both these passages at

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somewhat smaller velocities, and tend to converge between Perry Point of De Horsey Island and Hegan Point of the mainland. With the Skeena River water moving in from the east, this region is one of violent tide-rips, particularly during the larger tidal ranges, and these can be aggravated by winds blowing in a direction opposing the predominant flow of water.

The charts indicate that the streams turn from a flooding direction to an ebbing flow approximately one hour after high tide. This is somewhat surprising, inasmuch as one would expect, from normal effects of river discharge on tides, that the current should turn before high tide, with the runoff dominating the tidal effect at this stage.

According to the hydrographic charts, the ebb current seldom appears to flow along the same axis as the flood current, the former often being at an angle of about 30° to the axis of the latter. Undoubtedly, this is part of the topographic effect influencing the current directions. This is especially true between islands where the channel is short and connects two other channels on opposite ends.

It is quite clear that runoff in the Skeena River estuary complicates an already highly dynamic situation caused by tides. For these reasons, vessel handling in this area is plagued with special problems. Also, with the strong tidal currents, it is little wonder that there is little deposition of Skeena River sediments in the estuarine channels.

5 (iv) TIDES AND TIDAL EXCHANGE

The closest permanent tide gauge in the vicinity of the Skeena River estuary is at Prince Rupert. Tidal records have been taken there since 1939, and more recently, this tidal station has been tied into the Pacific Tsunami Warning System.

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Tidal observations have been made at a number of locations within the Skeena River estuary itself for periods of one to several months. These secondary stations include Claxton, Essington, Haysport, Khyex and Kwinitsa.

According to the Canadian tide and current tables (Canadian Hydrographic Service, 1973), the highest high water recorded at Prince Rupert was 26.2 ft., and the lowest was -1.3, with a tidal range of 27.5 ft. (8.4 m). In the lower Skeena River and estuary, the following are the respective mean and large tidal ranges: Claxton: 15.2, 23.2 ft.; Port Essington: 17.5, 25.0 ft.; Ecstall River: 15.5, 18.8 ft.; Khyex Point: 15.7, 19.9 ft.; and Kwinitsa River: 9.4, 13.5 ft. In the order given, these secondary ports are progressively further upstream in the Skeena River, beginning with Claxton on the east side of the entrance to the Skeena River, opposite the southern tip (Parry Point) of De Horsey Island.

Characteristic of the Pacific coast, the tides in the Skeena River estuary are of the mixed type, having two lows and two highs in a tidal day and a large diurnal inequality between succeeding lows and highs. The tidal range in this region is the largest on the Canadian Pacific coast, exceeded only in some inlets where there tends to be an amplification of the tidal range because of a funnelling effect on incoming water.

The tides have a major influence on the coastal water characteristics of this area. Since large volumes of water have to be moved through constricted passages in some channels, to reach tidal equilibrium in a limited span of time, they create strong currents and intensive tidal turbulence. Consequently, the typical estuarine system of two-layer flow does not always exist here, and water characteristics may be uniform from top to bottom, as shown for Porpoise Channel in Figure 5.6. This has its implications in waste disposal, since anything introduced into coastal waters tends to become mixed into the system from

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top to bottom. Moreover, because of the strong tidal transport, there is a rapid exchange of waters.

However, one should not be deluded into the notion that flushing of all waters adjacent to the Skeena River is very rapid and pollution problems could not arise. Isolated bodies of water, connected to the open ocean only via restricted channels, cannot maintain tidal equilibrium with outside waters during a tidal period. The pollution problems in Porpoise Harbour and Wainwright Basin from pulp mill wastes attest to this (see the Pollution section of this report for details of this situation).

Although tides have a certain daily rhythmicity associated with the gravitational pull of the moon and sun, sea level can be considerably modified by atmospheric effects. It is generally recognized that sea level functions as an inverted column of mercury, responding in the same way to atmospheric pressure as a mercury barometer. Studies of the daily and seasonal sea level oscillations on the Pacific coast of Canada (Waldichuk, 1964) included Prince Rupert, it being one of the stations for which adequate data were available for investigating the effects of barometric pressure.

The daily oscillations of sea level and barometric pressure showed a close correlation. Mean sea level showed a range of about 1 ft. (30 cm), with a low in May and a high in December corresponding to high and low atmospheric pressure systems, respectively. Even with the large tidal range in the Prince Rupert area, the daily mean sea level changes of up to 50 cm, due to barometric pressure, can be quite significant.

On top of the purely barometric pressure effect, there can also be the effect of "set-up", due to the stress of winds. Often these wind effects occur in parallel with the barometric pressure effects, causing amplification in the sea level change

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by a combination of meteorological forces. These factors should be taken into account when considering the effects of sea level on shore processes and ecological phenomena.

5 (v) WAVES

To our knowledge, no studies have been conducted on waves in the Skeena River estuary. However, something might be said in terms of wave action that could be expected in this area.

As noted earlier, the inner estuary (inside a line from Gust Point to Lambert Point) is completely protected from exposed waters of Chatham Sound by Smith and De Horsey islands. Consequently, any wave action within the inner Skeena River estuary would have to be generated locally. There is no long fetch for winds to generate swells or large waves, either from the east or from the west. Waves would be of 3 to 4 ft. maximum height during intensive storms, and could be expected to be comparatively short and choppy.

However, tide-rips could develop as a result of a combination of converging tidal currents and wind effects in the Marcus Passage-Telegraph Passage-Skeena River confluence area. In some cases, these turbulent sea-surface conditions could, in themselves, generate very steep, short waves of 2 to 3 ft. in height, even without intensive storm activity. In the narrow Inverness Passage area, a sweep of wind from the northwest or from the southeast could have a fetch of nearly 10 miles and might generate some moderate seas. However, again, this wave action would be strictly stirred up as a result of local wind activity, and would have little consequence for anything except small boat traffic.

The main exposure to wind and wave action from Chatham

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Sound would occur in the outer Marcus Passage region, with winds blowing from the northwest. The Base Sand bank, northeast of the northern tip of Kennedy Island, could be affected by wave action from this area.

It is noted in the British Columbia Pilot (Canadian Hydrographic Service, 1969) that "anchorage may be obtained by vessels with local knowledge westward of the point on which Port Essington stands, in a depth of about $4\frac{1}{2}$ fathoms (8m2) mud, but a heavy cross sea is caused here by strong winds from seaward, and vessels are liable to foul their anchors at such times". It should be noted that at this point, there is a fetch of about 5 miles of open water from the west-southwest, which can develop a considerable sea when wind is blowing strongly for a sustained period.

5 (vi) NAVIGABILITY OF THE SKEENA RIVER ESTUARY

The Skeena River, and its approaches, is one of the more difficult areas along the British Columbia coast to navigate. It is not meant for amateurs, and some prior knowledge of the area is essential even for recreational boaters with small vessels. Canadian Hydrographic charts No. 3735 (British Columbia, CHATHAM SOUND Approaches to Prince Rupert and Skeena River), No. 3713 (Approaches to Skeena River) and No. 3756 (Port Essington to Telegraph Point) should be carefully followed, with the precaution that sizes, shapes and locations of shoals and banks can change rather rapidly. In surveys of the Skeena River mouth and approaches in 1974 by the *William J. Stewart*, major changes were found in banks and shoals which will require recharting as soon as possible (Canadian Hydrographic Service, 1975).

To quote from the British Columbia Pilot (Canadian Hydrographic Service, 1969) on navigable Skeena depths: "The entrance of Skeena River, which is 6 miles below Port Essington,

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is approached by three channels, named Telegraph, Marcus and Inverness passages. Telegraph Passage, the entrance from southward, has a depth of not less than 19 feet (5m8) by keeping close to the eastern shore. Marcus Passage carries a least depth of 13 feet (4m0) across the southeastern bar between Parry Point and Marked Tree Bluff. Inverness Passage has a least depth of 15 feet (4m6) in the fairway, which is very narrow at its junction with the Skeena River off the northeastern side of De Horsey Island".

The following warning accompanies these facts: "banks in the Skeena River and its approaches are subject to periodical changes, and although there are buoys and beacons established to assist in the navigation of the various passages, strangers are advised to employ a pilot" (Canadian Hydrographic Service, 1969).

The Skeena River and its approaches, while generally broad enough (both major approach channels [Marcus and Telegraph passages] being 2-3 n.mi. wide), have very narrow navigable channels in some areas. In certain reaches, these channels may be only 1 to 2 cables (600-1200 ft.) wide. Inverness Passage is particularly shallow, with only shallow-draft vessels (<20 ft.) being able to safely navigate through to Chatham Sound. Some of the banks are exposed at mid-tide, but others are always submerged and only 1/2 to 1 fathom (3 - 6 ft.) deep. Specific shoals and banks which are usually submerged and, therefore, cause a navigational hazard in and around the mouth of the Skeena River include Isbister Shoals, Davies Bank, Base Sand, Robertson Banks, Flora Bank, Agnew Bank, and Horsey Bank. Details on these areas are shown in Table 5.1.

5 (vii) SUMMARY

There is little known about the oceanography of the

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Table 5.1. Shoals and banks near the mouth of the Skeena River which represent navigational hazards.

Shoal or Bank	Location	Characteristics
Isbister Shoal	between Marrack Island and southern extremity of Kennedy Island.	minimum depth of 2 to 3 fathoms (12-18 ft.).
Davies Bank	parallel to east coast of Kennedy Island	southern portion awash only at low tide; extends 4 miles in a 2 mile-wide band; depth = $1/4$ to $3/4$ fathoms ($1\frac{1}{2}$ - $4\frac{1}{2}$ ft.) below lower low water.
Base Sand	northwest from north end of Kennedy Island	0.5 n.mi-wide strip exposed at low water, with a submerged 2 mi.-wide adjunct bank on the northeast.
Robertson Banks	entrance to the Skeena River, between De Horsey Island and the mainland (Claxton to Vetch Point)	exposed at low tide; submerged sections at depths <5 fathoms (30 ft.) on both sides, particularly bordering to the northwest of the Skeena navigational channel.
Flora Bank	western entrance to Inverness Passage	most exposed at low tide.
Agnew Bank	northwest of Inverness Passage	--
Horsey Bank	Kitson and Lelu islands to within $1/2$ mile of Smith Island	submerged (1-3 fm. or 6-18 ft.).

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Skeena River estuary *per se*. Most of the oceanographic observations made there have been related to other studies such as the Skeena River salmon fisheries, the pulp mill pollution in Wainwright Basin and Porpoise Harbour, and the general oceanography of Chatham Sound. The area has been charted quite well hydrographically for navigational purposes, but the British Columbia Pilot points out that navigators must be extremely cautious because of the changing positions of the shoals due to the currents and sedimentation of the silt from the Skeena River.

The Skeena estuary differs from most of those along the British Columbia coast. It has two moderate-sized tributaries, the Ecstall and Scotia rivers, draining into it only a few miles from its mouth. Its approaches are trifurcated through three channels: Inverness, Marcus and Telegraph passages. Most of the river water flows out into Chatham Sound through the latter two passages. Shoals and banks are scattered throughout these channels, but there is no region of integrated tide flats that can be considered the delta of the Skeena River estuary. The entire area is characterized by large tidal ranges, with associated strong tidal currents and vigorous mixing. These are modified by the Skeena River flow, accelerating the current on the ebb tide and retarding it on the flood, and introducing some stratification at certain periods.

As a result of the strong tidal action through the channels, the waters are generally well mixed from top to bottom, although some stratification may occur during certain periods of high runoff and small tidal range. Rather than a deep salt wedge penetrating under the Skeena River water, the waters in the mouth of the river appear to be vertically mixed almost to homogeneity. This, however, changes from season to season, and particularly with varying tidal range and river discharge.

Wave action is considerably dampened by the various islands and shoals at the approaches to the Skeena River entrance.

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Three islands, Smith, De Horsey and Kennedy, front on the Skeena River, and these are backed by the much larger Porcher Island, so that any oceanic waves and swells through Hecate Strait and Dixon Entrance are eliminated, or at least strongly modified. Local winds and the restricted fetch of open "inside" waters would only allow relatively small waves, with steep crests, to develop. These can have adverse effects on navigation and certain undetermined influences on the ecology.

Although the tidal action is very effective in flushing Chatham Sound and most of the waters along the Skeena River estuary, some of the more confined basins such as Wainwright and Morse, at the approaches to the Skeena River estuary, are poorly flushed by tidal action because of the constrictions in the passages connecting them with the open sea. No such constrictions appear to affect waters in the immediate vicinity of the Skeena River mouth, but judging by the distribution of tidal flats, some areas have considerably less water movement than others.

6. INVERTEBRATE BIOLOGY

As virtually no information dealing with the terrestrial invertebrate fauna of the Skeena area could be found, the following discussion will be concerned with only aquatic life. This will be subdivided into the freshwater and marine forms. Once having established the physical habitat, the fauna can be further categorized as benthic or planktonic, and, within the benthos, as epifaunal or infaunal. The reader is referred to the glossary for definitions of the above terminology.

6 (i) FRESHWATER INVERTEBRATES

Very little information exists concerning freshwater invertebrates of the Skeena. Some data can be obtained from fish ecology studies, which include notes on the invertebrates utilized as food resources by resident fish species.

1. BENTHOS:

Godfrey (1955) did an in-depth study of the ecology of Skeena River whitefishes, and included some data on benthic invertebrate communities. While much of this work was done on Skeena River tributaries and lakes, rather than on the Skeena itself, the information can be considered as representative of the drainage basin in general.

Lakelse Lake was found to have an abundant invertebrate fauna. Bivalves (mainly *Pisidium* and *Sphaerium*), gastropods (mostly *Planorbis*), amphipods (*Hyalella* sp.), mayfly nymphs (mostly *Ephemera*), chironomids (species unidentified), oligochaetes (species unidentified) and caddisflies (species unidentified) were the dominant groups found. In addition, occasionally leeches, damselfly nymphs, fly larvae, water mites, true bugs, spiders, ants, bees, or beetles were also obtained. Bryozoans and the freshwater sponge *Spongilla* were frequently found as well (Godfrey, 1955).

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Babine Lake, further up the drainage system, contained a relatively poor invertebrate fauna, in comparison with Lakelse Lake, in terms of abundance, although the species variety was very similar. Gastropods were most abundant, followed by bivalves, chironomid larvae, amphipods (*Hyalella* and *Gammarus*) and oligochaetes. Other forms included bryozoans, mayfly nymphs, caddisfly larvae, beetles, stoneflies, fly larvae, true bugs, leeches, spiders, and water mites (Godfrey, 1955).

Morrison Lake, near Babine, contained the most meagre benthic populations of those studied. Mayfly nymphs, lace wing nymphs, and fly larvae were most abundant, while stoneflies, caddisflies, beetles, mites, bivalves, gastropods, oligochaetes, and amphipods (*Hyalella* and *Gammarus*) were found (Godfrey, 1955).

McDonald (1960), in studying the downstream migration of Skeena salmon, noted that more fry from the lower Skeena drainage contained food organisms than did fry from the upper drainage. Stomach contents revealed larval and nymphal mayflies, stoneflies, crane flies, midges, and red water mites.

Hallam *et al.* (1975), in a study to assess the possible environmental pollution of fresh water adjacent to a mine in the Smithers area, collected benthic invertebrate samples from Cronin Creek and classified the organisms found into three groups according to their ability to tolerate polluted conditions. The most tolerant organisms were oligochaete worms. Of the moderately tolerant group, all of which were either dipteran insects (flies) or water mites, the Tendipedidae were most abundant. The intolerant assemblage included beetles, stoneflies, mayflies, and caddisflies, the most abundant being mayflies.

A recent study by Lee Doran Associates Ltd. (1975), to assess the aquatic environments of possible port development sites in the Prince Rupert region, included a few notes on

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freshwater benthic populations. Stumaun Creek, in the Port Simpson area, supported an average of only 90.8 organisms per square meter, the main groups being stonefly nymphs, midge larvae and adults, and roundworms. McNichol Creek contained fewer species of invertebrates, but more individuals per species. Caddisfly larvae predominated in these samples.

Appendix 6.1 includes a list of the freshwater species, as well as the marine benthic organisms, found in the Skeena and its estuary.

2. PLANKTON:

Although Godfrey (1955) did not specifically analyze the water column of the areas he studied for zooplankton, some information can be obtained on these populations from fish stomach contents.

Planktonic organisms consumed by resident fish species included copepods (*Heterocope* sp., *Diaptomus* sp., and *Cyclops* sp.), cladocerans (*Daphnia* sp. and *Bosmina* sp.), ostracods (Cyprinidae), and mysids (*Mysis* sp.).

During the 1940's, the Fisheries Research Board did quick analyses of many of the Skeena drainage basin lakes, in an attempt to predict declines in the salmon populations. Planktonic organisms important in the diet of juvenile salmon were noted. Copepods (mainly *Heterocope septentrionalis*, *Diaptomus* sp., and *Cyclops* sp.) and cladocerans (such as *Daphnia longispina*, *Bosmina longispina*, and *Polyphemus pediculus*) formed the bulk of the fry diets (Foskett, 1947a and b; Withler, 1948; Withler, McConnell, and McMahon, 1949).

One is referred to Appendix 6.2 for a complete list of the zooplankton of the Skeena River and estuary.

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6 (ii) MARINE INVERTEBRATES

1. BENTHOS:

Various faunistic surveys note the presence of individual invertebrate species within the Skeena estuary area.

Butler (1964b) identified the shrimps *Pandalopsis dispar*, *Pandalus borealis*, *Pandalus platyceros*, and *Pandalus goniurus* as occurring in Chatham Sound, while Bourne (1969) reported finding scallops (*Chlamys* sp.) in the same area.

Waldichuk and Bousfield (1962) recorded the presence of abundant benthic amphipods (*Anisogammarus pugettensis*) and the isopod *Synidotea* sp. in Porpoise Harbour.

A British Columbia Fish and Wildlife Branch report (no date) indicated that littleneck (*Venerupis japonica*) and butter (*Saxidomus giganteus*) clams are found at Metlakatla Bar and Casey Point near Prince Rupert, while crabs (*Cancer magister*) occur on Kitson Island, and in Tuck Inlet and Venn Passage.

Such records as the above provide little real information on the benthic invertebrates of the Skeena estuary. There are, in fact, very little detailed data on this topic. Various consultants and government agencies have included short discussions on the invertebrate faunas in their reports, and the following account is taken from these documents. In general, however, the data are patchy, and since these organisms are the basic food source for the abundant fish of the area, there is a need for much more concentrated research on Skeena estuary invertebrates.

The earliest study of the effects on the environment by the pulp mill on Watson Island was that done by Stokes (1953) for the Department of Fisheries. As an aside to his water quality research, Stokes noted the invertebrate life encountered

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during the study period. Porpoise Harbour, adjacent to the mill, was found to be relatively unharmed biologically. Mussels (*Mytilus edulis*), barnacles (*Balanus* sp.), and hermit crabs (Paguridae) were found in the mill vicinity.

Waldichuk (1962), in a later study, found the remains of what appeared to have been sizeable populations of bivalves in Porpoise Channel. Shells of *Astarte alaskana*, *Venericardia ventricosa*, *Macoma* sp., and *Chlamys* sp., were found, along with the shells of the gastropod *Ocenebra tenuisculpta* and the limpet *Puncturella cucullata*.

From Porpoise Harbour, Waldichuk (1962) reported finding the shells of a brachiopod (*Terebratalia transversa*), and the bivalves *Macoma irus* and *Macoma inconspicua*. Living specimens of the sea urchin *Strongylocentrotus* sp., the clam *Macoma inconspicua*, the snail *Littorina sitkana*, the limpet *Acmaea pelta*, barnacles [*Balanus* sp. (probably *B. glandula*)], crabs (*Hemigrapsus* sp.), polychaetes (*Eunoe nodosa* and *Cirratulus* sp.), amphipods (*Anisogammarus pugettensis*), and the isopod *Synidotea* sp. were found at various stations throughout the harbour, most of which were located near Zanardi Rapids.

The only living organisms recorded from Wainwright Basin during the study were limpets (*Acmaea pelta*) (Waldichuk, 1962).

Somewhat more recently, Goyette *et al.* (1970) compiled a summary of water quality data for the Porpoise Harbour-Wainwright Basin area, and included results of their own field studies. Their observations of the intertidal areas indicated that most common marine forms had been eliminated from both Wainwright Basin and Porpoise Harbour. Only large numbers of nematodes and amphipods remained. It was not until far out in Porpoise Channel that normal marine faunas were apparent.

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In response to the possibility of construction of a deep-sea port in the Prince Rupert area, the Department of Environment undertook an environmental impact study of the proposed development sites and surrounding areas (Dept. of Environ., 1973a and b). In conjunction with this study, F.F. Slaney and Company were commissioned to carry out much of the preliminary, non-fisheries, work, and their report was incorporated into that of the Department of Environment (1973b). The following account of benthic invertebrate life of the Skeena estuary area relies on this document.

The F.F. Slaney report (In: Dept. of Environ., 1973b) included short descriptions of intertidal benthos from Ridley Island and Kitson Island. Within the small bay used by the Canadian Cellulose pulp mill for red liquor discharge very little life was found. On the seaward side of this cove, relatively large numbers of capitellid polychaetes and barnacles occurred, while there were only a few amphipods and limpets (*Acmaea* sp.), and virtually no isopods or echinoderms. The only other organisms found were a few flatworms, a nemertean, a few bivalves, some snails (*Littorina* sp.), and some chironomids. Thus, life outside the discharge cove was also adversely affected by the effluent.

Kitson Island had a fairly typical British Columbia intertidal zone. Isopods and amphipods were abundant, as were snails (*Littorina* sp.) and barnacles. Other common organisms included crabs, chitons, limpets (*Acmaea* sp.), and bivalves, with specimens of sea cucumbers, starfish, polychaetes, sponges, hydroids, and nemerteans being found periodically.

Fisheries Service conducted a small study of subtidal benthos for the Department of Environment assessment (1973b). Their results indicated that the most important invertebrate areas were located on Flora Bank. Polychaetes formed the largest taxonomic group and were abundant on Flora Bank,

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along with large numbers of bivalves, amphipods, and isopods. Echinoderms were only found on the bank. Stations located in the direct influence of Skeena River outflow were generally devoid of invertebrate life, probably due to lowered salinity. The entire list of benthic organisms found in the study is incorporated into the general invertebrate species list in Appendix 6.1.

During the summer of 1973, the provincial Pollution Control Branch undertook a study of the benthic populations of the Skeena estuary area (Drinnan, 1974). This project was directly concerned with, among other things, the effects of the red liquor effluent, and other pulp mill wastes, emanating from the Canadian Cellulose pulp mill on Watson Island.

Drinnan (1974) recorded fifty different invertebrates, which were then grouped into 27 categories for ease of handling. These categories were analyzed in relation to pollution sources found in the study area, and rated as pollution sensitive, moderately pollution tolerant, and very pollution tolerant. After analyzing the data, it was determined that, of the various possible pollution sources that could affect invertebrates, only the Canadian Cellulose pulp mill discharges had a significant effect.

Listed as "pollution sensitive" were sponges, sea anemones (*Tealia* sp.), shore crabs (*Hemigrapsus* spp.), edible crabs (*Cancer* spp.), large barnacles (*Balanus cariosus*), purple rock whelks (*Thais* spp.), starfish, sea cucumbers, and sea urchins (*Strongylocentrotus droebachiensis*). These were the species which were first to disappear when pollution stress increased.

The "moderately pollution-tolerant" organisms included hermit crabs, limpets (*Acmaea* spp.), and chitons (*Katherina tunicata*), while isopods (*Idothea* sp. and *Cirolana* sp.), amphipods

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(*Anisogammarus confervicolus*), medium-sized barnacles (*Balanus balanus*), littorine snails (*Littorina* spp.), and mussels (*Mytilus edulis*) formed the "highly pollution-tolerant" list.

Some of the field observations on the relative abundance of some species as the pollution stress increased are worth noting. While both isopods and amphipods were found in polluted areas, amphipods were, by far, more abundant at the severest sites (e.g. Wainwright Basin), while the proportion of isopods increased in more favourable areas (e.g. Morse Basin). In unaffected areas, both organisms declined in numbers, with amphipods becoming most scarce.

Similarly, both shore (*Hemigrapsus* spp.) and hermit (Paguridae) crabs were abundant at unaffected sites, but as stress increased, shore crabs became less and less common.

Three "tolerant" species were common throughout the study area - the medium-sized barnacle (*Balanus balanus*), the mussel (*Mytilus edulis*), and the littorine snail (*Littorina* spp.). All three are characteristically high intertidal organisms, which are normally able to adapt to exposure and dessication.

Generally, the health and abundance of the invertebrate faunas paralleled that of the algal populations. It was not known whether this was a function of some toxic component in the environment which killed both, or if the destruction of the algal food source and protection resulted in the loss of benthic organisms.

The above discussion has dealt with rocky areas only. Some soft-bottom areas were also analyzed. In general, bivalves, polychaetes, and some mud shrimp (*Callinassa californiensis*) were found in such locations.

The complete list of organisms found by Drinnan (1974)

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is incorporated in the general list of Appendix 6.1.

Levings (1974), as part of a series of analyses of polluted British Columbia inlets and estuaries to study the amphipod *Anisogammarus* spp., collected some as-yet-unanalyzed intertidal benthic samples near the red liquor outfall on Ridley Island, and from Porpoise Harbour and Wainwright Basin. As well, some sublittoral samples were taken in Porpoise Harbour. Levings' cruise report (1974) indicated that organisms were totally absent on the beach adjacent to the sulphite liquor outfall on Ridley Island. However, less than $\frac{1}{4}$ mile from this site, littoral communities (including *Balanus cariosus*, *Littorina sitkana*, *Anisogammarus* spp., and *Macoma*) were found to be relatively normal.

In Porpoise Harbour, amphipods (especially *Anisogammarus locustoides*) were very abundant on a small island in the northwest corner, and a generally diverse invertebrate population was found. Freshwater organisms (insect larvae) were noted where the pulp mill effluent discharge line leaves the water, on the east shore of Ridley Island (Levings, 1974).

Adjacent to the sulphate waste discharge area, in the southwest sector of Wainwright Basin, oligochaetes were the only intertidal invertebrates seen, while further away, on muddy beaches, amphipods were found (Levings, 1974).

The sublittoral samples taken in Porpoise Harbour revealed amphipods (*Anisogammarus* spp.) and capitellid polychaetes (Levings, 1974).

A second study of the Skeena area, done by the Environmental Protection Service in the summer of 1974, attempted to assess the effect of the pulp mill sulphite wastes on the intertidal and sublittoral benthic populations of Ridley Island. Although the data are not yet analyzed, researchers

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indicated that the intertidal zone of the discharge cove was completely dead - the rocks being littered with empty barnacle shells and the mud containing perfectly intact, "mummified", long-since deceased bivalves, complete with siphons to the substrate surface (Hoos, pers. comm.).

The zone of transition (approximately $\frac{1}{4}$ mile from the completely "dead area") was marked by the presence of a few living organisms. However, species which normally had hard calcareous shells were found to be very fragile. The slightest pressure exerted on a limpet, for example, would completely crush its shell. Beyond this transition zone, the intertidal area appeared relatively normal, with several species, such as *Thais* sp., *Katherina tunicata*, *Mytilus edulis*, *Acmaea* sp., *Littorina* sp., *Balanus cariosus*, and *B. glandula* occurring in the lower intertidal zone (Hoos, pers. comm.).

The most recent work on estuarine and marine benthos of the Skeena region was done by Lee Doran Associates Ltd. (1975) as part of an assessment of aquatic environments in proposed port development locations. Subtidal and intertidal populations were analyzed.

The subtidal benthic faunas of Prince Rupert and Port Simpson were dominated by bivalves and errant polychaete worms. A maximum of 28 and a minimum of 5 species were found, while the total number of individuals varied from 10 to 91 per sample. The mean number of species per sample for Prince Rupert Harbour was 17, while that for Port Simpson was 11.

Two locations in Prince Rupert Harbour showed evidence of damage to the shallow subtidal fauna as a result of log booming. Species diversity was low at these locations, while mud was found to contain wood debris and smelled of hydrogen sulphide.

In general, of the sites studied, Ridley Island

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supported the greatest number of species and highest species diversity for subtidal samples, with the eelgrass populations at Stumaun Bay (in Venn Passage) being second. Gammarid amphipods (*Anisogammarus confervicolus*) were extremely abundant in Ridley Island samples.

Subtidal samples from DeHorsey and Flora banks contained unusually large populations of the bivalve *Transennella tantilla*. They were generally found in association with the cockle *Clinocardium californiense*, and the tellen *Tellina nukuloides*, on Flora Bank; while the polychaete *Nephtys punctata* was commonly found with *Transennella* in samples from DeHorsey Bank.

In general, the intertidal fauna of all of the sites was composed of species characteristic to areas of moderate surf exposure. Common organisms included barnacles (*Balanus* sp.), amphipods (*Orchestia* sp.), hermit crabs (*Pagurus* sp.), limpets (*Acmaea digitalis* and *A. scutum*), periwinkles (*Littorina* sp.), and mussels (*Mytilus edulis*).

At the Port Simpson site, the hermit crab dominated the lower intertidal area, while periwinkles and barnacles occurred together in the mid-intertidal zone. A large number of juvenile crabs also occurred in the Port Simpson region.

The Ridley Island intertidal zone supported the largest number of species of those sites analyzed. Periwinkle snails dominated the lower intertidal zone, along with an unidentified sponge and amphipods. The barnacle *Balanus* sp. covered an average of 25% of the mid-intertidal zone, where limpets were also moderately abundant. The upper intertidal area was characterized by barnacles and mussels. A beach seine of the region netted several decapod crustacea, mysids, and large numbers of the amphipod *Anisogammarus confervicolus*.

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A complete list of the benthic invertebrate species known to occur in the Skeena estuary area can be found in Appendix 6.1.

2. PLANKTON:

As was the case with benthic research in the Skeena estuary area, very few studies have been done on the planktonic fauna of the water column. Some information can be obtained from fish feeding studies and incidental observations made during pollution (etc.) surveys.

Waldichuk and Bousfield (1962) reported obtaining the amphipods *Allorchestes angustus* and *Anisogammarus pugettensis* in a bucket sample taken of the surface water of Porpoise Harbour. It was speculated that the large numbers of amphipods found near the surface was a result of active movement by the organisms to escape the low dissolved oxygen levels of bottom waters.

LeBrasseur (1966) analyzed and compared the stomach contents of various anadromous fish from different parts of the northeast Pacific. The Skeena estuary falls within LeBrasseur's "coastal" zone. Within this area, various fish (pink, coho, chum, and sockeye salmon, and steelhead trout) were found to consume various components of the plankton community, including amphipods, copepods, euphausiids, squid, and the pteropod *Limacina* sp.

A few years later, Manzer (1969) analyzed the stomach contents of Chatham Sound salmon. The dominant planktonic organisms consumed were copepods, barnacle larvae, amphipods, euphausiids, crab larvae, insects, and larvaceans (*Oikopleura* spp.). Other less common species were chaetognaths, cladocerans, gastropods, polychaetes, ostracods, mysids, cumaceans, and isopods.

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In response to the initial proposal to develop the Skeena estuary as a deep-sea port, the federal Fisheries Service did a cursory survey of productivity in the Flora Bank area, including some zooplankton sampling (Fisheries Service, 1972). In August and October, juvenile copepodites dominated the samples, which also contained *Pseudocalanus minutus*, *Acartia longiremis*, *Oithona* sp., *Noctiluca* sp., and *Oikopleura* sp. The stomach contents of resident fish species revealed other members of the plankton community, including *Calanus glacialis*, *Centropages abdominalis*, and *Tortanus* sp.

The following summer (i.e. 1972) the Department of Environment undertook a more detailed survey of the same area, as well as other possible sites within the Skeena's area of influence (Dept. of Environ., 1973a and b). In general, copepods (particularly calanoid copepods) were most abundant and most diverse. Juvenile specimens (nauplii and copepodites) made up the greater portion of the large numbers found. Those stations located closest to the Skeena outflow had the fewest individuals and the lowest diversity. Included in the plankton community were the following organisms: fish larvae, polychaetes, chaetognaths, hydrozoans, bivalves, snails, euphausiid nauplii, barnacle cyprid larvae, barnacle nauplii, *Oikopleura* sp., *Noctiluca* sp., *Evadne* sp., *Podon* sp., harpacticoid copepods, *Oithona* sp., *Eurytemora pacifica*, *Calanus* sp., *Tortanus discaudatus*, *Centropages abdominalis*, *Pseudocalanus minutus*, *Acartia longiremis*, calanoid copepodites, and calanoid nauplii.

A recent study by Lee Doran Associates Ltd. (1975), on the aquatic environments of proposed port development sites, took zooplankton tows in Prince Rupert Harbour and Port Simpson Harbour. Copepods dominated the fauna in numbers, but larger organisms such as euphausiids, mysids, and amphipods dominated in terms of biomass. There appeared to be a greater abundance of the euphausiid *Euphausia pacifica* toward the head of Prince Rupert Harbour than at more seaward locations.

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A complete species list of zooplanktonic organisms known to inhabit the Skeena estuary area can be found in Appendix 6.2.

6 (iii) INVERTEBRATE FISHERIES RESOURCE

As was the case with each of the previous sub-sections, very little information exists regarding the commercially and/or recreationally harvestable invertebrates.

Berkeley (1930), Heritage and Butler (1967), Butler (1968) and Butler and Smith (1968) all record the presence of a shrimp fishery (*Pandalus borealis* and *Pandalopsis dispar*) near Prince Rupert, dating back to World War I. Fishing dropped off after the second World War, and did not increase in Chatham Sound until the 1960's, after the Fisheries Research Board conducted exploratory surveys in the area (Butler, 1953; Butler and Légaré, 1954; Butler and Dubokovic, 1955a,b, and c). The area now supports a major fishery.

A British Columbia Fish and Wildlife report (no date) indicates that a commercial crab fishery exists on Kitson Island, as well as in Tuck Inlet and Venn Passage. Much of the Prince Rupert area is closed to the taking of shellfish due to sewage pollution and red tides.

The same B.C. Fish and Wildlife report noted that clam beds are located at Metlakatla Bar and Casey Point, and some littleneck and butter clams are consumed locally despite the closures.

Quayle (1971) reported on an attempt to culture Pacific oysters (*Crassostrea gigas*) in the Nicol Creek area near Prince Rupert. Although many of the spat survived, the cold water temperatures retarded their growth so severely as to make

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the venture uneconomical. However, oysters are reported to be cultured in Melville Arm, across from Prince Rupert Harbour (Anon., 1962).

Finally, Bourne (1969) recorded the presence of scallops (*Chlamys* sp.) in Dixon Entrance and Chatham Sound. However, whether or not these populations are sufficiently large to support a commercial fishery remains to be seen.

Prince Rupert has two crab canneries and several fresh and frozen shrimp operations. Yearly landings at the port for crab and shrimp are in the order of 1,500,000 pieces and 270,000 pounds, respectively. The fishery is carried out by about 10 crab boats and 12 shrimp trawlers, and, in 1969, had a landed value of 14,000 (for crab) and 63,000 (for shrimp) dollars (City of Prince Rupert, 1971).

In 1969, octopus, valued at \$6,000, was also taken commercially, probably incidentally to fishing for other animals (City of Prince Rupert, 1971).

7. FISH

7 (i) GENERAL DISCUSSION

The Skeena River ranks second only to the Fraser River (see Hoos and Packman, 1974) as a salmon producer in British Columbia (not to mention the other abundant species inhabiting the river and its estuary), and as such is the major single source of income to the residents of the Prince Rupert area (Higgins and Schouwenburg, 1973). In fact, nearly 42% of Prince Rupert's basic employment and approximately 36% of its basic income, during 1970, were supplied by commercial fishing (Sinclair, 1971).

In light of these facts, it is no wonder that the Skeena fisheries have been studied in much greater detail than have the other biological populations of the estuary. It would seem valuable to expand the research on these other faunas to gain insight into the entire estuary ecosystem, and, therefore, to shed light on the role of the fish populations in that system.

1. SALMON:

The Skeena River is best known for its production of salmon, and of sockeye salmon (*Oncorhynchus nerka*), in particular. Sizeable populations of pinks (*O. gorbuscha*) are also reared in the river system, along with less abundant stocks of coho (*O. kisutch*), chum (*O. keta*), and chinook (*O. tshawytscha*).

The most productive salmon region of the Skeena drainage basin is the Babine tributary system. In 1951, a rock slide substantially reduced the salmon stocks from this area, resulting in a drastic loss to the commercial fishery. In the 1960's, the federal Fisheries Service began an intensive program to restore the salmon resources to their previous level. This involved the installation of spawning channels in tributary streams and

stringent management regulations. In conjunction with this program, a wide variety of studies (the majority dealing with sockeye salmon) were undertaken to determine salmon distributions, migration patterns, feeding habits, behaviour, life histories, etc. Due to a lack of space, it is not possible to describe all of these studies here. Instead, a brief description of the habits of each species will be included and the reader is referred to the bibliography for an entire list of the pertinent literature.

(a) Sockeye salmon (*Oncorhynchus nerka*). Between 1908 and 1967, the average annual sockeye yield to the commercial fishery was 881,000 fish. About twenty-one lakes, together with their tributary streams, support sockeye, but by far the most important of these is the Babine system which accommodates about 90% of the total Skeena sockeye run (Larkin and McDonald, 1968).

In general, spawning occurs from late summer through autumn, with two main peaks, the first from late July to early August, and the second from September through October, the eggs being layed in gravel areas in the tributary streams and lakes up-river (Foerester, 1968).

Emergence occurs in early spring (April to May), with the fry moving up or downstream to one of the Skeena lakes, where they are resident for one to three years before migrating downstream to the sea. Seaward migration takes place anywhere from April to June (Foerester, 1968), peaking in mid-May (Higgins and Schouwenburg, 1973) (see Appendix 7.1).

Upon reaching the Skeena estuary, some move out along the mainland beaches or beaches on the islands to the west, while the majority stay right in the river mouth, or on Flora Bank and near Kitson Island. They remain in these localities for no more than a few weeks to a month (till mid-July) before moving out to sea (Manzer, 1956; Higgins and Schouwenburg, 1973).

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This pattern is very similar to that found for sockeye of the Fraser River (Hoos and Packman, 1974).

(b) Pink salmon (*Oncorhynchus gorbuscha*). In the Skeena River system, both odd and even-year pink salmon runs are important. The average annual odd-year catch at the river mouth (1951 to 1963) was 953,000, while that for even-years for the same period was 707,000 million. Fewer lakes and streams support pink salmon than support sockeye, the majority of pink spawning locations being closer to the sea. The Lakelse River, and its tributaries, is the most important system in both the even-year and the odd-year cycles (Aro and Shepard, 1967; Fish. Serv., unpubl. data).

Migration of the adults, from the sea, begins in mid-July, with spawning occurring up-river in late August through late October. All pinks spawn when they are two years old, whether they are from even-year or odd-year runs (Aro and Shepard, 1967).

Pink fry emerge from the gravel in April to early May, and immediately migrate to the sea. Higgins and Schouwenburg (1973) indicated the peak of the run to be in mid-May, with the end occurring by mid-June (see Appendix 7.1).

Unlike sockeye, pink salmon do not remain in the mouth of the Skeena itself. Instead, they move out into the shallow estuary channels, along the beaches and sand banks (particularly Flora Bank and, to a lesser degree, De Horsey Bank) of the mainland, and onto the shores of the western Chatham Sound islands. Their residences here are short-lived, however, since within a month they have moved out to sea (Manzer, 1956; Higgins and Schouwenburg, 1973).

(c) Coho salmon (*Oncorhynchus kisutch*). Coho salmon are not nearly as abundant in the Skeena system as pink or sockeye. However, an annual average catch in the order of 100,000 fish

has occurred from 1951 through 1963. As was the case for pink salmon, most coho tend to spawn relatively close to the sea, although runs to Babine Lake do occur. The main spawning channels appear to be Lakelse, Morice, Babine, Erstew, Kasiks, and Copper rivers and Kadeene Creek (Aro and Shepard, 1967; Fish. Serv., unpubl. data).

Spawning occurs in October or early November, with emergence taking place the following spring. A few fry move directly to the sea, but the majority remain in the Skeena drainage lakes and tributaries for at least one year before migrating seaward. Higgins and Schouwenburg (1973) indicated that coho do not have a major seaward migration peak, instead having several smaller peaks, the largest of which coincided, in that year (1972), with a very high discharge period in the Skeena River in early June.

Coho salmon are known to have a relatively longer estuary residence than either of the two species discussed previously. Juveniles reach the estuary in early June and remain in the shallow waters of the sand banks, particularly of Inverness Passage, for several weeks to two months before moving out to sea (Higgins and Schouwenburg, 1973).

(d) Chum salmon (*Oncorhynchus keta*). Chum salmon are less abundant in the Skeena system than are coho, averaging an annual catch, from 1951 through 1963, of about 50,000 fish (Aro and Shepard, 1967).

Very little is known about which of the many streams and lakes support chum spawning. Unpublished Fisheries Service records indicate that spawning occurs in the Ecstall, Kispiox, Lakelse, Kasiks, and Kalum rivers, as well as in the Skeena mainstem. Adults move upstream during mid-summer, with spawning occurring in August and early September. The fry emerge in the spring, and move directly to the sea without stopping to feed

until they reach the estuary.

Like coho, chum salmon have a relatively long estuarine residence, utilizing mainly Inverness Passage. Higgins and Schouwenburg (1973) reported finding chum juveniles in the Skeena estuary as early as May, with peak numbers being recorded in mid-July. Fry were still abundant in August. Manzer (1956) indicated that chum fry, from the Skeena, did not migrate out to sea until late August or early September.

(e) Chinook salmon (*Oncorhynchus tshawytscha*). The average annual catch (1951 to 1963) of chinook salmon from the Skeena is about 50,000 fish, with the Bear, Morice, Babine, Kispiox, Kalum, and Ecstall rivers supporting most of the spawning (Aro and Shepard, 1967; Fish. Serv., unpubl. data).

Adults move upstream during the summer, with spawning occurring in September. The fry emerge the following spring, and migrate to the sea, after spending from a few days to a year in their natal stream.

Upon reaching the estuary, fry tend to delay movement to the sea. Like coho and chum, chinook take up residence in the estuary shallows of Inverness Passage for the summer, and do not leave until September. Higgins and Schouwenburg (1973) reported finding chinook salmon in their earliest May samples, and in their last samples in August, with peak numbers occurring in mid-June coincidental to the peak discharge of the Skeena River.

2. STEELHEAD:

Very little information could be found concerning the populations of steelhead (*Salmo gairdneri*) inhabiting the Skeena River drainage basin. Shepard and Stevenson (1956) and Withler (1972) indicated that the Skeena ranks as one of the top steelhead producers in the province, and, therefore, this lack of

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data is somewhat incongruous.

Steelhead are taken by commercial fishermen incidental to their fishing for salmon, since spring and fall migration times are very similar for both genera. Withler (1972) reported that these major Skeena steelhead runs are to the Kispiox, Babine, and Morice river systems, while a Fisheries Service (1972) report states that an important run to the Sustut River also occurs.

Spawning occurs early in the year (January to June) in the gravel of the tributary streams, with the resulting fry emerging from June through September. The young spend from one to five years in the streams, rivers, and lakes of the Skeena system until reaching smolt size, and then migrate downstream, in the spring, to the sea (Withler, 1972).

Nothing is known of the length of residence in the Skeena estuary prior to movement to the open sea. No mention is made of this species in the study by Higgins and Schouwenburg (1973) on estuary fish distributions. Information gathered for the Fraser and Squamish river estuaries (Hoos and Packman, 1974; Hoos and Vold, 1975) would seem to indicate that juvenile steelhead remain close to the river mouth for only a short period of time, prior to moving out to sea.

3. RESIDENT FRESHWATER SPECIES:

During the late 1940's, the Fisheries Research Board undertook a series of studies of some of the lakes of the Skeena drainage basin. Although research was concentrated on the salmon populations of the lakes, notes were made on the other fish species found. Since most of the lakes contained the same species, the following will be a summary of all of the studies put together. For details of individual lakes, the reader is referred to Brett, 1946; Brett and Pritchard, 1946a, 1946b; McConnell and Brett, 1946; Foskett, 1947a, 1947b; McMahon, 1948;

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Withler, 1948; and Withler, McConnell, and McMahon, 1949.

Various fish species were found to be predators on the juvenile salmon populations, including lake trout (*Cristivomer namaycush*), burbot (*Lota lota*), dolly varden (*Salvelinus malma*), rainbow trout (*Salmo gairdneri*), and cutthroat trout (*Salmo clarkii clarkii*). Other species, such as eastern whitefish (*Coregonus clupeaformis*), Rocky Mountain whitefish (*Prosopium williamsoni*), and peamouth chub (*Mylocheilus caurinus*), were in direct competition with salmon for food.

In addition to the above species, squawfish (*Ptychocheilus oregonensis*), bullhead sculpin (*Cottus asper*), burbot (*Lota lota*), stickleback (*Gasterosteus aculeatus*), shiner (*Richardsonius balteatus*), long-nose dace (*Rhinichthys cataractae*), and chub minnow (*Couesius greeni*) were also commonly found, along with a variety of suckers [fine-scaled or long-nosed (*Catostomus catostomus*), common or white (*C. commersonii*), and coarse-scaled (*C. machrocheilus*)].

Godfrey (1955) carried out an in-depth ecological study of whitefishes from the Skeena River, and included a species list of other fish found to inhabit the same areas as the whitefish species he analyzed. Most of these were the same as those listed above, with the inclusion of redbelly dace (*Chrosomus eos*) and kokanee (*Oncorhynchus nerka kennerlyi*). Since this study concentrated on areas other than the lower Skeena River itself, details of Godfrey's findings will not be included here. The reader is referred to this article for information on ecosystem interrelationships between the various fish which are resident in the upper Skeena drainage basin.

4. MARINE SPECIES:

Somewhat removed from, but still within the influence of, the Skeena River, lies the major trawl fishing ground of

British Columbia - Butterworth-Warrior rocks. This area has been the dominant producer of rock sole (*Lepidopsetta bilineata*), in Canada, for the past twenty years (Forrester and Thomson, 1969). Other species making up the bulk of the average annual groundfish catch (1945-1964) from these flats include English sole (*Parophrys vetulus*) and Pacific cod (*Gadus macrocephalus*). Lesser species also netted are Dover sole (*Microstomus pacificus*), rex sole (*Glyptocephalus zachirus*), petrale sole (*Eopsetta jordani*), butter sole (*Isopsetta isolepis*), turbot or arrow-toothed flounder (*Atheresthes stomias*), starry flounder (*Platichthys stellatus*), and lingcod (*Ophiodon elongatus*). However, Pacific halibut (*Hippoglossus stenolepis*), caught by line rather than trawl, is the major non-salmonid commercial fish species of the Prince Rupert area.

Four species of smelts are known to inhabit the Skeena estuary. The most abundant of these is the surf or silver smelt (*Hypomesus pretiosus*). These fish spawn during the summer in sheltered, shaded gravel beaches. Since few young are ever caught in beach seines, it is likely that the fry move directly out to sea upon emergence (Hart and McHugh, 1944).

Eulachon (*Thaleichthys pacificus*) are known to spawn upriver in the Skeena system (Hart and McHugh, 1944), but not in great abundance. The spawning migration takes place in early spring (mid-March to mid-May), and is characterized by a migration of seals upstream in pursuit of any easy meal (Slaney, *et al.*, 1973). Upon emergence, the fry are carried downstream to the estuary, where they may or may not take up residence (Hart and McHugh, 1944).

The third smelt species found in the Skeena estuary is the capelin (*Mallotus villosus*). Like the silver smelt, the capelin spawns on the beaches of marine or estuarine areas, such as enclosed bays or coves. Spawning occurs in the autumn, and the eggs hatch in two to three weeks. The larval fish disappear

from the beaches very quickly, not returning until they have reached maturity and are ready to spawn (Hart and McHugh, 1944).

The long-fin smelt (*Spirinchus dilatatus*) was collected in the Skeena estuary by Higgins and Schouwenburg (1973) in a Fisheries Service study in the summer of 1972. This species, like the eulachon, spawns in fresh water and, at least in the case of the Fraser River, the juveniles spend considerable time in the estuary area prior to moving offshore (Hoos and Packman, 1974). However, no information on the life history of the long-fin smelt in the Skeena estuary could be found.

The records for the Pacific herring (*Clupea pallasii*) in the Skeena area indicate that the population is highly variable from year to year. Large spawning schools were reported for the turn of the century in the Prince Rupert area, but a substantial decline in stocks was found in the late 1930's and 1940's (Sunderland, 1935, 1936; Boughton, 1939; Tester, 1945). There is a gap in the data over the next decade, but records of the late 1950's and early 1960's showed marked increases in the herring populations of the estuary area (Outram, 1961a and b, 1963). However, the increase was short-lived. By 1969, herring stocks had reached an all-time low in the Skeena estuary area (Outram and Haegele, 1969), when only 2 miles of spawn were recorded, as compared to the 25-year average of 18 miles.

In the Fisheries Service study by Higgins and Schouwenburg (1973), spawn was again recorded as very low. The only place with measurable quantities was the west side of Digby Island. Purse seine catches of adult herring were greatest in Chatham Sound and near Ridley Island, where the fish were moving randomly in search of a suitable spawning area out of the direct influence of fresh water from the Skeena. Despite the abundant eelgrass found on Flora Bank, herring were not using the area for spawning, presumably due to the decreased salinity of its waters.

A wide variety of other fish have been recorded for the Skeena estuary area, but no information is available on their life histories and/or their niches within the estuary ecosystem. Among those most often found in species lists of the area are Pacific lamprey (*Entosphenus tridentatus*), sand sole (*Psettichthys melanostictus*), lemon sole (*Parophrys vetulus*), sandfish (*Trichodon trichodon*), various sculpins [spiny-nosed (*Radulinus taylori*), padded (*Artedius fenestralis*), buffalo (*Enophrys bison*), staghorn (*Leptocottus armatus*), and grunt (*Rhamphocottus richardsoni*)], deep-pitted poacher (*Bothragomus swanii*), spiny lump sucker (*Eumicrotremus orbis*), tadpole snailfish (*Nectoliparis pelagicus*), threespine stickleback (*Gasterosteus aculeatus*), white-barred prickleback (*Poroclinus rothrocki*), red brotula (*Brosmophycis marginata*), flathead clingfish (*Gobiesox masandricus*), ratfish (*Hydrolagus colliciei*), yellow shiner (*Cymatogasteris aggregata*), flathead sole (*Hippoglossoides elassodon*), starry flounder (*Platichthys stellatus*), and dogfish (*Squalus suckleyi*) (Levings and Chilton, 1969; Higgins and Schouwenburg, 1973; Lee Doran Assoc. Ltd., 1975; Hoos, pers. comm.).

All of the fish species described here form an important part in the Skeena River estuary ecosystem. Some of them relate to the estuary only through their interrelationships with anadromous species while the migrating species are freshwater residents. Others spend much of their lives directly within the estuary. Each has its own niche in the system, and as such is important to the whole.

A complete list of the fish species of the Skeena River estuary, as compiled from the available literature, can be found in Appendix 7.2.

7 (ii) THE FISHERIES RESOURCE

Several of the fish species of the Skeena area are

commercially and/or recreationally important, as well as providing a major food source for native peoples.

1. COMMERCIAL FISHING:

Commercial fishing for Skeena sockeye salmon began before the turn of the century. Due to overfishing, the stocks had declined substantially by the late 1920's and early 1930's. Although fishing effort increased over the next decade, the catch did not, and by the beginning of World War II, the effort level also declined (Shepard and Stevenson, 1956).

With the drastic landslide at Babine in 1951, sockeye salmon stocks declined once more. However, increased research and management undertaken by the federal Fisheries Service did much to restore this stock. Presently, 90% of the total Skeena sockeye spawners are supported by the Babine system, and the Skeena River system, as a whole, provides 8% (or 485,500 fish) of the total British Columbia sockeye catch annually (1951-1963) (Aro and Shepard, 1967; Larkin and McDonald, 1968).

The commercial sockeye fishery extends from mid-June to mid-August, with peak catches occurring during the last two weeks of July and the first week of August. The majority of the gillnet fishery occurs in the river mouth, in Inverness Passage, west of Smith Island, in Edge Passage, off Finlayson Island, and in Chatham Sound (Milne, 1955; Fish. Serv., unpubl. data). Since 1972, there has also been a three-week seine fishery of local waters (Fish. Serv., unpubl. data).

The greater portion of Skeena sockeye is canned. Inverness Cannery, the first cannery located on the Skeena, opened in 1877. By 1926, the number of establishments had jumped to fifteen. The number has since declined, with six presently in operation.

Commercial exploitation of pink salmon did not begin

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until around 1920. A marked slump occurred in catches in 1932, presumably the result of a severe drought in 1930 (Shepard and Stevenson, 1956). Presently, an annual average yield of 953,000 fish (1951-1963) is taken off the mouth of the Skeena during the odd-year cycle, and about the same quantity (707,000) is fished during the even-year cycle. Both runs begin in mid-July and peak in early August (Aro and Shepard, 1967).

Coho salmon are taken by net and troll, with peak catches occurring in late July and early August. The average annual catch (1951-1963) is 120,000 fish (Aro and Shepard, 1967). Until just recently, coho catches remained relatively constant. However, Fisheries Service data indicate a reduction in the stocks since 1970.

Chum fishing did not get under way until about 1920, and the stocks have varied considerably in abundance over the past forty years. Unlike sockeye or pink salmon, many chum salmon are frozen or kept fresh rather than being canned, and this has expanded the market for this species (Shepard and Stevenson, 1956). An average annual catch of 44,000 fish (1951-1963) indicates, however, that the Skeena is a poor supplier of chum salmon. Most of the fish are caught in late August by netting (Aro and Shepard, 1967; Fish. Serv., unpubl. data).

Like coho and chum, fishing for chinook salmon did not become well established until about 1920. Early records of catch are sparse, but Shepard and Stevenson (1956) indicated that landings of 2,500 to 4,000 lb. landed weight (1945-1954) was about the highest possible sustained yield. From 1951 to 1963, the commercial catch of Skeena chinook has annually averaged 38,000, more than one half having been taken by trolling. The fishing run lasts from late February or early March to late August, with peak catches occurring in mid-July (Aro and Shepard, 1967; Fish. Serv., unpubl. data).

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In 1969, the total salmon pack from Prince Rupert was 180,000 cases, out of 624,000 cases from the entire province. This represents an annual net catch of 4 to 8 million pounds, valued at about 4 million dollars (City of Prince Rupert, 1971).

Very little information could be found concerning the commercial fishing of steelhead. Shepard and Stevenson (1956) indicated that most of these fish are taken by gill nets, with the majority of the catch being taken from the Skeena River. Early catches averaged approximately 30,000 to 40,000 annually, while more recent landings are in the order of 10,000 to 12,000 annually (Shepard and Stevenson, 1956; Fish. Serv., unpubl. data).

As was mentioned in the General Discussion sub-section of this chapter, Butterworth-Warrior rocks is the main trawl fishing area in British Columbia, and has remained so for nearly thirty years. Between 1945 and 1955, these flats supplied 80% of the total Canadian catch of rock sole. The average annual groundfish catch (1945-1964) was 4.6 million pounds, the greater portion of which consisted of rock sole, English sole, and Pacific cod (Forrester and Thomson, 1969). By the late 1960's, the rock sole stocks had declined, the fishery now concentrating on Pacific cod (Smith, 1971). Although recent catches are down over those of the late 1960's, a total landing, in 1970, of 11.6 million lb., or 38% of the British Columbia trawl catch, would indicate that this area is still the most valuable of the provinces' trawling grounds.

Various Fisheries Research Board scientists have documented the trawl fishery from its beginning (around 1915) until the present day (Shepard and Stevenson, 1956; Thomson, 1965, 1967; Forrester and Holmberg, 1967; Ketchen, 1967b; Prest, 1968; Forrester and Prest, 1968; Forrester and Smith, 1969; Smith, 1971). It is obvious from these accounts that the trawl fishery has been unstable, shifting its emphasis from bank to bank and from species to species as stocks became depleted.

Unlike other groundfish, Prince Rupert's most important fishery, that of the Pacific halibut, has been maintained at a nearly constant level in recent years through the management of the International Pacific Halibut Commission. This group was established in the late 1920's or early 1930's to stabilize the halibut fishery, which first began in British Columbia in 1888 (Shepard and Stevenson, 1956).

Halibut fishing is mostly done by long-lining, although trolling is permitted and is often used by salmon fishermen when the salmon are not running. In 1969, Prince Rupert claimed over 19 million pounds landed at her port, approximately 2/3 of the total British Columbia landings. Most of these fish were shipped frozen to the east and south, and had a value of \$8,780,000 (City of Prince Rupert, 1971).

The smelt fishery varies with the species being considered, but in the Skeena area none is sufficient to support a fishery. Surf smelt, although fairly abundant in the Skeena estuary, are not taken commercially. On some beaches they may be dip-netted for personal use. The same is true for eulachon, although this species may have been netted, and salted or smoked, around the turn of the century. Capelin and long-finned smelt are probably also dip-netted for local use (Hart and McHugh, 1944).

The final species to be discussed under the topic of commercial fishing is the Pacific herring. Herring have been fished in British Columbia since 1877, but it was not until catch quotas were imposed on the Vancouver Island fishery in 1936, that the northern coast resources were utilized. It was learned in the 1940's that a wide variety of factors could influence the survival of herring larvae, and the amount of spawn and the extent of fishing has been highly variable over the years. However, recent figures for amount of spawn in Fisheries statistical area #4, which includes the Skeena estuary,

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(3.79 miles of spawn in 1974, as compared to the usual average of 18 miles since 1940) would seem to indicate that herring fishing in this zone is declining (Outram and Haegele, 1969; Fish. Serv., unpubl. data).

In 1969, the total fish catch at Prince Rupert was valued at nearly 13.5 million dollars (City of Prince Rupert, 1971).

Prior to the institution of fisheries management regulations, and during the peak of production, eighteen canneries were in operation in the Skeena estuary. Along Inverness Channel there were five - Inverness, North Pacific, Sunnyside, Cassiar, and Dominion, while the Oceanic Cannery was located on the outer side of Smith Island. On the banks of the Skeena, there were Aberdeen and Haysport on the north, Alexandria and Balmoral on the east shore of the Ecstall River, A.B.C. Packing Company, Skeena River Commercial Company and R. Cunningham and Son at Port Essington, and Carlisle, Claxton, and Standard canneries on the south shore. Humpback Bay Cannery operated on Porcher Island, while the Port Edward was located in Porpoise Harbour (Large, 1957).

Of all of these, only one has retained its original identity - Cassiar. All of those located on the Skeena itself were abandoned. Two companies now operate the remaining canneries. The Canadian Fishing Co. operates the Prince Rupert industry, while Port Edward, originally American owned, is now run by B.C. Packers Ltd. (Fish. Serv., unpubl. data). Not included in this list are the facilities of the Fisheries Co-operative at Prince Rupert.

In addition to the salmon canneries, there are six cold storage plants with a loading capacity of more than 30,000,000 pounds, and a daily freezing capacity of 500,000 pounds. They are able to produce over 200 tons of ice per day.

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As well, there are four reduction plants using herring and salmon offal to produce oil, meal, and fertilizer; smokehouses for salmon, sablefish and kippers; and filleting plants for sole, cod, and halibut (City of Prince Rupert, 1971).

The Prince Rupert fishing fleet, in 1973, was made up of about 748 vessels, of which 513 were gillnetters, 54 were seiners, 151 were salmon trollers, 10 were crab boats or shrimp trawlers, and 20 were halibut long-liners (Johnston Assoc. Mgmt. Ltd., 1975). At the height of the 1969 season, the industry employed nearly 5,000 people (City of Prince Rupert, 1971).

As was mentioned at the beginning of this chapter, and illustrated by the statistics above, the fishing industry is extremely important to the economy of the people living in the Prince Rupert area. A socio-economic survey by Sinclair and Boland (1973), of the federal Fisheries and Marine Service, serves to further illustrate this importance.

During 1970, 79% of the fishing vessels operating north of Cape Caution, including the Queen Charlotte Islands, were from the Prince Rupert area. Most of these vessels were owned by regional fishermen who spent at least 16 weeks fishing in 1970. Fishermen from the Prince Rupert area were found to have larger investments in their vessels, and earned higher incomes, than fishermen of other districts. When not fishing, many of these people supplemented their incomes by working in the many fish processing plants located in the Skeena River-Prince Rupert area.

A recent report by Johnston Associates Management Limited (1975) provides the best information available regarding the actual economic value of commercial fishing to the Prince Rupert region. The study discussed the industry under three main topics - commercial fishing (*per se*), fish processing, and fishing-dependent activities.

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As noted previously, 748 fishing vessels were used in the commercial fishery in 1973. By far, the majority were utilized in the fishing of salmon. An estimate of the average annual number of crew members employed on these boats was 1,423 (1971-1973). Since the actual time spent fishing in a year is relatively short, the researchers calculated that approximately 600 man-years of employment (in 1973) was generated by commercial fishing in the Prince Rupert area annually. In terms of monetary return, the study estimated a net income per fisherman of approximately \$6,047 per year, with an annual overall value for the fishing industry being about \$8.6 million, in 1973.

The fish processing industry employs many hundreds of people on a seasonal basis, the average annual number being 1,137 (1970-1973). The annual gross wages and salaries earned by these people averaged \$8,710,000 (1970-1973). This segment of the fishing industry will expand in the near future, with the construction of a new processing plant at Port Simpson and the completion of the rebuilt Oceanside Cannery, recently destroyed by fire.

The fishing industry supplies additional employment and income through its many service and supply companies. Estimates of indirect employment and indirect income created by fishing were set at 3,127 man-years and \$19,465,000, respectively.

It is obvious, therefore, that without the commercial fishing industry, the economy of Prince Rupert would be in trouble.

2. THE SPORT FISHERY:

The recreation of sport fishing is becoming increasingly popular as more and more people have greater amounts of leisure time. The increased interest in the sport in recent years is reflected in the ever-increasing numbers of people frequenting British Columbia's northern lakes and streams during

the summer and early fall. The tourist trade resulting from these vacationers is becoming an important part of the economy in such areas.

The Skeena River, with its dozens of lakes and tributary streams, is ideal for sport fishing. Abundant stocks of salmon, steelhead, and trout offer a variety of challenges to the recreational fisherman. A recent Fisheries and Marine Service report (Reid, 1974) serves to illustrate this point.

Reid divided his Skeena study area into two zones - the Morice-Bulkley valley region and the lower Skeena valley region. During 1972-1973, the Morice-Bulkley region attracted 5,366 party-days (defined as a day, or reasonable part of a day, stayed in the area by a group of people travelling in a single vehicle) in which sport fishing was identified (out of a possible 8,118 party-days). Of all such days spent in the region by non-residents, 46% were associated with sport fishing. As well, approximately 975 local anglers (or 14% of the local population) derived benefit from the sport fishery.

The Morice-Bulkley region supported an average effort of 24,419 angler-days (1972-1973), of which 45% were spent in steelhead fishing. Non-residents accounted for 31% of the total angling effort, and of the non-residents, 65% were Canadian. Most non-resident sport fishermen were either retired or employed in the technical-tradesman or professional categories. Most resident fishermen were classed as either technical-tradesmen or labourers.

During the summer, most sport fishermen were interested in fishing for salmon or steelhead, with trout fishing being slightly more important to non-Canadians. The Bulkley and Morice rivers were the two most popular rivers in the zone. Most salmon fishermen indicated that they would not have visited the area if sport fishing had not been available.

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In monetary terms, during 1972-1973, \$195,246 was spent by angler parties in the region, and \$159,904 of this was directly attributable to sport fishing. Non-resident expenditures on sport fishing provided an average of 13 full-time jobs during 1972-1973, while \$184,500 (annual revenue) was generated by businesses of the region as a result of the sport fishery. Overall, the present value of net benefits to the Morice-Bulkley valley residents from non-residents' participation in the sport fishery is \$476,245.

The lower Skeena valley region attracted over five times as many total party-days (27,117) during 1972-1973, as did the Morice-Bulkley zone. Of these, 15,898 days were identified as sport fish parties. About 41% of the non-resident visitors participated in the sport fishery, while 7,700 local anglers (19% of the population) derived direct benefit from the sport.

The streams and lakes of the lower Skeena supported an average effort of 147,980 angler days during 1972-1973, of which non-residents accounted for 13% of the effort. About 59% of the non-resident effort was provided by Canadians. Angler effort for salmon and trout rose by 44.7% (1972-1973), while the non-Canadian steelhead effort rose by 25% during the same period. Employment for non-residents and residents was the same as in the Morice-Bulkley region.

The majority of the participants were interested in shoreline river fishing for salmon. The Skeena and Kispiox rivers were the most used by non-residents, while residents preferred the Skeena and Lakelse system. For steelhead, non-resident Canadians favoured the Zymoetz River, while non-Canadians mainly utilized the Kispiox River.

Sport fish parties spent \$529,728 annually in the lower Skeena zone. Of this, \$412,361 was attributable to the sport fishery. Thirty-eight man years annually of employment

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was supplied by non-resident expenditures in 1972 and 1973. Annual business revenues of \$583,700 per year (1972, 1973) were generated by non-resident anglers. In total, the present value of net benefits from non-resident sport fishermen to residents of the lower Skeena valley is \$2.5 million.

By combining the net value of the two regions analyzed by Reid (1974), nearly three million dollars annually is added to the economy of the Skeena River basin by non-resident sport fishermen.

The recent report by Johnston Associates Management Limited (1974), mentioned in the previous sub-section on commercial fishing, included a discussion of sport fishing in the Prince Rupert area, and the following description of tidal fishing relies on this reference.

Tidal sport fishing in the Prince Rupert area takes place within a zone bounded by Dundas Island on the north, Porcher Island on the south, and Hecate Strait on the west. Fisheries Service statistics (in: Johnston Assoc. Mgmt. Ltd., 1975) indicate an average annual salmon sport fishing effort (1970-1973) for this zone of 1,555 boat days, or, converted to angler effort, of nearly 3,900 salmon angler days annually. Of these angler days, non-residents accounted for 390 and residents for 3,510, annually. Based on data found in Sinclair (1972), the researchers estimated that the total resident and non-resident tidal angling days equalled 4,060 and 465 fishing days, respectively, since 86.5% of resident sport fishermen fish for salmon, while for non-resident sport fishermen the comparable value is 83.8%. Therefore, the total number of angling days (residents and non-residents, salmon and other species) for the tidal fishery was estimated to be 4,525.

The above study placed a primary benefit value of approximately \$1.7 million on the entire resident salmon/steelhead

sport fishery of the Skeena drainage basin and estuary. In addition, a further \$138,370 was estimated as the average net value of the non-resident sport fishery of the region.

3. INDIAN FOOD FISHERY:

Very little information was found concerning the types and quantities of fish taken by the native peoples for food. Eulachon were heavily fished for their oil from the Nass River, long before the coming of the whiteman, and it can be assumed that this species was also taken from the Skeena. It is possible that local peoples also dip-netted the other three smelt species for food (Hart and McHugh, 1944).

Unpublished data provided by the Fisheries Service would indicate that salmon and steelhead form an important component of the native diet. Long-term average catches (1960-1973) for salmon are as follows: 45,659 sockeye; 3,841 coho; 5,697 pink; 5,332 chum; and 36,177 chinook. The comparable number for steelhead was 12,669. These averages reflect fish taken throughout the entire Skeena watershed and estuary by native peoples.

Using the average weights per fish included in the recent report by Johnston Associates Management Limited (1975) on cultural aspects of proposed port development sites (that is, 6 lbs./sockeye, 9 lbs./coho, 3 lbs./pink, 12 lbs./chum, 17 lbs./chinook, and 11 lbs./steelhead), the average annual landed weights by species, for the period 1960 to 1973, were 273,954 lbs. of sockeye; 34,569 lbs. of coho; 17,091 lbs. of pink; 63,984 lbs. of chum; 615,009 lbs. of chinook; and 139,359 lbs. of steelhead. This gives a total average catch of 1,143,966 lbs. of salmon and steelhead, annually.

It is difficult to estimate a price value for this fishery. The Johnston Associates Management Limited report (1975) used the price per pound for 1973 to calculate an

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approximate value for a 5-year fishing average. Applying these 1973 wholesale prices (that is, \$1.45 for sockeye, \$1.12 for coho, \$0.93 for pink, \$0.78 for chum, \$1.23 for chinook, and \$0.97 for steelhead), the average annual wholesale value for each species was as follows: \$397,233.30 for sockeye; \$38,717.28 for coho; \$15,894.63 for pink; \$49,907.52 for chum; \$756,461.07 for chinook; and \$135,168.23 for steelhead. This gives an average total of \$1,393,382.03, annually (at 1973 wholesale prices).

Although these figures are somewhat hypothetical, they do serve to indicate the importance of the native food fishery in the Skeena region.

8. FLORA

The floral communities of the Skeena estuary have yet to be described and/or mapped, and, therefore, the following discussion relies on the meagre information contained in general studies of the area, most of which were done in relation to industrial development of the Prince Rupert vicinity. Since no data were found concerning the marine phytoplankton or marsh vegetation of the estuary, the discussion will be limited to freshwater phytoplankton, benthic algae, vascular aquatic plants, and terrestrial vegetation.

As was noted in the reports on the Fraser River estuary (Hoos and Packman, 1974) and the Squamish River estuary (Hoos and Vold, 1975), the flora of an area plays several vital roles in the ecosystem. Plants supply the initial energy for all levels of the food hierarchy. In addition, they provide protected spawning and rearing areas for fish and invertebrate life, and nesting and resting locations for wildlife. When one considers these facts, it becomes obvious that it is absolutely necessary to do detailed analyses of the floral communities of the Skeena estuary area, or any area for that matter, before sound decisions regarding its industrial development can be made.

8 (i) AQUATIC VEGETATION

1. FRESHWATER PHYTOPLANKTON:

The most detailed account of freshwater phytoplankton for the Skeena drainage basin is a report by Stockner and Shortreed (1974) on the primary production and species succession in the Babine system. Six different sampling areas were studied, the general findings including the following information.

The spring diatom bloom was dominated by *Rhizosolenia*

longiseta, with *Cyclotella stelligera* being a close second. Populations of *Melosira italica* and *Asterionella formosa* also peaked in June, but to a lesser magnitude than the two former species. A fall bloom did not occur in all parts of the system, but when it did *Tabellaria fenestrata* was usually responsible, along with some increases in *Fragilaria* spp.

Following the diatom bloom, flagellated Chrysophytes (particularly *Ankistrodesmus* sp., *Cryptomonas* sp., and *Chromulina* sp.) tended to increase. The only blue-green algae found in significant numbers were *Oscillatoria* sp. and *Chroococcus* sp., although *Anabaena* sp. attained lesser prominence later in the season. A complete list of the phytoplankton species found is included in Appendix 8.1.

In general, primary production followed the normal pattern of a spring peak, a second smaller increase in late June, a summer decline, and (at southern stations) an autumn peak. Also, all primary production parameters indicated greater production in the southern part of the lake than in the north. The reason for this was hypothesized to be related to lake physics and surface flow disparity.

Hallam *et al.* (1975), during their study of possible mining pollution in Cronin Creek, recorded several algal species from rock-scraping samples, the most common being *Diatoma* sp., *Synedra* sp. and *Hannaea arcus*.

A list of the freshwater phytoplankton of the Skeena drainage system can be found in Appendix 8.1.

2. BENTHIC ALGAE:

Greenius (1973), in a study of the status of the seaweed industry in British Columbia, noted the presence of fairly extensive kelp beds (*Macrocystis* and *Nereocystis*) in

various bays on the islands just off the mouth of the Skeena, particularly those of Porcher Island. Various parts of the coasts of these islands and the mainland are licensed for seaweed harvesting, but how extensive or important the industry is to the area was not known.

F.F. Slaney and Company Limited (1973) was contracted by the Department of the Environment to do a preliminary environmental effect assessment of the various sites being proposed for port development in the Skeena area. Included in their report were some notes on the intertidal algae found at the various locations.

On Ridley Island it was found that the algae of the rocky intertidal zone were seriously affected by the heated spent sulphite liquor being discharged into a small cove. The cove itself was completely devoid of benthic algae. As distance from the outfall increased, species of *Enteromorpha* were found. *Fucus*, usually abundant on British Columbia coasts, was sparse, and those plants that were found were generally stunted and weak. Density and vigor of the plants increased with distance from the effluent discharge point (F.F. Slaney, *et al.*, 1973).

Kitson Island had a better algal population. Though *Enteromorpha* was not a prominent member of the community, *Fucus* populations were well developed in the upper-middle intertidal zone. Various red algal species were found below this *Fucus* line (F.F. Slaney, *et al.*, 1973).

One of the most recent, and most detailed, studies of intertidal algae of the proposed and existing industrial sites of the Prince Rupert area is that by Drinnan (1974), done for the British Columbia Pollution Control Branch as part of a provincial interagency program. Drinnan attempted to classify the species found into three categories, depending on their ability to withstand pollution stress. These categories were pollution-

sensitive, moderately pollution-tolerant, and very pollution-tolerant.

A total of fifty-eight algal species were collected in the survey. In general, there was an inverse relationship between the degree of pollution at a site and the number of algal species present. Red and brown algae were more often found at unpolluted or only slightly polluted locations, while green species were more common in moderately polluted or polluted areas.

Thirty-seven of the total number of species were recorded at five or fewer stations, and were, therefore, considered "rare". The majority of these rare forms were red species, and most were found at unpolluted sites. Several of the rare species were considered to be pollution indicators due to their sensitivity, including the red species *Callithamnion* sp. (*C. bisporum* or *C. biseriatum*), *Callithamnion pikeanum*, *Halosaccion gladiforme*, *Ptilota tenuis*, and *Porphyra miniata*, and the green alga *Rhizoclonium riparium*. Also, four green species were considered pollution-tolerant. These were *Enteromorpha clathrata* var. *crinata*, *E. compressa*, *Monstroma fuscum*, and *Prasiola meridionalis*.

The remaining twenty-one algal species occurred at more than five sites. Of these, the following species were considered pollution-sensitive: *Rhodoglossum roseum*, *Dilsea californica*, *Cryptosiphonia woodii*, *Pterosiphonia bipinnata*, *Rhodomenia palmata*, and *Phycodrys setchellii*, all of which are red algae; and *Alaria marginata* and *Laminaria groelandica*, which are brown species.

Moderately tolerant species included the greens *Spongomorpha saxatilis* and *Ulva* spp., and the red *Polysiphonia* spp.

The most pollution-tolerant species were the green algae *Enteromorpha* spp. (6 species), *E. intestinalis*, and *E.i.* var. *cylindracea*; the red algae *Rhodomela larix* and *Gigartina papillata*; and the brown alga *Fucus distichus*.

Water quality data collected at the same stations as those sampled for algae indicated that locations supporting few algal species were, in general, high in colour, spent sulphite liquor, and turbidity, and low in nutrients and dissolved oxygen. It would seem, therefore, that pollution from the pulp mill was restricting algal growth.

Areas affected by pollution (mostly organic matter and silt) from fish processing plants also had less abundant and less vigorous algal populations due to smothering by debris. This effect was, however, quite localized.

Of the areas sampled, Chatham Sound, Prince Rupert Harbour (except for the town waterfront), the northern portion of Morse Basin, and the southern end of Porpoise Harbour all had diverse and abundant algal populations. In general, the community consisted of many red algal species, particularly filamentous and branching types, including *Callithamnion* spp., *Cryptosiphonia woodii*, *Dilsea californica*, *Rhodoglossum roseum*, and *Phycodrys setchellii*, and the large brown species *Laminaria groelandica* and *Alaria marginata*. As the actual Skeena delta is not industrialized, it is very likely that this algal community is also found in the estuary itself.

A recent report by Lee Doran Associates Ltd. (1975), on aquatic environments at possible port development sites, included a note on the benthic algae of some locations. They found *Ulva* sp., *Endocladia muricata*, *Gigartina* sp., and *Fucus gardneri* to be the most abundant species at all sites analyzed. The red coralline alga *Lithothamnion* sp. was a predominate member of Port Simpson lower intertidal flora, while kelp beds (*Nereocystis*

lutkeana) grew in the outer harbour area.

A complete list of the benthic algae compiled from the available literature can be found in Appendix 8.1.

3. VASCULAR AQUATIC VEGETATION:

The only vascular aquatic plants in the estuary, noted in the literature surveyed, were eelgrass (*Zostera marina*) and surf grass (*Phyllospadix scouleri*).

A Fisheries Service study (1972) indicated that Flora Bank supported between 50 and 60 percent of the total eelgrass of the Skeena estuary. Figure 8.1 shows a diagrammatic representation of the distribution of these eelgrass beds on the bank.

Flora Bank was included in one of the sites for possible port development by B.C. Rail, and was slated to be dredged and filled to form a causeway for truck and train transport to and from Kitson Island (Swan Wooster, 1974). This would have led to the complete destruction of what the initial, cursory Fisheries report (1972) and a later, more detailed Fisheries Service study (Higgins and Schouwenburg, 1973) indicated to be a vital fish-rearing area. Other important eelgrass beds occur on the sand flats at Duncan Bay, Big Bay, Venn Passage and Stumaun Bay (Lee Doran Assoc. Ltd., 1975). These areas have also been proposed as possible sites for port development.

Eelgrass is important in estuary food webs in several ways, including its primary productivity, its epiphytes, its associated micro and macro-invertebrate faunas, and its conversion to detritus. As well, in this case, it provides shelter for extensive Skeena juvenile fish populations.

Surf grass, closely related to eelgrass and filling

107. FLORA

LEGEND



Eelgrass



Flora Bank boundary

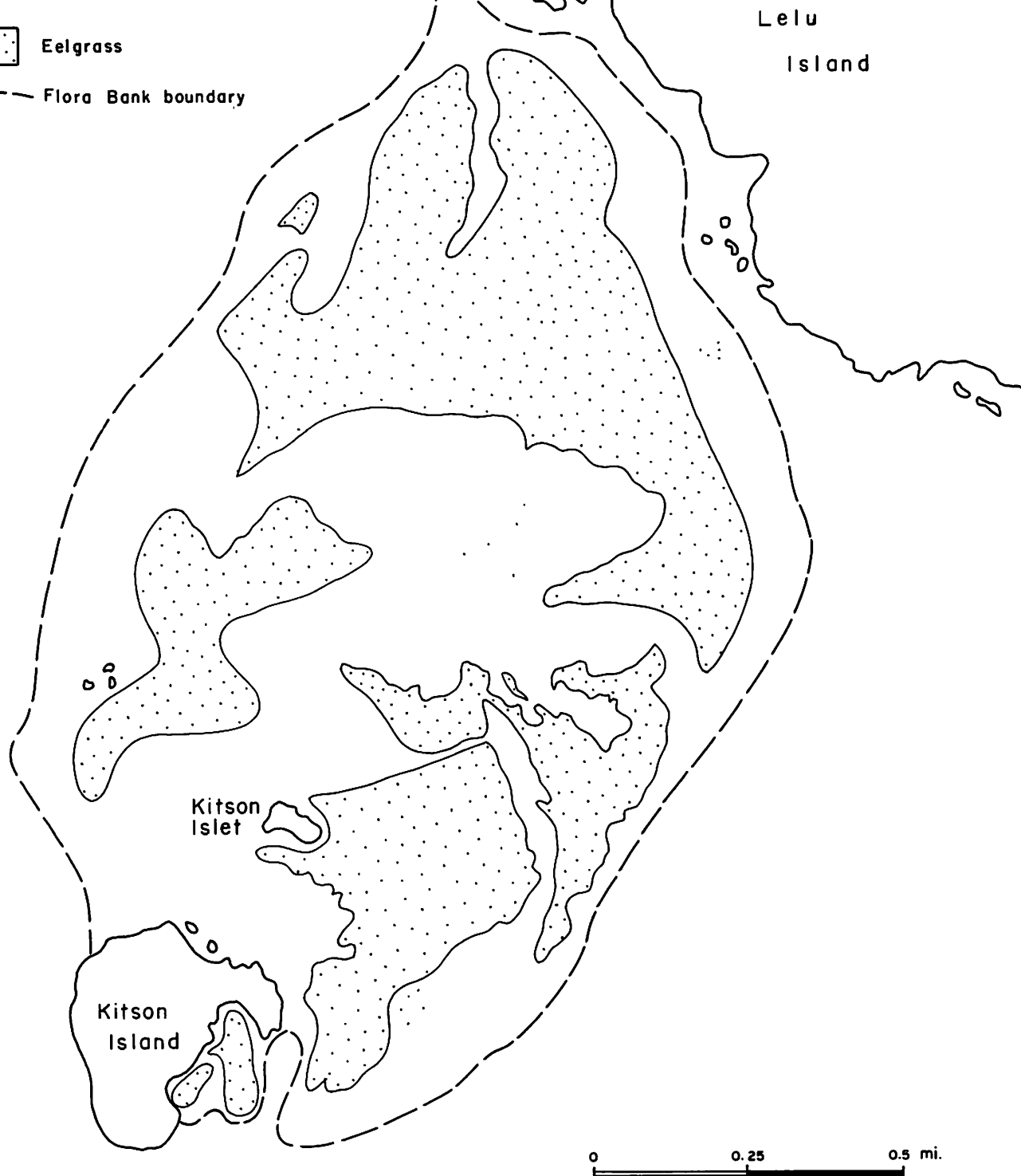


FIGURE 8.1. Flora Bank eelgrass distribution
July 25, 1971.
(from Fisheries Service, 1972).

the same ecological role, was noted in low density patches in various parts of inner Prince Rupert Harbour by researchers analyzing aquatic environments of various proposed port development sites (Lee Doran Assoc. Ltd., 1975).

It was indicated by Brett and Pritchard (1946) that stands of horsetails (*Equisetum* sp.), cat-tails (*Typha latifolia*), bulrushes (*Scirpus* spp.), sedges (*Carex* spp.), wild rice and water lillies (*Nuphar polysepalum*) were abundant in shallow bays of Lakelse Lake, and that such areas were utilized by migratory waterfowl and juvenile fish. The same was found to be the case at Kitwanga Lake (McConnell and Brett, 1946) and, more recently, at Neaxtoalk Lake on the Tsimpsean peninsula (Lee Doran Assoc. Ltd., 1975). Pond weed (*Potamogeton* sp.) was abundant in parts of Swan and Stephens lakes (Withler, 1948). Other species commonly found in such environments include yellow water lily (*Nuphar polysepalum*), bur reed (*Sparganium* spp.), bog bean (*Menyanthes trifoliata*), manna grass (*Glyceria occidentalis*), cotton grass (*Eriophorum angustifolium*), waterstar (*Callitriche* spp.), coontail (*Myriophyllum spicatum*), aquatic buttercup (*Ranunculus aquatilis*), and bladderwort (*Utricularia* spp.) (Tera Environ. Resource Analysts, 1975).

The floral species list found in Appendix 8.1 includes the above species, as well as other aquatic plants probably associated with them.

8 (ii) TERRESTRIAL VEGETATION

The Skeena River estuary lies within the coastal western hemlock biogeoclimatic zone (Krajina, 1965). The characteristic tree species are western hemlock (*Tsuga heterophylla*) and western red cedar (*Thuja plicata*). Minor species are yellow cedar (*Chamaecyparis nootkatensis*), lodgepole pine (*Pinus contorta*), and sitka spruce (*Picea sitchensis*). Other common

community members are amabilis fir (*Abies amabilis*), Douglas fir (*Pseudotsuga menziessi*), salmon berry (*Rubus spectabilis*), and salal (*Gaultheria shallon*) (Hancock and Stirling, 1973).

F.F. Slaney's report (1973), regarding possible sites for port development, included brief descriptions of the vegetative cover at each location. Four local vegetation zones were distinguished. On undisturbed, well-to-imperfectly drained sites with podzolic and/or folisolic soils, the normal forest of western hemlock and western red cedar occurred. The understory here consisted of salal (*Gaultheria shallon*), blackberry (*Rubus* spp.), and huckleberry (*Vaccinium* spp.).

Where the original vegetation had been disturbed, but the drainage and soils were the same as those above, red alder (*Alnus rubra*) predominated.

The third zone was that of the bog, characterized by stunted lodgepole pine, low-growing shrubs of red cedar, yellow cedar and juniper (*Juniperus* sp.), labrador tea (*Ledum groenlandicum*), huckleberry, and a ground cover of mosses, lichens, and mushrooms (*Lycopodium* spp.). Such an assemblage was found where deep organic soils (mesic fibrisols) were very poorly drained.

The final zone was considered a transition between the first and the third, and consisted of small western red cedar and western hemlock, medium-sized lodgepole pine, and an understory of salal, huckleberry, and labrador tea. The ground cover was of mosses and lichens. Such communities occurred on medium-depth organic soils (lithic fibrisols and mesic fibrisols) which were poorly drained.

A map of the study area indicated that Ridley, Lelu, and Kitson islands had well developed zone 1 forests (western hemlock and western red cedar) along their entire coastlines.

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As most of the shores of these islands are rocky, there is none of the marsh vegetation which has been so prominent in previous estuaries of this report series (Hoos and Packman, 1974; Hoos and Vold, 1975). Inland of these zone 1 forests, on the two larger islands (Ridley and Lelu), was found a western red cedar/western hemlock/lodgepole pine community (zone 4). Ridley, the largest of the three islands, was also the site of a sizeable bog assemblage (zone 3) (see Figure 8.2) (F.F. Slaney, *et al.*, 1973).

More detailed descriptions of the individual port sites were also given (F.F. Slaney, *et al.*, 1973). All four vegetation zones were found on Ridley Island. The western hemlock/western red cedar (zone 1) and red alder (zone 2) communities were located along the steep, well drained slopes of the island's outer perimeter. Most of the trees, except the red alder, were considered "over mature", being over 250 years old. Heights ranged from 66 to 95 feet, and stocking was rated at more than 30 trees per acre.

A transition zone (zone 4) was found on the better-drained parts of the wet interior of the island. Trees ranged from 5 to 50 feet in height.

A typical *Sphagnum* bog (zone 3), with its associated lodgepole pine, was found on the wettest parts of the island's interior.

The only type of forest found on Kitson Island was zone 1, or western hemlock/western red cedar. Trees were described as "over mature" (over 250 years old), stood 66 to 95 feet high, and were stocked at over 31 trees per acre.

Sparse notes on terrestrial vegetation were included in various reports on Skeena drainage basin lakes which were published in the 1940's. Shorelines of lakes located in

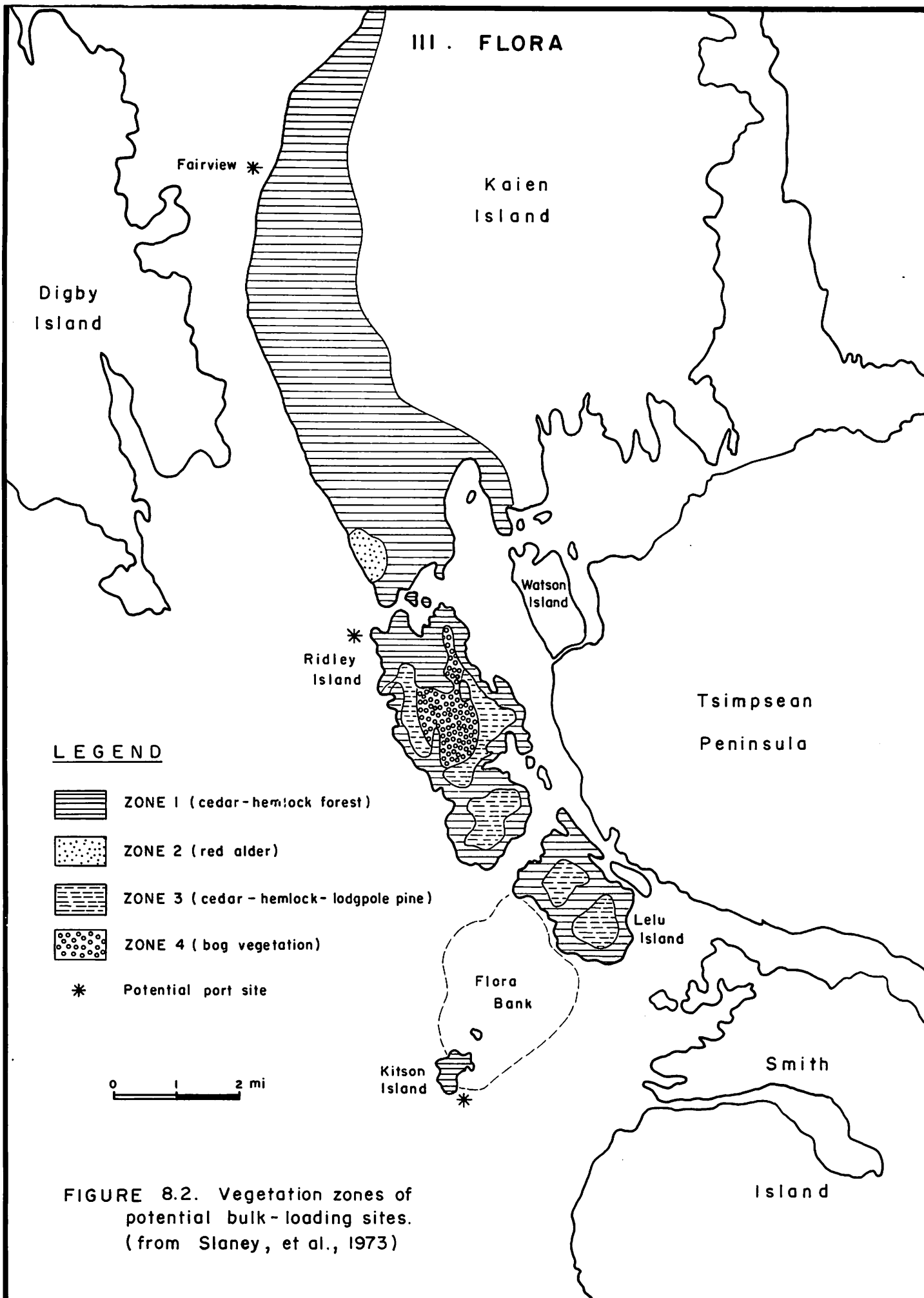


FIGURE 8.2. Vegetation zones of potential bulk-loading sites.
(from Slaney, et al., 1973)

mountainous terrain were characterized by stands of spruce (*Picea* sp.), jack pine (*Pinus* sp.), and hemlock (*Tsuga heterophylla*), with an underlying blanket of moss. Other areas graded from pine forest into willow (*Salix* sp.) and alder (*Alnus* sp.) flats, with an understory of Devil's club (*Oplopanax horridus*) and blueberry bushes (*Vaccinium scopium*) (Foskett, 1947a, 1947b; Withler, 1948; Withler, McConnell, and McMahon, 1949).

Detailed discussions of the coastal western hemlock zone in general can be found in Lesko (1961), Orloci (1961, 1964), and Krajina (1965). A recent report by Tera Environment Resource Analysts (1975) used these basic references to describe a variety of plant communities occurring, or probably occurring, in the Skeena drainage basin and/or estuary. Although most of these communities are only hypothesized as occurring in the region, it is highly probable that when the actual plant populations are finally described, the hypothetical communities will be found to actually exist.

Coastal forests of the Skeena region are composed of western hemlock, sitka spruce, red cedar, red alder (*Alnus rubra*), mountain hemlock (*Tsuga mertensiana*), Pacific silver fir (*Abies lasiocarpa*), and yellow cedar. Common shrubs associated with these trees include blueberry (*Vaccinium* spp.), false azalea (*Menziesia ferruginea*), salal, and red huckleberry (*Vaccinium parvifolium*), while various ferns and forbs, such as false lily-of-the-valley (*Maiantheomum dilatatum*), foam flower (*Tiarella trifoliata*), dwarf dogwood (*Cornus canadensis*), and twayblade orchid (*Listera* spp.) form the understory. Other common plants found when the forest is in an exposed coastal location are red elderberry (*Vaccinium* spp.), salmonberry (*Rubus spectabilis*), Nootka bluejoint (*Calamagrostis nutkaensis*) and licorice fern (*Polypodium glycyrrhiza*).

Slightly different forest vegetation occurs on the floodplains and terraces of the Skeena and its tributaries. Tree

species include sitka spruce, western hemlock, red alder, red cedar, and western crabapple (*Pyrus fusca*). Typical shrubs are blue currant (*Ribes bracteosum*), red elderberry, devil's club (*Oplopanax horridum*), false azalea, and salmonberry; while the dominant understory species are sweet cicely (*Osmorhiza purpurea*), enchanter's nightshade (*Circaea alpina*), skunk cabbage (*Lysichitum americanum*), false lily-of-the valley, yellow violet (*Viola glabella*), buttercup (*Ranunculus* spp.), and twisted stalk (*Streptopus* spp.).

Where timber has been logged or burned-over, a succession forest of red alder, sitka alder (*Alnus sinuata*), western hemlock, red cedar, sitka spruce, mountain ash (*Sorbus sitchensis*), salal, red elderberry, blueberry, oak fern (*Gymnocarpium dryopteris*), fireweed (*Epilobium* spp.), trailing bramble (*Rubus ursinus*), chickweed (*Cerastium vulgatum*), madder (*Galium triflorum*), and various grasses re-vegetates the area.

Often a narrow fringe of shrub-dominated vegetation is found between the foreshore and the coastal forest, particularly in sheltered regions and near stream mouths. Typical species include false azalea, salal, red huckleberry, western crabapple, red alder, sitka alder, salmonberry, thimbleberry (*Rubus parviflorus*), blueberry, black twinberry (*Lonicera involucrata*), blue currant, red elderberry, sitka mountain ash (*Sorbus sitchensis*), and devil's club. Associated understory plants are false lily-of-the-valley, beach lovage (*Ligustichum scoticum*), hemlock-parsley (*Conioselinum pacificum*), sea-watch (*Angelica lucida*), Nootka bluejoint, giant vetch (*Vicia gigantea*), yarrow (*Achillea millefolium*), limegrass (*Elymus mollis*), buttercup, chocolate lily (*Fritillaria camschateensis*), holygrass (*Hierochloa odorata*), sea barley (*Hordeum brachyantherum*), hairgrass (*Deschampsia caespitosa*), aster (*Aster subspicatus*), yellow paintbrush (*Castilleja unalaschoensis*), skunk cabbage, red fescue (*Festuca rubra*), and bentgrass (*Agrostis* spp.).

(*Spergularia marina*), pearlwort (*Sagina maxima*), pickleweed (*Salicornia pacifica*), orache, and sea arrowgrass (*Triglochin maritimum*) are common. Still further up the shore, one finds the hairgrass-sedge zone, composed of hairgrass, Lyngbye's sedge (*Carex lyngbyei*), red fescue, bentgrass, sea barley, and Baltic rush (*Juncus balticus*). Finally, just before entering the forest, a plant community of grass-forb meadow may be encountered. Typical species include limegrass, Nootka bluejoint, hairgrass, bluegrass (*Poa* spp.), holygrass, Pacific brome (*Bromus pacificus*), Lyngbye's sedge, chocolate lily, bedstraw (*Galium trifidum*), yarrow, silverweed cinquefoil (*Potentilla pacifica*), yellow paintbrush, hemlock-parsley, beach lovage, sea-watch, aster, and Pacific clover (*Trifolium wormskjoldii*).

Sand beaches are very uncommon in the Skeena estuary area and, therefore, the plant communities associated with them will not be discussed here. The same is true for highly-saline marshes. The reader is referred to the Tera report (1975) for details concerning these community types.

Rocky bluffs and headlands over-looking the sea usually have a sparse vegetation of salt-resistant species such as sea plantain, wooly cinquefoil (*Potentilla villosa*), scurvy grass, pearlwort, sea purslane, hemlock-parsley, beach lovage, rusty saxifrage (*Saxifraga ferruginea*), madder, yarrow, hairy rockcress (*Arabis hirsuta*), sea mustard (*Draba hyperborea*), strawberry (*Fragaria chiloensis*), chocolate lily, yellow paintbrush, sea-watch, red fescue, sea barley, limegrass, alkaligrass (*Puccinellia* spp.), and hairgrass. Similar species, with the additions of red stonecrop (*Sedum roseum*) and false lily-of-the-valley, inhabit rocky islets which support bird rookeries. Such plants are nitrogen-tolerant, as well as salt-tolerant.

Any marshes located in the Skeena estuary would have low-salinity waters as a result of the freshwater influx from the river. The Tera report (1975) indicates that such marshes

Large areas of the terrain in the Skeena region are covered in muskeg. The vegetation of these bogs is highly specialized to the unique soil and water conditions found there. The trees are usually stunted and contorted, the common species being shore or lodgepole pine, yellow cedar, western hemlock, and red cedar. Shrubs include labrador tea, bog laurel (*Kalmia polifolia*), bog rosemary (*Andromeda polifolia*), bog cranberry (*Vaccinium oxycoccus*), dwarf azalea (*Loiseluria procumbens*), bog blueberry, lingonberry (*Vaccinium vitis-idaea*), sweet gale (*Myrica gale*), crowberry (*Empetrum nigrum*), spreading juniper (*Juniperus communis*), and yew (*Taxus brevifolia*). Characteristic forb species are cloudberry (*Rubus chamaemorus*), sundew (*Drosera rotundifolia*), burnet (*Sanguisorba officinalis*), goldthread (*Coptis trifolia*), white gentian (*Gentiana douglasiana*), star-flower (*Trientalis arctica*), skunk cabbage, and deer cabbage (*Fauria crista-galli*); while other common associated forms include sedges (*Carex* spp.), cotton grass (*Eriophorum angustifolium*), white beakrush (*Rhynchospora alba*), tufted clubrush (*Scirpus caespitosus*), and slender bentgrass (*Agrostis aequivalvis*). *Sphagnum* moss forms the floor of muskeg regions.

The beaches of the Skeena estuary, where they exist, are usually composed of shingle and are exposed to heavy wave action. Isolated patches of scurvy grass (*Cochlearia officinalis*), sea purslane (*Honkenya peploides*), orache (*Atriplex patula*), and sea rocket (*Cakile edentula*) may be found on the lower beach, while further up a community consisting of salal, limegrass, Nootka bluejoint, beach lovage, hemlock-parsley, sea watch, chocolate lily, and giant vetch might occur.

Sheltered shingle beaches have their vegetation divided into four or five distinct zones. In the subtidal to lower intertidal regions one finds eelgrass and submerged aquatics. The mid-intertidal areas are characterized by benthic algae. Above these zones, in regions inundated only at high tide, species such as scurvy grass, seablite (*Suaeda maritima*), sea spurry

can be found on the delta's of the McNeil and Khyex rivers and the flats along De Horsey Passage. Three vegetation zones are apparent in these marshes. The soft muds of the lower river flats are partially covered with waterstar and widgeon grass (*Ruppia maritima*). Other plants found here include flowering quillwort (*Lilaea scilloides*), mudwort (*Limosella aquatica*), water plantain (*Alisma plantago-aquatica*), wapato (*Sagittaria latifolia*), bur reed, spike rush (*Eleocharis* spp.), and buttercup. Above this zone, one finds the sedge-water hemlock marsh. Typical species of this zone are slough sedge (*Carex obnupta*), water hemlock (*Cicuta douglasii*), bulrush (*Scirpus validus*), water parsnip (*Sium suave*), bentgrass, Baltic rush, sea-watch, silverweed cinquefoil, deer cabbage, speedwell (*Veronica americana*), and horsetail (*Equisetum arvense*). Finally, fringing the forest is a shrub-forb zone composed of sitka willow (*Salix sitchensis*), peachleaf willow (*S. lasiandra*), Scouler's willow (*S. scouleriana*), red alder, western crabapple, red huckleberry, skunk cabbage, false lily-of-the-valley, slough sedge, small-fruited bulrush (*Scirpus microcarpus*), hairgrass, horsetail, Canada bluejoint (*Calamagrostis canadensis*), sea-watch, beach lovage, chocolate lily, giant vetch, aster, and water parsley (*Oenanthe sarmentosa*).

The final community described in the Tera report (1975) is montane vegetation, that is, the plant assemblage found at higher elevations in the region. Dominant species are mountain hemlock, Pacific silver fir, and yellow cedar. Shrub thickets of blueberry, false azalea, copperbush (*Cladothamnus pyrolaeiflorus*), and sitka mountain ash are common.

The reader is referred to Appendix 8.1 for a complete list of floral species of the Skeena region, as compiled from the available literature.

9. WILDLIFE

Extremely little information exists on the vertebrate faunas of the Skeena estuary. Virtually nothing was found dealing with the amphibians and reptiles of the area, while avian and mammalian records were very sparse.

Species lists can be generated from general publications, such as those by Brooks and Swarth (1925), Munro and Cowan (1947), Drent and Guiguet (1961), Guiguet (1958; 1960a,b; 1962; 1967a,b; 1970; 1971; 1973), Cowan and Guiguet (1965), Carl (1966), and Carl and Guiguet (1958), and these appear in Appendix 9.1. Species lists, however, are of little value when attempting to assess the effects of development of the estuary on the wildlife inhabiting the area. For this purpose, it is necessary to have life history, distribution, feeding, and breeding data which have been gathered from the exact location under study. Since this information is not available for the Skeena estuary and environs, researchers have had to extrapolate from known general patterns and supplement this information with data from local persons and quick field notes. Two recent reports which relied on this method of gathering wildlife information will be used extensively for this chapter, but the reader is reminded of the limitations imposed on the data cited. The two studies are by F.F. Slaney and Company (1973), on the environmental effects of proposed port development, and by Tera Environment Resource Analysts (1975), regarding terrestrial habitats of proposed port development sites.

9 (i) WATERFOWL

Approximately thirty species of waterfowl are listed as occurring in the Skeena area. Of these, only three commonly breed here, and eleven others use the area during migrations and

for over-wintering. Breeding is limited by the rugged topography. Most shorelines are rocky, and there are very few marshes in which birds can find protected nesting sites. As well, unstable water conditions, such as occur during the spring freshet, often result in the flooding of suitable nesting sites. The Canada Land Inventory rates most of the area as having negligible or non-existent waterfowl production potential. Some marsh areas are found on Lakelse and Kitwanga lakes, and these are used by migratory birds to some degree (Brett and Pritchard, 1946; McConnell and Brett, 1946).

However, fairly abundant resting and over-wintering sites are found in the form of extensive sand and mud flats at the mouth of the Skeena. These areas are excellent diving duck feeding and resting sites, since the waters are generally shallow, and invertebrates, therefore, are accessible.

The three waterfowl that do breed on the estuary, nesting in the coastal muskeg and lower estuary and freshwater marshes, are the Canada goose (*Branta canadensis*), the mallard duck (*Anas platyrhynchos*), and the common merganser (*Mergus merganser*). Harlequin ducks (*Histrionicus histrionicus*), snow geese (*Chen caerulescens*), pintail (*Anas acuta*), greater scaup (*Aythya marila*), common goldeneye (*Bucephala clangula*), Barrow's goldeneye (*B. islandica*), bufflehead (*B. albeola*), oldsquaw (*Clangula hyemalis*), red-breasted mergansers (*Mergus serrator*), white-winged scoters (*Melanitta deglandi*), and surf scoters (*M. perspicillata*) are common spring and/or fall migrants and/or winter residents.

In addition, Canadian Wildlife Service records indicate that trumpeter swans (*Olor buccinator*) are common migrants in the Lakelse Lake region, and may be nesting just north of Terrace, B.C. (D. Trethewey, pers. comm.).

The remaining waterfowl species recorded from the

Skeena area are mostly visitants which are seen only rarely during their migrations up and down the coast. One is referred to Appendix 9.1 for a list of these birds.

9 (ii) MARSHBIRDS AND SHOREBIRDS

Only two members of this group reportedly nest on the estuary. The spotted sandpiper (*Actitis macularia*) commonly breeds on the estuary, while the sandhill crane (*Grus canadensis*) sparingly nests in muskeg regions of the Skeena River mouth islands. Black turnstones (*Arenaria melanocephala*), rock sandpipers (*Calidris ptilocnemis*) and dunlin (*C. alpina*) commonly over-winter in the area. Other shorebird species recorded from the Skeena area as migrant and/or winter visitants are listed in Appendix 9.1.

Shorebirds are usually found along beaches or exposed sand and mud flats, where they forage for food. The extensive delta flats off the Skeena River mouth would seem to be ideal habitats for these species, and it is possible that their lack of occurrence there is due more to a lack of records than anything else.

9 (iii) GULLS

The common resident gull species is the glaucous-winged gull (*Larus glaucescens*). Glaucous (*L. hyperboreus*), herring (*L. argentatus*), mew (*L. canus*), and Bonaparte's (*L. philadelphia*) gulls are migrant or over-wintering species. Various gull nesting sites exist close to the Skeena delta - on Green Island, Inez Island, unnamed islets near Triple Island, and Lucy Island. Gulls feed and roost in several estuary areas, particularly in the vicinity of the fish packing plants.

9 (iv) OTHER WATER BIRDS

Loons and grebes, which nest in freshwater habitats, move to marine areas to over-winter. Those recorded as doing so, in the Skeena area, include the common loon (*Gavia immer*), the arctic loon (*G. arctica*), the red-throated loon (*G. stellata*), the red-necked grebe (*Podiceps grisegna*), and the horned grebe (*P. auritus*).

About twelve pairs of pelagic cormorants (*Phalacrocorax pelagicus*) breed approximately twenty miles from the Skeena delta, on an unnamed islet near Triple Island. It is the most common cormorant seen in the area, while the double-crested species (*P. auritus*) is recorded periodically during the winter.

Other common estuary residents are the pigeon guillemot (*Cepphus columba*) and the marbled murrelet (*Brachyramphus marmoratum*). Rhinoceros auklets (*Cerorhinca monocerata*) are known to breed on Lucy Island with the glaucous-winged gulls, while Cassin's auklets (*Ptychoramphus aleuticus*) are infrequent summer residents. As well, common murrelets (*Uria aalge*) often over-winter on the delta, being replaced in the summer (although not frequently) by ancient murrelets (*Synthliboramphus antiquus*).

Species known to frequent the delta less often than those noted here are listed in Appendix 9.1.

9 (v) RAPTORIAL BIRDS

Three raptorial birds are known to inhabit the Skeena estuary. Relatively rare are ospreys (*Pandion haliaetus*) and peregrine falcons (*Falco peregrinus*), which are only sighted occasionally along the shoreline.

A very common resident, however, is the bald eagle

(*Haliaeetus leucocephalus*). Wintering eagles have been observed feeding on spawning herring and eulachon, and as many as 200 have been recorded within one mile of Skeena shoreline during the eulachon run. The tall trees of the western hemlock/western red cedar forests, which cover the islands and mainland shore, as well as the terrain inland, offer abundant roosting and nesting sites for these impressive birds.

Further inland, various owls frequent the marshy areas surrounding some of the Skeena lakes (Withler, 1948).

9 (vi) OTHER BIRD SPECIES

Porcher Island and the other small islands lying off the mouth of the Skeena were reported to support sizeable populations of ruffed grouse (*Bonasa umbellus*) and willow ptarmigan (*Lagopus lagopus*) earlier in the century (Skeena Land Recording Division, 1920). Blue grouse (*Dendragapus obscurus*) are reportedly associated with the margins of forests and muskeg areas of the study region (Tera Environ. Resource Analysts, 1975). These are the only records found concerning terrestrial game birds in the Skeena area.

Hancock and Stirling (1973) indicate that the red-breasted sapsucker (*Sphyrapicus varius ruber*), Steller's jay (*Cyanocitta stelleri*), chestnut-backed chickadee (*Parus rufescens*), varied thrush (*Ixoreus naevius*), and Townsend's warbler (*Dendroica townsendi*) are characteristic terrestrial species of the western hemlock/western red cedar forests covering the terrain of the Skeena area. Also, ravens (*Corvus corax*) have been noted in the lake areas of the drainage basin (Withler, 1948). These were the only references found which dealt with the terrestrial birdlife, other than very general distribution papers. Such documents were used to compile a species list of birds probably occurring on the delta and in the

lower drainage basin of the Skeena River (see Appendix 9.1).

9 (vii) MAMMALS

Information concerning mammals of the Skeena area is more scarce than that of the birds, and, therefore, one must rely even more heavily on extrapolated data from general publications.

A Skeena Land Recording Division report, published in 1920, noted the presence of abundant deer on Porcher and other small islands at the mouth of the Skeena, while O'Neill (1960) mentioned bears in his historical notes of early days on the river. No species names were included in these documentations.

Williams (1935) published a book on fish and game in British Columbia, including descriptions of areas considered good for hunting. The Skeena area (including its drainage basin) was noted for its populations of American wapiti (*Cervus canadensis*), caribou (*Rangifer tarandus caribou*), coast deer (*Odocoileus hemionus columbianus*), mountain sheep (*Ovis* sp.), black bear (*Ursus americanus*), and grizzly bear (*Ursus arctos horribilis*).

A few notes on mammalian wildlife inhabiting the areas surrounding the lakes of the Skeena basin were included in various reports published by the Fisheries Research Board in the 1940's. Smaller animals recorded were the red-backed vole (*Clethrionomys* sp.), marmots (*Marmota* sp.), squirrels (*Tamiasciurus* sp.), lemmings (*Synaptomys borealis*), shrews (*Sorex* sp.), packrats (*Neotoma cinerea*), mink (*Mustela vison*), marten (*Martes americana*), and beaver (*Castor canadensis*). As well, wolves (*Canis lupus*), coyotes (*Canis latrans*), black bears (*Ursus americanus*), grizzly bears (*Ursus arctos horribilis*), moose (*Alces alces andersoni*), caribou (*Rangifer tarandus*), deer

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(*Odocoileus* sp.), goats (*Oreamnos* sp.), and hair seals (*Phoca vitulina*) were found to be abundant (Brett and Pritchard, 1946a, 1946b; McConnell and Brett, 1946; Foskett, 1947a, 1947b; Withler, 1948; Withler, McConnell, and McMahon, 1949).

More recently, Naumann (1962) prepared an economic survey of the Prince Rupert area for the city, and included a few notes on the wildlife abundant in the vicinity, which could be considered a recreational resource. Thinhorn sheep (*Ovis dalli*), moose (*Alces alces andersoni*), caribou, mountain goat (*Oreamnos americanus americanus*), grizzly bear, wolves (*Canus lupus fuscus*), and beavers (*Castor canadensis belugae*) were mentioned as being common.

The environmental impact report prepared by F.F. Slaney (1973) provides a few additions to the list of animals above. Mink (*Mustela vison energumenos*) and marten (*Martes americana causina*) are found along the shoreline and are trapped for their fur. As rodents are a staple in their diets, various other species must also occur in the same location, but these were not described.

Sitka deer (*Odocoileus hemionus sitkensis*), a coastal subspecies of the mule deer, were observed by the Slaney researchers on Ridley Island. The Canada Land Inventory assigned this area a "moderate" rating, indicating that moderately severe limitations exist for ungulate production (Slaney, *et al.*, 1973). A recent study on terrestrial habitats of proposed port sites by Tera Environment Resource Analysts (1975) indicated that deer of the study area appeared to depend on marine vegetation of the intertidal zone and on upland vegetation in the adjacent forest fringe. Areas noted as having sizeable deer populations were the coastal fringes of Digby, Kaien, Ridley, and Lelu islands, and the fringe of De Horsey Passage. The study estimated a total deer population in the study area of approximately 400 animals.

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In addition to deer, the Tera report (1975) discussed various other game animals in the estuary area. Black bear, common on the mainland and erratic in distribution on the islands, was thought to feed on plant materials in the coastal muskeg and marsh areas during much of the year, while supplementing its diet with spawning salmon in the late summer and fall. The estimated population for the estuary area was about 400 individuals.

Wolves were noted as occurring throughout the study area except on small islands and near human habitation. Local observers indicated that the population has increased substantially in recent years, but no reason was given for this. Deer were their preferred food, but beaver, salmon, small mammals, and various invertebrates were also consumed. Their distribution in the study area was very similar to that of the deer populations.

Killer whales (*Orcinus orca*), harbour porpoises (*Phocoena phocoena*), and Dall's porpoises (*Phocoenoides dalli*), have been sighted in the estuary area (Slaney, *et al.*, 1973; Tera Environ. Resource Analysts, 1975).

The only mammals from the Skeena estuary which have been studied in any detail at all are the seals. During the 1940's, the hair or harbour seal, *Phoca vitulina richardii*, became a problem to the salmon fishery of the estuary. Seals were reportedly stealing the catch from fishermen's nets and traps, and destroying much of their gear while doing so. The Federal Fisheries Department undertook a "seal control" program in 1944, and between 1944 and 1960, 200 seals were killed annually. In 1960, commercial harvesting began and large numbers were taken for several years until the demand for skins declined. Since 1964 few have been taken, and the animals are now protected by fisheries regulations.

In 1946, Fisher (1947, 1952) estimated the seal

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population of the estuary to conservatively number 450 adults, located from the mouth of the Skeena to, and including, Ecstall and Lamb islands. Figure 9.1 shows the "hauling-out" sights used by seals in the estuary. Several hundred more were thought to be distributed as far up the river as Hazelton (nearly 200 miles from salt water). Seals were known to migrate upriver during the March eulachon run and prior to the spring salmon migration, and have been recorded from Lakelse Lake and Terrace (Fisher, 1947, 1952). The present population is estimated at 200-300 animals (Tera Environ. Resource Analysts, 1975).

According to Fisher's research (1947, 1952), breeding, in the Skeena area, occurs in September and October, with birth of the young occurring on the sand bars near the mouth of the river in late May and early June. Pups were always scarce in the De Horsey area, the majority of births having taken place upriver on the Skeena and Ecstall sand bars.

Northern sea-lions (*Eumetopias jubata*) are known to follow spawning eulachon into the estuary, although they generally tend to remain further offshore. Periodically migrant northern fur-seals (*Callorhinus ursinus cynocephalus*) are also sighted offshore (Slaney, *et al.*, 1973; Tera Environ. Resource Analysts, 1975).

A species list of known and probable mammalian species of the Skeena estuary can be found in Appendix 9.1.

9 (viii) WILDLIFE AND HUMAN INTERACTIONS

It has been noted in previous reports of this series (Hoos and Packman, 1974; Hoos and Vold, 1975) that wildlife can serve a very worthwhile human purpose. That purpose is one of recreation. It was indicated in the mammal sub-section of this chapter that many of the species abundant in the Skeena drainage

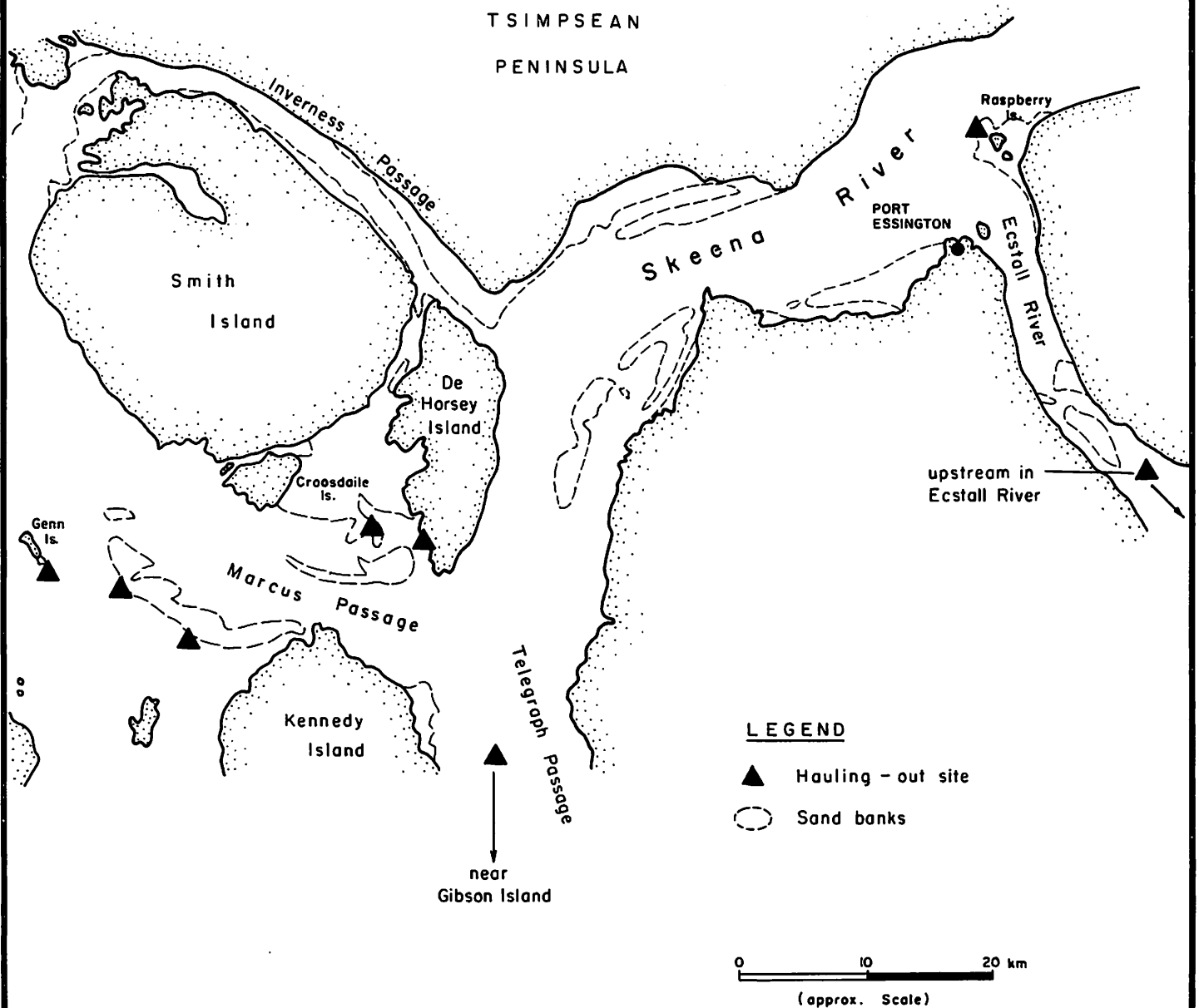


FIGURE 9.1. Mouth of the Skeena River showing hauling - out sites of the harbour seal (from Fisher, 1952).

basin are highly prized by hunters. The same can be said of many of the waterfowl species and the game birds inhabiting the delta. In addition, several species are prized for their skins. The recent report by Tera Environment Resource Analysts (1975), on terrestrial habitats of proposed port sites in the Skeena estuary region, serves to illustrate these facts.

There were 3,000 licensed hunters in the Prince Rupert district in 1972. Most of the actual hunting in the Skeena region takes place upriver where big game is more abundant and more readily accessible.

Within the estuary region, waterfowl contributed the greatest harvest to recreational hunting. Most of the duck species taken were migrant forms, while geese of both local and migrant stocks were hunted. Approximately 75 locally bred geese are taken annually by hunters, while a few more are killed for food by local Indians.

Deer populations of the estuary are hunted only sparingly due to restricted access and difficult hunting conditions. Some are taken by Indians on reserve lands. Most of the deer hunting by Prince Rupert residents occurs in the Terrace-Prince George region and on Porcher Island.

Besides deer and waterfowl, other species hunted in the area include black and grizzly bear, blue and ruffed grouse, goat, moose, etc.

The actual value placed on waterfowl and deer hunting in the study area, in 1972, was only \$10,500. It was felt that the social benefits provided by the hunting opportunity and non-consumptive appreciation of wildlife was of greater importance to the local participant than the actual return for time and money spent.

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The Tera report (1975) also provides some information on trapping of fur-bearing species in the Skeena estuary area. Of the sixteen trap lines existing in the region, only five were active in 1973. Of these five, two lines, with a 1973 harvest of 25 mink, were located on Croosdale-Smith, Ridley-Lelu, and Digby islands. Three lines at Rupert Harbour, Tuck Inlet, and Moore Basin yielded 63 marten, 30 mink, 16 otter, and 2 beaver, in the same year. In addition, a few Indian trap lines were probably in use, but no data regarding their status were found. Obviously, trapping of fur-bearing animals is not a common or economically beneficial activity in the estuary area.

Besides these consumptive uses, wildlife can form the basis of non-consumptive recreation in the form of bird watching, nature study, and photography.

Although the area is not rated as a valuable breeding or migratory location for bird life, it does support local bird and mammal populations which have their role to play in the ecosystem as a whole. Therefore, it is still important that serious consideration be given to the fate of this resource should the estuary be developed.

10. LAND USE

The Skeena River, located approximately 470 miles northwest of Vancouver, flows out of the Coast Mountains and forms, at its mouth, a delta of islands and shifting sandbars. This delta, and the mainland valley through which the Skeena flows, has been the scene of a fascinating series of events during the past hundred, or more, years. As was noted for the Fraser and Squamish river estuaries (Hoos and Packman, 1974; Hoos and Vold, 1975), however, land use trends have changed substantially in the Skeena area since the whiteman first settled there.

10 (i) HISTORICAL PERSPECTIVE

The following sub-section relies almost completely on one source of information - Large (1957). Other references will be indicated where applicable.

1. GENERAL HISTORY OF SETTLEMENT:

In 1778, Captain Charles Duncan named what was to later become known as the Skeena River, Ayton's River. The name was short-lived, and was changed to Simpson's or Babine River by the 1800's. However, by 1867, maps indicated it by its present name - Skeena, a derivative of the Indian "K-shian" or "water of the clouds".

The tribes that first settled the Skeena estuary were known as the Tsimpseans - "people of the mouth of the K-shian". These people based their lives around the cedar trees and salmon, deriving all of life's necessities from the forests, or the river and its estuary. Eventually, some of the natives moved upstream, following the migrating salmon. They formed the Gitekshan tribe, or "people who live up the K-shian".

As well as these two main tribes, a group of Carrier or Dene Indians settled along the Bulkley River and on Babine and Bear lakes. These were nomadic people, probably coming from inland villages of the Fraser drainage basin to live on the Skeena system.

A significant feature of the life of all of these native peoples was the annual eulachon run on the Nass River to the north. At first all of the Indians of the north coast and interior would descend on the Nass delta to catch this fish, whose oil was prized for a variety of uses, including cooking and lighting. Later, the tribes that actually inhabited the Nass delta took over the eulachon fishery, and established the first trading routes in the north by blazing trails through the rugged country to connect their villages with those of the Skeena peoples. These routes became known as "grease" trails, and played an important role in the economy of the native civilizations.

The earliest white visitors to the northern coast were European explorers in search of a "northwest passage". When the abundance of furs obtainable from the natives was realized, emphasis shifted to trading. However, few of these people ever ventured between the many islands of the north coast to explore the mainland. The Tsimpseans guarded their trading privileges jealously, and would not allow the whiteman to ascend the river to trade with more distant villages. First exploration of the Skeena was finally accomplished from the headwaters rather than from the sea. D.W. Harmon and J. McDougall can be credited with this accomplishment, having crossed inland from Stuart Lake to Babine Lake in 1812. In 1822, Fort Kilmaurs was constructed by the Hudson's Bay Company on the shores of Babine Lake. A second fort, Fort Connolly, was constructed in 1826 on Bear Lake, and the area became an official trading post. As well as expanding the fur trade, these two locations were ideally situated for the fishing of salmon, and soon became major food depots for

trappers and settlers of the valley.

The Hudson's Bay Company became supreme ruler of the trading industry in the north. In 1834, Port Simpson was built at a point midway between the Nass and Skeena rivers, and it soon became the headquarters of the north coast fur trade and the centre of civilization.

Unlike the history of the rest of Canada, that of the development of the north did not follow the usual explorers, exploiters, settlers, clergy pattern. With the establishment of Port Simpson, the British Church Missionary Society took it upon itself to send a missionary to the area to save the souls of the "heathen" natives. In 1857, William Duncan landed at Port Simpson, and by 1862 had sufficient converts amongst the natives to establish his own settlement in Venn Passage. The village was named Metlakatla, and it served as a centre for the educating of the native peoples to the ways of the whiteman. Among its establishments were a trading post and a fish cannery.

In 1859, the first whiteman traversed the Skeena from its mouth to the Hudson's Bay forts far inland, and, in 1864, the first river steamer (*Union*) navigated ninety miles upriver. Two years later, a party completed a telegraph line to Kispiox, under the direction of C.S. Bulkley. The line was originally to have been part of a transcontinental line to Europe via Russia, but with the laying of an Atlantic cable, the project was abandoned. Some of the men stayed in the area that winter, establishing a settlement on the Skeena in 1868, which was to later become Hazelton.

With the gold rush on the Fraser came a general influx of prospectors to all areas of the mainland, the Skeena being no exception, particularly since it was the only navigable channel to the northern interior. In 1870, a village, variously called Skeenamouth, Skeena Bay, or Woodcock's Landing, was

constructed at the mouth of the river to serve as a base for would-be miners for obtaining supplies before moving upriver in search of gold.

The gold rush of 1871-1872 followed a route up the Skeena to Hazelton, and then overland to Babine Lake, up the lake by boat, and overland to Tahtla Lake, etc., until reaching the Omineca River. As a result, Hazelton became a bustling centre of activity. Gold was discovered on Lorne Creek, located about two-thirds the distance from the mouth to Hazelton, and ranches were established along the river banks near the town.

With the Yukon gold rush in 1890, the once abandoned telegraph line was completed to Atlin in 1901, with a branch line to Port Essington, a new town established on the south bank of the Skeena, just below the mouth of the Ecstall River. The Hudson's Bay Company built a trading post here, and the settlement soon became the initial port-of-call for all travel upriver. The fishing industry on the river became a booming business, and the town swelled in size and economic importance. However, with the coming of the railroad to Kaien Island in 1914, and the use of modern commercial fishing techniques offshore causing declines in river stocks, Port Essington began a slow death. Today only a few Indians and a handful of fishermen still live in what remains of the town.

In 1876, the first commercial salmon cannery was built at Woodcock's Landing by the North Western Commercial Company. Although it has changed hands several times, the same cannery exists today, now being known as the Inverness Cannery. By the 1890's there were seven canneries in the estuary area, and the first cold storage plant was built in 1892.

The city of Prince Rupert grew out of the plan by C.M. Hays to construct a railway through the coastal mountains and onward to the east coast. The construction of the Grand Trunk

Pacific line will be discussed in a later sub-section of this chapter, but some background information on its beginning is provided here.

When it was decided that a line would definitely be built to the north Pacific coast, land speculators assumed the natural place for a western terminus would be either Kitimat or Port Simpson, and most likely the latter, since it was the best port on the coast. To stop the land speculating in the area, the provincial government put a reserve on the land of the entire Tsimpsean peninsula in 1891. However, in 1904, Mr. George Kane made application to the government to acquire 640 acres of Kaien Island through a special scrip he held for unoccupied Crown Lands. Kane was not successful, but his interest in Kaien Island as a potential site for the terminus started a controversy over the entire project, which eventually ended in a special commission to review the entire situation. In the end it was revealed that, through various private individuals, the government had become convinced of Kaien Islands' worth as the terminus of the line, and had sold 10,000 acres of the land to the Grand Trunk Pacific Railway for one dollar per acre. One quarter of the proposed townsite was reserved for the government, including one quarter of the waterfront.

On May 17th, 1906, the first party of men arrived to begin construction of the terminal site on Kaien Island. The first thing to be completed was the wharf, followed by the company offices, and then a road from the wharf into the wilderness. This was Center Street, and the town was underway. However, the Grand Trunk Pacific Railway owned the land, and had not opened it for settlement. They allowed various individuals and parties to establish businesses at the site to serve the company's needs, keeping a tight hold on the development. But people were undaunted, and, by filing a mineral claim on land tracts, they were able to take up residence in the town area.

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By October, 1907, the work of clearing land had begun. Docks and warehouses were being constructed, and a sawmill was established at Seal Cove. By May, 1909, the town had acquired 1,000 inhabitants and 150 businesses, and, with the official sale of lots, the town became an entity known as Prince Rupert. On March 3, 1910, Prince Rupert was incorporated as a city.

New industries sprang up. The Canadian Fish and Cold Storage Plant at Seal Cove became the world's largest fish cold storage facility, and was the forerunner of the city's halibut industry. The Grand Trunk Pacific established a drydock and shipyard, and included in their construction the first permanent school and a hospital.

The defeat of the Liberal government in Ottawa (the Grand Trunk Pacific's mainstay) over Reciprocity, and the death of C.M. Hays, President of the Grand Trunk Pacific Railway and "Father of Prince Rupert", caused a disastrous slump in Prince Rupert's economy. Hays had envisioned a city of 50,000 people, a thriving seaport and rail terminal, and with him died the inspiration to reach this goal. These two blows to the economy were followed soon after by World War I in 1914, and a devastating flu epidemic in 1918, leaving the city almost a ghost town in comparison with its earlier economic level.

As if to deal the final blow, in 1922 the Grand Trunk Pacific and Canadian Northern railways got into financial problems and the federal government was forced to take them both over. They were amalgamated into the Canadian National Railway, and the chosen mainline was that to Vancouver, with the one from Jasper to Prince Rupert taking branch-line status. The town seemed doomed to disappear, like so many of its predecessors.

During the later years of the 1920's, a rush for new ships to replace those devastated by the war brought a lift to the city's economy. However, the lift was short-lived, and when

the depression hit in 1929, the 6,000 inhabitants found it impossible to carry the town's tax debt. In 1933, Prince Rupert was declared bankrupt. It took ten years to re-establish the city's financial solvency. By that time, the second World War had broken out, and the troops from the Canadian and American armies stationed in the region helped the city recover its prosperity.

During its lean years, Prince Rupert relied on its fishing industry for its life. Halibut had been exploited for years before Prince Rupert ever existed, by American companies fishing Hecate Strait. A packing plant had been built in Eddy Pass to service these companies. The Canadian Fish and Cold Storage Company pioneered the city's halibut fishery, and soon many companies and individuals were involved in the industry. At first the steam trawler was the vessel most used, but later the dory and power gurdy took over. Prince Rupert became the home port of the world's halibut fishery, with over 20 million pounds being landed annually.

With the economic slump of the 1930's, the local fishermen established a co-operative association to protect their interests in the industry, and it has since become one of the most profitable groups in the region, having its own cold storage, processing, and reduction facilities.

In addition to the halibut fishery, the close proximity of the Prince Rupert to the Skeena soon brought the salmon into the city's fishing industry. Processing and reduction plants, as well as the fishing fleet, added to the economy of the area.

The city's need for electricity eventually resulted in the damming of the Ecstall River at Big Falls, by the Northern B.C. Power Company, in 1939. Power lines led down the Ecstall, across the Skeena, and into the city.

Although of minor importance in the early days, the forest products industry of the Skeena area today rivals the fishing industry for importance. Hemlock, spruce, balsam, cedar, and cottonwood are abundant in the region's forests. As was noted earlier, many of the small towns owed their initial existence to the small sawmills established at their sites. However, these water-powered or steam-powered plants were insufficient to supply the needs of the entire Skeena region, and it was not until the railroad became a reality, with its needs for poles and ties, that lumbering became a viable industry. After World War II, there was a "boom" on cut lumber for the entire country, and sawmills sprang up all over the Skeena drainage basin. By 1954, there were 180 mills in operation in the region.

In addition to the need for cut timber, wood pulp was becoming important for a variety of uses. In the late 1940's, the Columbia Cellulose Company applied for and received a provincial government forest management license covering six hundred thousand acres in the Skeena and Nass valleys and adjacent coast. The area was estimated to contain 3 billion cubic feet of timber. By 1951, the company had established a bleached sulphite pulp mill on Watson Island, about seven miles south of Prince Rupert. The mill provided well-paid employment to the people of the area, and gave the economy of the region a definite boost by producing 535 tons of pulp per day since it began operation.

During the 1950's there was a steady growth in industry, business, government agencies, and professional services in the Prince Rupert area. The population swelled from 8,500 in 1951, to about 12,000 in 1961. Most of the people lived in Prince Rupert, and the economy continued to rely heavily on fishing and fish processing, the lumbering industry, and, to a small extent, agriculture and mining.

2. HISTORY OF TRANSPORTATION:

The first method of transport for goods and people of the Skeena area was the canoe. Large, strong cedar canoes were used by the Indians for ocean trips, and for short trips in and around the Skeena estuary. Upriver, the cedar trees were not large enough to make good canoes, and cottonwood was used instead. For many years canoes were the only means of transport, and these were even used by the Hudson's Bay Company to carry tons of goods to and from upriver trading posts. Pack-trains were employed, where possible, for inland travel.

Finally, in 1891, the first full-time steamer, the *Caledonia*, was put into service between Port Essington and Hazelton. The boat was owned by the Hudson's Bay Company, which, by 1903, had taken complete control of the steamboat river traffic on the Skeena by buying out its rivals and increasing the size of its steamers. With the coming of the Grand Trunk Pacific Railway in 1914, the steamboats were no longer needed and retired into oblivion.

In 1902, Mr. C.M. Hays approached Prime Minister Sir Wilfred Laurier with a scheme to construct a second trans-continental railroad (the Canadian Pacific was already completed), this time terminating on the northern Pacific coast. Hays was successful, and in 1903 an Act was passed incorporating the Grand Trunk Pacific Railway Company. The line was to be built in two sections - the first, from Moncton to Winnipeg, to be paid by the government, and the second, from Winnipeg to the Pacific coast, to be funded by the Grand Trunk Railway.

Building across the prairies went quickly, and by 1910 the line had passed Edmonton and reached Wolf Creek. Kaien Island was eventually chosen as the western terminus, and after much haggling over land between the federal and provincial governments and several private parties, construction by the firm

of Foley, Welch, and Stewart finally began on the western end, in 1907.

The chosen route through the mountains ran down the Bulkley River to the Skeena Forks, and then down the Skeena to Kaien Island. Although longer than some other prospective routes, the chosen line would service both the mining areas inland, as well as the agricultural areas around Hazelton.

The actual building of the railway caused a minor "boom" in the region's economy, as companies were established to supply the workers along the Skeena with food and other goods. An explosives factory was built on Wolf Island, in Prince Rupert Harbour, to meet the needs of the line which was slowly blasting its way through the mountains.

In 1910, the bridge connecting Kaien Island with the mainland, over Zanardi Rapids, was completed, and by 1912, the three tunnels in Kitselas Canyon were finished. After the completion of the 930-foot long bridge at Kitsequecla, connecting the Skeena portion with the Bulkley section, the line moved hastily to completion at Fraser Lake, in 1914.

Development in the form of improved transportation did not occur again in the Skeena area until after World War II. At this time the government constructed Highway 16 from Prince Rupert, through the Skeena and Bulkley valleys, and across the interior plateau, to Prince George. At last the city was linked with the roads of the rest of the province.

After the highway was constructed, the provincial government completed the link between Prince Rupert and the more populated areas of the southern coast by instigating an automobile ferry service from Vancouver Island to Prince Rupert. Just prior to this, the Alaska Ferry System had instituted a run between Haines and Prince Rupert.

The region obtained public air transportation in the 1950's, when an airport was constructed on Digby Island. Also, a seaplane base, originally established during World War II at Seal Cove, was re-opened to make travel to more remote northern areas easier.

10 (ii) PRESENT LAND USE TRENDS

Three recent reports [those by Naumann (1962), the City of Prince Rupert (1971), and Johnston Associates Management Limited (1975)] serve to bring the land use trends in the Skeena area up to date.

The vast majority (95%) of the inhabitants of the lower Skeena valley and estuary live in or near the city of Prince Rupert (Johnston Assoc. Mgmt. Ltd., 1975). In 1962, the total population of the city was about 12,000, of which more than 1,000 were native Indians (Naumann, 1962). The present population is estimated at 17,500 (17.9% being native people), with a projected 1981 level of 26,560 (Johnston Assoc. Mgmt. Ltd., 1975).

As a result of the difficulty in construction of roads, owing to rock and muskeg, the residential areas of Prince Rupert are tightly regulated. Most are built on the hills behind the business district, the oldest areas being those centred directly behind the downtown, and the newest occurring on a ridge to the west of the core. In 1962, as much as 1/3 of the housing was considered to be sub-standard (Naumann, 1962).

The business district forms an east-west bend in the centre of the city closest to the waterfront. The waterfront is occupied by industrial plants and the railway line. Most of the shoreline buildings, including the grain elevator, are constructed on piles. Fish processing plants, including facilities

for receiving and unloading fish and issuing of supplies to boats, are located on the water's edge. Two large boatbuilding and repair operations have waterfront land at Fairview Point and Hays Cove. Railway facilities occupy a large segment of the waterfront. Other waterfront construction includes a barge slip, a grain elevator and its dock, a second ocean dock and warehouse, and the former shipyard, much of which is presently used as a sawmill. At Seal Cove, there is a seaplane base and marine service station. Further south, at Sourdough Bay, there is a federal Fisheries station.

Schools are dotted throughout the city. There are two radio stations, live television, two theatres, and several night spots with live entertainment. Three new shopping complexes have recently, or soon will be, opened to serve the needs of the populace (City of Prince Rupert, 1971; Johnston Assoc. Mgmt. Ltd., 1975).

The Prince Rupert area abounds with recreational facilities and opportunities. Within the city itself there are nine playgrounds, three playing fields, and 256 acres of park. The two main parks are located on Acropolis Hill and in Hays Creek valley, the latter of which has a swimming pool, play space, picnic area, and sports fields. The new 68,000 sq. ft. Prince Rupert Civic Centre houses an ice arena, courts, spectator areas for indoor sports, etc. A six sheet curling rink and three outdoor tennis courts are also available. The city has a scuba diving club and a newly formed canoe club. A ski run is operated on Mt. Ptarmigan, close to the city, and a large new ski facility is planned for Mt. Hays, where large numbers of people already enjoy cross-country skiing each winter. A public golf course is situated near the city, while trailer facilities are found in Roosevelt Park. There are three pleasure boat mooring areas in the city harbour area (Naumann, 1962; City of Prince Rupert, 1971; Johnston Assoc. Mgmt. Ltd., 1975). It is estimated that about 90% of Prince Rupert's pleasure boating takes place in

the sheltered waters around Digby, Ridley, and Smith islands (Johnston Assoc. Mgmt. Ltd., 1975).

The provincial government operates three small parks near Prince Rupert, with a total acreage of 113 acres. These are Oliver Lake, Prudhomme Lake, and Salt Lake parks. All three have picnicking facilities, while Prudhomme also has a camping area. Other provincial recreational facilities include picnic sites at Galloway Rapids, boat launching facilities at Rainbow Lake, and various viewpoints on local highways and roads. In 1962, 685 acres of Digby Island were set aside as a provincial reserve, of which four miles was beach front. As well, another reserve rings Prudhomme Lake, and all of Kaien Island is a game sanctuary (Johnston Assoc. Mgmt. Ltd., 1975).

Manufacturing industries employ approximately 28% of the region's labour force, with another 19% being utilized by service industries. Fishing and fish processing are still mainstays of the region's economy. Five processing firms are located in Prince Rupert, with a sixth at Port Edward, and there are two cold storage plants in operation. Together, in 1962, they employed 358 men and 181 women, who earned \$2.2 million annually. These numbers have increased substantially in the past decade, with 1,087 people being employed and \$10.9 million being earned in 1973 (Naumann, 1962; Johnston Assoc. Mgmt. Ltd., 1975). Contrary to Naumann's study in 1962, which predicted a stabilization, but no increase, in the fishing industry, the economy of Prince Rupert continues to expand on the basis of its oldest industry.

The other important industry in the area is that of forestry, and, within this, the Canadian Cellulose pulp mill on Watson Island. Since it began production in 1951, the operation has expanded (in 1966) to include a Kraft pulp mill, with a production rate of 750 tons per day. The company employs over 1,000 people year round, with an annual payroll in excess of \$11 million.

It is the largest civic taxpayer in Prince Rupert (City of Prince Rupert, 1971).

Sawmills, as indicated earlier, have played an important role in the economy of the Skeena area, and will continue to do so. It is cheaper to process the logs near their point of origin, than to ship them to a larger centre, such as Vancouver.

A recent study by Tera Environment Resource Analysts (1975) attempted to evaluate the forest wealth of Crown and Indian Reserve lands on the Tsimpsean peninsula in relation to possible acreage losses due to port development. The major harvestable tree species occurring below 1000 feet elevation in the region are western hemlock, western red cedar, yellow cedar, sitka spruce, balsam fir, and lodgepole pine. Of these, the largest and soundest trees are sitka spruce.

The Port Simpson area was found to have the greatest volume and value of forest wealth. The regions' large, harvestable stands of cedar, hemlock, and spruce were appraised at \$125,070, with a net value of mean annual increment of \$1,206. An additional \$110,400 was the appraised value of mature timber occurring on railroad right-of-ways in the area, this having a net value of mean annual increment of \$1,024. In total, the Port Simpson region had an appraised forest value of \$235,470, with a net value of mean annual increment of \$2,230.

Very little of Smith Island has harvestable forest resources. A rail or road right-of-way was found to have 8 acres of timber, with an appraised merchantable value of \$2,360, and an annual value of increment of \$18.

Both Kitson and Ridley islands were found to have no marketable timber, as the trees of the region are small and of poor quality. On the other hand, Digby Island supports mature

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timber with an estimated value of \$21,180. The annual mean increment value of the region was \$107.

Fairview Point was indicated by the study as being the best location for port development from a loss of forest wealth point of view. The region had previously been cleared, and therefore, the only loss would be the estimated annual mean increment value of \$39.

To summarize, the total appraised value of mature timber growing on the possible port development sites was \$259,010, with a mean annual increment value of \$2,394. As these sites represent only a small fraction of the total acreage covered in marketable timber in the lower Skeena valley and estuary, it is obvious that the forest industry will continue to be viable and increasingly important to the economy of the Prince Rupert region, as more and more of its forest resources are utilized.

Recently, a Japanese steel company, Nippon Kokan K.K., has been considering the construction of a massive steel mill in British Columbia, one place being the Skeena estuary coast. The amount of land required is estimated at 1500 acres initially, with 2,500 more for expansion. Needless to say, the idea is undergoing close scrutiny by all levels and branches of government. Such a huge development would undoubtedly cause a multitude of environmental ramifications throughout the area.

In the area of transportation, Naumann (1962) predicted an increase in employment for two reasons - increased rail shipment of goods through Prince Rupert to overseas ports, and increased rail, boat, and air traffic through an expanded tourist industry. It is these two factors which will decide the ultimate future of Prince Rupert.

Prince Rupert has been proposed for development as a

deep-sea port. The idea has been met with a variety of reactions and has been the subject of a great many engineering and environmental reports. Because it is such an important topic, a discussion of the scheme, and its possible ramifications, will form a separate chapter.

The second area for economic expansion in the Prince Rupert vicinity, and the entire Skeena valley for that matter, is that of increased tourism. It was indicated in the Biology sections of this report that there is a great potential in the Skeena area for consumptive and non-consumptive uses of the fish and wildlife resources of the area. The economy of the entire region could be improved through the development of wildlife reserves, parks with nature trails for bird-watching and photography, camping and trailer facilities, more and better hotels and restaurants, fishing and game-hunting lodges, stores for food and clothing supplies, more and better service stations, pleasure craft boating facilities, etc., etc. The natural beauty of the mountains and abundant lakes of the Skeena drainage basin represent an untapped resource. It is necessary, however, to carefully manage its use.

11. POLLUTION

11 (i) WATER POLLUTION

Water pollution sources of the Skeena estuary can be divided into several categories - sewage, fish processing, pulp mills, log handling and log storage, chemical industry, recreational activity, shipping, mining, and cement operations. Very little information, specific to the Skeena area, is available on some of these topics. As well, some aspects of the expected effect of the effluents from several of the sources listed have been dealt with in detail in either the Fraser River estuary report (Hoos and Packman, 1974), or in the Squamish River estuary report (Hoos and Vold, 1975), and will, therefore, not be discussed further here. The reader is referred to the aforementioned documents for more information and pertinent references. A very good description of the general effects of some specific types of pollution can be found in Waldichuk (1974).

A recent Environmental Protection Service (EPS) (1975) submission to the Estuary Working Group, providing an up-to-date list of pollution sources for the Skeena, together with pertinent statistics, can be found in Appendix 11.1. Figure 11.1 gives the locations of these effluent sources on the Skeena estuary.

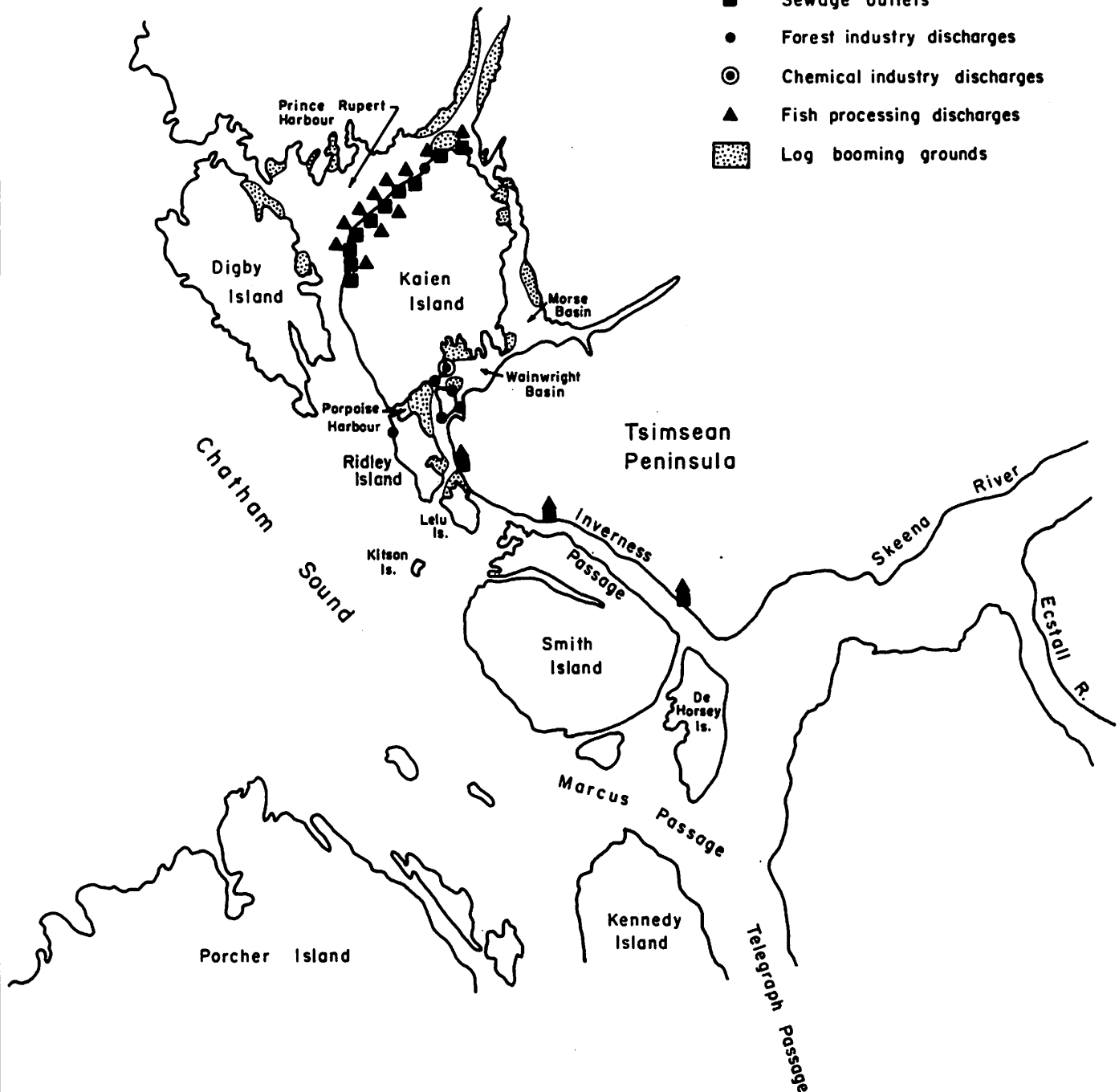
1. DOMESTIC SEWAGE:

The Environmental Protection Service (1973, 1975) reports that the British Columbia Pollution Control Branch (PCB) has permits for fifteen domestic sewage outlets to the Skeena estuary, and a further nine sources upriver. By far, the largest of these is that from the city of Prince Rupert, which is permitted to discharge its sewage into Prince Rupert Harbour at the rate of 2,690,000 Imperial gallons per day (IGD). As this combined sewage and storm water waste is completely untreated, it is considered to be a potential health and aesthetic

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LEGEND

- Sewage outlets
- Forest industry discharges
- ⊙ Chemical industry discharges
- ▲ Fish processing discharges
- ▨ Log booming grounds



0 5 10 km

FIGURE II.1. Locations and types of effluent discharges to the Skeena estuary. (after Environ. Prot. Serv., 1975).

problem.

There are eleven other sewage outlets on Prince Rupert Harbour, of which ten are typical septic tank discharges, with flow rates ranging from 30 to 5,000 IGD. Most of these are also thought to be possible public health problems. The eleventh source, that of the British Columbia Transport and Communication Ferry terminal, discharges up to 5,000 IGD from its packaged sewage treatment plant, which has chlorination facilities.

Two fish processing plants, located on Inverness Passage, discharge wastes from their septic tanks at rates of 500 and 2,000 IGD per day.

The last of the registered sewage sources on the estuary is the British Columbia Packers Ltd. plant, which may release 4,000 IGD (June 15 - October 31) of domestic septic tank wastes to Porpoise Harbour. This effluent is also thought to be a potentially harmful public health problem.

There are three large towns located on the Skeena drainage which discharge sewage (treated to various degrees) to the river system. The largest of these is Terrace, which releases approximately 2,000,000 IGD of primary treated sewage to the Skeena. By 1980, the town will have secondary treatment facilities.

Smithers, located on the Bulkley River, is permitted to discharge as much as 625,000 IGD of secondarily treated (activated sludge with chlorination) sewage to the Skeena tributary. Houston, also located on the Bulkley River, may release a further 340,000 IGD of sewage, which has been treated by aeration and chlorination.

In addition to these larger centres, three small settlements discharge sewage to the Skeena system. New Hazelton

releases up to 50,000 IGD, while the old town of Hazelton has a permit for 40,000 IGD, both with outlets leading ultimately to the Skeena. As well, the village of Granisle, on Babine Lake, can release up to 120,000 IGD to the Babine system, which is tributary to the Skeena.

Three other permits for sewage discharges to the Skeena system belong to individual groups, including Totem Marina Ltd. on Babine Lake, Skogland Hotsprings Hotel and Resort on Lakelse Lake, and Winck Memorial in Hazelton. These are permitted to release 11,000, 10,000, and 25,000 IGD, respectively.

In general, the main effects of sewage discharges on the receiving waters include increased turbidity, depletion of oxygen, increase in nutrients, the addition of toxic substances, heat pollution, bacterial pollution, odors, and unsightliness. Each of these, in turn, may cause changes in the flora and fauna living in the water. For example, high faecal coliform levels caused contamination of oyster beds in Melville Arm, in 1962 (Anon., 1962a). All of these effects can be greatly enhanced when the discharges also include storm water. However, due to the heavy rainfall nearly year-round in the Skeena area, storm water probably has little time to build up deleterious substances.

A recent PCB study of sewage waste in Prince Rupert Harbour (Pollution Control Branch, 1974) indicated that this sewage, for most of the parameters analyzed (NO_3 , PO_4 , S.S., T.O.C., and oil) was below typical sewage levels, except in the cases of pH and total solids, which were higher than normal. In a later study (Drinnan and Webster, 1974), slightly elevated faecal coliform bacterial counts were found in samples taken off the Prince Rupert waterfront near sewage outfalls, than were found at stations outside the harbour.

These two studies comprise the only information available on the effects of sewage on the environment of the Skeena

estuary. However, since a combined total of 5,934,980 IGD of sewage, in various stages of treatment, can legally be released into the river and/or its estuary, sewage pollution could become a more significant problem in the future, particularly if the urban populations of the larger centres continue to expand, and proper treatment facilities are not installed.

2. FISH PROCESSING:

As was noted previously in the chapters dealing with fisheries and land use, fish play a very important role in the lives of the people inhabiting the Skeena estuary. There are presently six salmon canneries operating in the Skeena area, along with various other establishments such as cold storage facilities, fish reduction plants, crab canneries, etc.

In general, wastes from such establishments contain high suspended solids levels, ether-soluble oils, brine, soluble protein, sodium hydroxide and aluminum sulphate (Environmental Protection Service, 1972b). The exact properties of the effluent depend upon the fish species being processed, the number of fish, and the type and degree of handling. As the Prince Rupert area has a representative plant for each of the five basic types of processing, each method and its effluent characteristics will be discussed separately. The Environmental Protection Service's inquiry into the food processing industries (1972b) will form the basis of this discussion.

Halibut, a very important fish species to the Prince Rupert fisherman, are dressed (that is, the viscera and gills are removed) on board ship (the waste being washed overboard), and the fish are then packed in ice. Before sale to the processor, the heads are removed. The majority of halibut is filleted and marketed frozen, although some are frozen whole or sold fresh. Whole fish are glazed with water at -20°F prior to freezing. The filleted, or more properly, fletched (boneless, skinless pieces weighing 5 to 20 pounds) fish are glazed, frozen,

and packaged, or cut into steaks or smaller fillets, or filleted and breaded.

The waste from the above procedure consists of heads, backbones, tails, skin, bits of flesh, and rinse water, most of which undergoes rendering, and is used in pet food or animal meal. The portion not rendered is screened and then released to the environment.

Other groundfish are handled in a similar manner. When landed, the fish are either stored whole, or are eviscerated prior to storage, the blood and viscera being washed overboard.

At the dock, fish are weighed, washed, and iced before being processed. Most plants today use mechanical filleting machines. The fish are washed, the skin is removed, and the fish is filleted. The fillets are washed, and may or may not be re-washed in brine, prior to inspection and packing or freezing. Fillets are marketed fresh, chilled, or frozen (fresh or breaded). Some fish are cut into steaks rather than fillets, and these are marketed fresh or frozen.

The wastes from the groundfish filleting process is made up of solids, slime, offal, and water, and, like halibut, these undergo rendering for pet food or fish meal. Any remaining material is discharged to the receiving waters.

The most important fish caught in the Skeena estuary is the salmon. Spring, coho, and some sockeye are caught by trolling. These fish are gutted at sea and stored in ice. A small portion are sold fresh, while the balance is either glazed whole, or is cut into steaks and frozen for marketing.

Most sockeye, as well as pinks and chums, are netted and taken to nearby canneries. Throughout the canning process,

the area is constantly washed with a stream of water. The fish are beheaded and eviscerated, then washed, inspected, and cut to control-length pieces. These pieces are then cut into can-length portions, the cans being filled automatically. Finally, the cans are sealed under a vacuum and retorted.

The wastes from salmon canning include blood, slime, viscera, heads, fins, pieces of flesh, and water. Again, part of this is rendered for pet food or fish meal, while the remainder is released to the receiving waters.

Herring are not as important to the Skeena fishery as are the aforementioned species. However, there is an operational herring reduction plant in the area. Herring are brined prior to removing the roe. The roe are salted, packaged and refrigerated before shipment. The flesh of the fish is reduced to fish meal or pet food. The solid waste from these processes is minimal, and these, together with brine and water, are released to the receiving waters.

Crab and shrimp are the other animals important in the fishing industry of Prince Rupert. Crabs are caught in traps and handled gently, since dead animals must be discarded owing to rapid decomposition. Usually, whole crabs are steamed in retorts for 20 to 30 minutes, and are then cooled. The backs are removed and the viscera are washed away. Cooked crabs are marketed in the shell (butchered or whole), or the meats are picked from the shell and sold fresh, frozen, or canned.

The cooking, cooling, and washing waters contain high concentrations of solids and organic materials, and, if the crab is canned, even more waste is generated. Most of this is screened, some of the residue being used in pet food production and the remainder being discarded.

Shrimp are caught by trawls and stored in ice until

ready for processing. They are then boiled from 1 to 3 minutes. They may or may not be peeled, a tedious process done by hand at the rate of 100 to 400 pounds per day. The meats are inspected again before packing. Shrimp are marketed fresh, frozen, breaded, canned, cured, or as a specialty product.

The wastes from the above procedure are the same as those for crab processing, and they are handled in the same manner.

Most of the fish processing described above included rendering of wastes for use as meal or pet food. The waste material, or offal, is conveyed to the fish meal plant and stored in pits until sufficient is accumulated for processing. During storage, some liquid is pressed from the offal. This liquid is high in dissolved organic substances, and usually enters the receiving waters through discharge in the plant effluent.

When ready for processing, the offal is mashed, and then cooked in direct or indirect heat continuous steam cookers for up to 10 minutes. Non-oily offal is added directly to the driers, while oily material is pressed prior to drying. The liquid obtained from pressing undergoes a fine-solids separation, followed by oil separation in nozzle centrifuges. The oil is clarified further in polishing centrifuges, before sale as an edible oil or an animal oil.

The residue from the above is called stickwater and can contain up to 6 percent organic solids. In recent years, these have been concentrated in evaporators to produce condensed fish solubles containing 30 to 50 percent solids. These solubles are marketed as poultry or animal feed or as a specialty fertilizer, or are sprayed back into the driers.

Fish meal driers are rotary kilns with either direct heat from a flame, or heat produced from steam. The solids are

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dried to between 5 and 10 percent moisture content, ground to pass 10 mesh screens, and sold in either 100 pound bags or in bulk.

As mentioned at the beginning of this sub-section, the effluents from fish processing plants contain high suspended solids levels, ether-soluble oils, brine, soluble organics, etc. The main problem created by such effluents is the loss of oxygen in receiving waters as a result of the decomposition of the organic materials. As well, suspended solids block out light for photosynthesis, and, when they finally do settle out, they can smother benthic life on the bottom. In addition to these effects, the poor aesthetic qualities of the effluent discharge location, in the form of odors and unsightliness, can add to environmental degradation of the area.

Practically nothing is known of the effects on the water quality and biota of the many fish processing plants in the Prince Rupert area. The only publications found that even mentioned the problem were those by Drinnan (1974), on the intertidal beach-biology of Prince Rupert Harbour and other nearby bodies of water, and Drinnan and Webster (1974), on the water quality of the same areas.

Drinnan (1974) noted that the eastern shore of Prince Rupert Harbour was the area most affected by the fish processing plant effluents, particularly those areas closest to the outfalls, many of which were covered in deposits of decaying organic matter and silt. A similar situation was found in the northern region of the Porpoise Harbour intertidal zone. As a result, benthic algae and invertebrates were smothered, or were found in only restricted patches with low diversity and biomass. Drinnan felt that, although the effects of fish processing plant discharges were severe when they occurred, the effects were localized and did not tend to spread to areas other than those directly associated with the effluent outfalls.

In their water quality study, Drinnan and Webster (1974) reported seeing fish offal floating near the fish processing plants of Prince Rupert Harbour on at least two separate occasions. However, oil and grease analyses proved negligible, and the problem, in the water column itself, was not thought to be significant.

Since fishing is such an important industry in the Prince Rupert district, it would seem valuable for the effects of the waste discharges from the processing plants to be studied in greater depth than they have been to date. A list of the PCB permitted effluents for the industry in the Skeena area appears in Appendix 11.1.

3. PULP MILLS:

Canadian Cellulose Company Limited operates two pulp mills on Watson Island, between Wainwright Basin and Porpoise Harbour. The first was constructed in 1950, and presently produces 188,000 tons of bleached sulphite pulp annually. The second, a Kraft mill with an annual capacity of 290,000 tons of pulp, opened in 1967. Together, the mills employ over 1,000 people year round, with an annual payroll of over \$11 million. Future expansion plans indicate an increase to 1,600 tons per day, which, if it becomes a reality, would make the establishment the largest centre in the world producing world marketable wood pulps (City of Prince Rupert, 1971).

At present, the two mills have a total of four PCB effluent discharge permits (Appendix 11.1). The effluent from the woodroom is released to Porpoise Harbour, at a maximum allowable rate of 2,300,000 IGD. As well, each mill has a separate effluent outlet to the harbour, with the sulphite mill releasing 32,000,000 IGD, and the Kraft mill discharging 29,000,000 IGD. Finally, red liquor waste is presently discharged into Chatham Sound at a permissible rate of 3,600,000 IGD. At one time this

effluent was also released into Porpoise Harbour.

A complete description of the characteristics of pulp mill wastes and their environmental effects was given in the report on the Squamish River estuary (Hoos and Vold, 1975), and, therefore, only a few general points will be included here. For details, the reader is referred to the aforementioned document, or to Waldichuk (1959, 1970, 1974), or Marier (1973), which give good accounts of the subject.

The Canadian Cellulose sulphite mill produces spent sulphite liquor (SSL) as a waste product from the cooking process, where sulfurous acid and ammonia are added to the wood-chips. SSL contains many organic compounds, including sugars. The main problem associated with organic compounds is their high oxygen demand, which results in the depletion or complete loss of dissolved oxygen in the receiving waters. This, in turn, results in the death of those organisms inhabiting the water and/or the bottom. In addition, some of the sugars themselves may also be toxic to various forms of life (Hoos, pers. comm.).

The Kraft mill process involves an alkaline digestion procedure using sodium hydroxide, sodium sulfate, and sodium sulfide, which, after pulping and washing, results in a residual solution called black liquor. This can be evaporated, and the concentrate burned. The amount of wastes being discharged is, therefore, substantially reduced. The effluent from the Kraft process, although not containing the large amounts of organic compounds found in SSL effluents, is often more toxic, owing to complex organo-sulphur compounds in the condensates and other wastes.

The pulp from both of the above processes is bleached, to some degree, by the addition of chemicals such as chlorine, caustic, calcium, and sodium hypochlorite. These additives can result in a highly toxic bleaching effluent, which,

depending on the stage of the process, is either highly alkaline or acidic.

A great deal of research has been done on the environmental problems associated with the two pulp mills on Watson Island. The first of these studies was carried out by J.W. Stokes for the Federal Fisheries Department, in 1953, shortly after the sulfite mill went into production. Stokes analyzed the dissolved oxygen of the water in Wainwright Basin, Porpoise Harbour, Zanardi Rapids, the entrance to Porpoise Channel, and Chatham Sound. The lowest value ($3.8 \text{ ppm} \equiv \text{mg/l}$) was found in the central portion of Porpoise Harbour, with Wainwright Basin taking a close second ($4.4 \text{ ppm} \equiv \text{mg/l}$). However, at that time the marine life appeared to be relatively unaffected, as mussels, barnacles, hermit crabs, and plankton were abundant in Porpoise Harbour.

Nothing more was done regarding the mill until 1961, when K. Jackson (also with the Fisheries Department) repeated Stokes' 1953 study. Jackson found similar results for dissolved oxygen, indicating, however, that the low dissolved oxygen zone was larger than that found by Stokes (Waldichuk, 1962d).

In that same year, Waldichuk (1962b and d) undertook a more detailed oceanographic survey of the pulp mill area. At that time three outlets discharged effluent into the channel between Watson Island and the mainland (known as Pulpmill Inlet). One pipe released a dark brown, foamy effluent from the bleaching plant, while a second carried the spent sulfite liquor from the mill. The third outlet was for general plant wastes.

Waldichuk found that dissolved oxygen concentrations were low from Porpoise Channel to the north end of Porpoise Harbour, the lowest values ($<0.5 \text{ mg/l} \equiv \text{ppm}$) occurring just off the pulp mill near the deep-sea wharf. Bottom water was found to contain greater amounts of dissolved oxygen, indicating that

this water was replenished more often than was that of intermediate depths.

Other analyses of Porpoise Harbour, such as pH and alkalinity, showed little variation from those of Chatham Sound. Bottom samples contained shells, wood chips, bark fragments and twigs, and were black in colour. Large numbers of amphipods, some isopods, and one sea urchin were found in the harbour.

The shoreline near Zanardi Rapids revealed scattered patches of *Fucus* (rockweed) and barnacles. Amphipods were abundant, several snails and limpets were seen on the rocks, and some shore crabs were found under rocks. A number of dead crabs and herring were found on the shore. No living clams inhabited the mud. In general, the intertidal zone was covered in a grey film, and patches of foam were washed onto the shore.

In Wainwright Basin, the dissolved oxygen was low at all stations, the highest being 3.5 mg/l(= ppm) at one surface station. Near the bottom, values were less than 0.5 mg/l(= ppm). PH values were lower than those of Porpoise Harbour, but not significantly different from that of normal sea water.

Near Zanardi Rapids, in the southwestern part of Wainwright Basin, dissolved oxygen was low (<0.5 mg/l = ppm), but limpets were found living on the shore, and stunted eelgrass grew in small patches. Some dead crabs and herring were found on the shore.

The upper end of Pulpmill Inlet acted as a settling basin for mill wastes, the entire area being covered in a thick deposit of fibres, calcium salts, and other materials. Nothing living was found in the area.

Between 1961 and 1967 no further information regarding

the pollution by the sulfite mill was published. However, with the opening of the Kraft mill in 1967, and the subsequent installation the following year of a red liquor pipeline to Chatham Sound, interest in the area was renewed.

In 1969, Fisheries Service (Goyette, *et al.*, 1970) undertook to analyze the waters of Porpoise Harbour and Wainwright Basin to ascertain the effectiveness of the red liquor line. The study showed a slight improvement in dissolved oxygen concentrations over those found in 1961, but this was not thought to be a great enough change to be significant.

In 1970, when the line was damaged and the red liquor was being discharged to Wainwright Basin, another series of dissolved oxygen analyses were done. The most dramatic finding at this time was that the low dissolved oxygen zone was much greater than normal, extending over $3\frac{1}{2}$ miles from the outfall, to the entrance of Porpoise Channel, where the average level was 3.6 ppm($\equiv$ mg/l). The researchers noted that, while the new line did not allow dissolved oxygen levels in the basin to return to normal, it was successful in preventing the spreading of low levels throughout the harbour, as was found to be the case when the line was broken.

Continuing this work, Goyette *et al.* (1970) did two more surveys during the spring of 1970, when the mills were shut down due to labour problems. It was found, assuming a steady daily increase in dissolved oxygen, that, in twenty days, the oxygen levels in Wainwright Basin increased from approximately 1.0 ppm($\equiv$ mg/l) to 5.9 ppm($\equiv$ mg/l), and seven days later reached 6.9 ppm($\equiv$ mg/l).

As part of the 1970 survey, Goyette *et al.* (1970) measured the area of the fibre bed in Wainwright Basin. It was found to occupy 2.01×10^7 sq. ft., or 53% of the total bottom. The biochemical oxygen demand (BOD) of such a bed was

calculated to be 2,160 lbs. Earlier, Werner (1968) had reported the presence of hydrogen sulfide gas in this area.

When the mills began operation again later in the summer, it took only six days for the dissolved oxygen of the basin to drop from 7.2 ppm($\equiv$ mg/l) to 0.3 ppm($\equiv$ mg/l). Substantial fish kills were recorded throughout the remainder of the summer. The species affected were herring, starry flounder, staghorn sculpin, stickleback, chum smolt, dolly varden, skate, and surf smelt. By August 12, 1970, Wainwright Basin was devoid of oxygen throughout its entire depth (150 ft.).

Intertidal studies carried out in conjunction with the oxygen work indicated that only nematodes and amphipods, along with a few scattered *Fucus* plants, still inhabited the shoreline of Wainwright Basin. Porpoise Harbour was similar, and it was not until one was well out in Porpoise Channel that normal communities were found. However, during the period when the mills were shut down, substantial growths of *Enteromorpha* occurred and a variety of fish were found in the basins. These were, of course, eliminated as soon as the plants resumed production.

In the autumn of 1973, the Environmental Protection Service did a short survey of the Porpoise Harbour - Wainwright Basin area, arriving at the same conclusions made by Waldichuk (1962b and d) in 1961 (Holman, 1973). Dissolved oxygen values in Porpoise Harbour were lower in the surface and intermediate layers than they were at the bottom, while in Wainwright Basin the opposite was the case. Values appeared to increase from Wainwright Basin south, through Porpoise Harbour, to Porpoise Channel.

Based on this preliminary survey, a more detailed study was undertaken in the summer of 1974. Although the results of this work have not yet been published, a few general statements can be made with regard to the red liquor discharge

cove on Ridley Island. The area was found to be completely dead. No living organisms were found in the intertidal zone. In fact, whole clams were found to be "mumified" in the mud - completely intact, but none of them alive (Hoos, pers. comm.).

Beyond the red liquor cove, a transition zone of approximately $\frac{1}{4}$ mile found, in which a few barnacles, limpets, mussels etc. inhabited the rocks of the intertidal area. However, organisms usually having hard calcareous shells were found to be very fragile, and the slightest pressure would shatter them. Beyond this region normal biotic communities were found (Hoos, pers. comm.).

Pictures taken of the discharge cove during this study show a fountain-like bubble of reddish-brown water rising in the middle of a small bay. Around the central "bubble" are concentric circles of thick foam. Aesthetically, the sight is very displeasing. It was later learned that this was an unusual circumstance caused by a break in the diffuser line.

Another study, undertaken in the summer of 1973, was a series of analyses done by the PCB to analyze the water quality (Drinnan and Webster, 1974) and the biological communities (Drinnan, 1974) of the pulp mill area.

Water quality analyses (Drinnan and Webster, 1974) were carried out on Porpoise Harbour, Wainwright Basin, Porpoise Channel, and the red liquor discharge cove in Chatham Sound. Field notes made in April indicated that the waters of Wainwright Basin were noticeably brown in colour on occasion, as was Porpoise Harbour, but to a lesser degree. Surface wood debris, sometimes extensive, was found in both areas, and gas bubbles from the decomposition of benthic deposits were seen rising to the surface of Wainwright Basin. The red liquor discharge cove was found to be a "rich orange-brown colour", covered in several inches of foam. The coloured plume appeared to be moving south

along the shore.

The pH was found to be lower in enclosed areas of Porpoise Harbour and Wainwright Basin, than values in open locations. In the red liquor plume, the pH fell to 3.0 over the outfall, but was nearly neutral (7.0-7.3) on the plume's periphery.

Dissolved oxygen values were greatest (84-96% saturation) in Chatham Sound, away from the discharge cove, while the lowest levels were found in Porpoise Harbour and Wainwright Basin (31-55% saturation). On the edge of the red liquor plume, concentrations were between these two extremes (approximately 70% saturation).

Phosphate and nitrate values decreased from Porpoise Harbour to Wainwright Basin, where the lowest concentrations were found (0.012-0.036 mg/l and 0.06 to 0.17 mg/l, respectively). Over the liquor outfall, the phosphate value jumped to 10.79 mg/l, while nitrate was not measured. Ammonia levels were less than 0.02 mg/l at all stations except in the liquor plume, where they ranged from 0.1 to 1.0 mg/l.

Total organic carbon levels were greatest in Porpoise Harbour and Wainwright Basin, with the exception of the discharge cove, where an extremely high value of 2188 mg/l was recorded over the outfall.

Similarly, colour values were generally less than 10 units, but in the discharge cove they ranged from 20 to 40 units on the outer edge, to 8400 units over the outfall. Values of 20 to 60 units were recorded in Porpoise Harbour and Wainwright Basin.

In general, the above results were representative of those obtained throughout the summer's study, when one takes

changes in phytoplankton activity and increasing temperatures into account.

Drinnan's study (1974) on the intertidal biology of the pulp mill area serves to illustrate the present status of the biological communities located within the area of influence of the mill effluents.

Drinnan indicated that the shores of Wainwright Basin, Porpoise Harbour, and Morse Basin close to Galloway Rapids were adversely affected, some severely by the mill effluents. As well, the red liquor discharge cove was badly affected, the affected area extending along the beach northward from the out-fall for 1/2 to 3/4 of a mile.

In general, there was an inverse relationship between the number of algal species found and the degree of pollution. Areas with little or no visible damage had an average of 13 algal species, while moderately to highly polluted locations had averages of 9 to 4 species.

Red and brown algae were more often found in relatively unpolluted areas, while green species were associated with a variety of environmental conditions. The reader is referred to the Flora section of this text for details of the exact species involved.

A similar situation was found with the invertebrate fauna of the intertidal zone. Certain species were pollution-sensitive, including sponges, sea anemones, shore crabs, edible crabs, large barnacles, rock whelks, urchins, starfish, and sea cucumbers. Others, such as nereid worms, hermit crabs, limpets, and chitons, were moderately tolerant of pollution. The very tolerant forms were isopods, amphipods, medium-sized barnacles, littorine snails, and mussels.

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The areas classed as "highly polluted" in Drinnan's study were located in Wainwright Basin, Porpoise Harbour, and the red liquor discharge cove on Ridley Island. In the worst areas, only a few of the hardiest species remained, and the rocks were coated in algal slimes. In the discharge cove itself, nothing at all was found alive. Levings (1974) reported the same fact.

It is the opinion of most of the researchers working in the Prince Rupert district that the Canadian Cellulose pulp mills are the greatest environmental pollution problems in the estuary area today. Should the company be allowed to expand its activities without greater effluent control, it would only be a matter of time until the whole coast of Ridley Island, as well as Porpoise Harbour, Wainwright Basin, and other nearby water bodies, were completely devoid of life.

4. LOG HANDLING AND LOG STORAGE:

The Skeena estuary and drainage basin fall within the Prince Rupert forest district. Timber rights to large tracts of the forests of the basin belong to the Canadian Cellulose Company, which operates the two pulp mills located on Watson Island near Prince Rupert. The company has two tree licenses. The first, for 892,000 productive acres, was granted in the late 1940's to supply the timber needs of the sulfite mill. The second, for a further 1,400,000 acres, was obtained prior to the opening of the Kraft mill in 1967 (City of Prince Rupert, 1971).

Log supply for both mills is handled by Twinriver Timber Limited, a subsidiary of Canadian Cellulose, from Terrace, British Columbia. Logs from the interior are shipped to Watson Island via the Canadian National Railway, using 37,000 cars annually. Additional logs are rafted from along the coast and are boomed near the mill (City of Prince Rupert, 1971) (see Figure 11.1).

In addition to Canadian Cellulose's activities, Prince Rupert Forest Products Ltd. operates a sawmill on Prince Rupert Harbour, the effluent from which has large amounts of suspended solids and is quite toxic (Environmental Protection Service, 1975).

As well, Northwood Pulp and Timber (formerly Bulkley Valley Forest Industries), at Houston, have run a large sawmill since 1970, and recent expansion included a plywood plant (City of Prince Rupert, 1971; Hallam, pers. comm.).

Logging, log handling, and log storage practices can have various effects on the environment, be it terrestrial or aquatic. These affects can then have ramifications throughout the biotic populations of the area. As these effects were discussed in detail in the Squamish River estuary report (Hoos and Vold, 1975), they will not be dealt with again here. The reader is referred to the aforementioned report and to the bibliography for more information.

5. CHEMICAL INDUSTRY:

To supply the Canadian Cellulose pulp mills with chlorine and caustic, Canadian Occidental Petroleum Limited, Hooker Chemical Division, operates a small chemical storage plant on Porpoise Harbour. The characteristics of the plant's effluent appear in Appendix 11.1.

No information regarding the effects of the effluent on the Porpoise Harbour environment was found, but, as the area is already severely polluted due to the wastes from the mills themselves, it is highly likely that any problem resulting from the chemical plant's discharge would be masked by that of the pulp mill effluents.

6. WASTES FROM RECREATIONAL ACTIVITIES:

Boat ramps are located within Prince Rupert Harbour and at Galloway Rapids, to serve the needs of marine-oriented recreational boating. In addition, several of the lakes and camping areas near Prince Rupert have boating facilities, including Digby Island, Prudhomme Lake, Salt Lake, Oliver Lake, Rainbow Lake, and Kloiya Bay (B.C. Fish and Wildlife, no date).

The detrimental effects of marinas on the aquatic environment, as noted in the Squamish River estuary report (Hoos and Vold, 1975), can be considerable. Although it has not been documented, it is highly unlikely that any of the above areas have become polluted as a result of recreational activity. However, should the tourist industry expand, as some groups have predicted it will, the possibility of such a problem occurring could be increased.

7. SHIPPING WASTES:

Prince Rupert is an important seaport. It is the southern terminus of the Alaska Ferry system, the northern terminus of the British Columbia Ferry Authority, and the home of one of the province's largest fishing fleets. Also, it is a stop for the Northland Navigation shipping company and during the summer, a port-of-call for four or five cruise ships per week. Tugs are active in the area hauling barges or log booms, and ten or twelve freighters dock each month. All of these vessels may contribute shipping wastes to the harbour and nearby waters (B.C. Fish and Wildlife, no date).

Most of the above list of vessels do not, or are not permitted by law to, pump their bilges in the harbour. Therefore, most of the waste released from them would be sewage. As well, fish boats wash out their holds or fish pens after unloading their catch. Waste from this procedure would contain blood, slime, and scales, along with any washing detergents employed

in the clean-up. In addition, there are the inevitable fuel leaks and spills, and the occasional loss of oil or cargo.

At the present time these wastes are not a problem. As noted in the previous sub-sections of this chapter, sewage and fish processing wastes are already released by the city and the fishing industry. The only discharges that could pose serious problems are fuel leaks and oil spills. Should large tankers be used to transport oil from Alaska to Seattle, the possibility of a major catastrophe is very real. As well, if bulk shipping from the Prince Rupert area becomes a reality, the threat is even greater. A recent report by B.R. Hinton and Associates Ltd. (1975) summarized the effects of oil pollution on the environment, and attempted to determine the possible number and size of spills expected, should a bulk loading facility be installed.

In general, the detrimental effects on the environment include smothering of benthos, coating and smothering of plankton, suffocation and surface fouling of the gills of fish, physical prevention of surface reoxygenation of waters causing lowered dissolved oxygen concentrations and secondary suffocation of aquatic organisms, reduced light penetration and subsequent losses of phytoplankton production, coating of waterfowl and shorebirds preventing flight, loss of natural protective feather oils on coated birds often resulting in pneumonia and death, and inclusion in the food chains of undesirable substances resulting from the chemical breakdown of oil.

Using the rate of shipping accidents and ship movements of Vancouver as a guide, the researchers estimated for the Prince Rupert region an average of less than 1.75 oil spills of over 20 barrels (840 gallons) per year which would cause detrimental environmental effects. One tenth of these were postulated as occurring in the Port Simpson area or Chatham Sound. In addition, based on known ship collisions for the region at present,

a major spill could be expected once every 25 years.

Using all of the available data, Hinton *et al.* (1975) indicated that Port Simpson would be the best site for port development from the viewpoint of oil spill threats, since it would require about 10% fewer ship movements, it has no major ship traffic at present, and its wind, current, and approach characteristics are better than those of Ridley and/or Kitson islands. The oil spill threat for Port Simpson was calculated at one ship collision per 35 years and an average of 0.8 other oil spills of over 20 barrels.

8. MINING:

The Skeena drainage basin contains extensive ore deposits, as illustrated by the gold rush in the 1870's. The number of claims in the Skeena and Omineca mining districts is impressive (see Appendix 11.2). Despite the huge number of claims, however, only three mines in the Skeena drainage are presently producing.

Granisle Mine, owned by Granisle Copper Limited, is located on McDonald (or Copper) Island in Babine Lake. The main ore being mined, since production began in 1966, is copper, with lesser amounts of silver and gold also being removed (B.C. Dept. Mines, Petro.. Res., 1972). When the mine first began, it discharged its tailings directly into Babine Lake (see Appendix 11.1). Tailings are now impounded and the process water is recycled, although at least one spill over the tailings dam has occurred (Hallam, pers. comm.).

Noranda Mines limited (Bell Copper Division) owns the Bell (or Newman) Mine, located on the tip of the Newman Peninsula on Babine Lake. The mine has been producing copper, along with small amounts of gold, since it became operational in 1972 (B.C. Dept. Mines, Petrol. Res., 1972). Initially, tailings were discharged to Workburn Lake. This pond is now filled with

tailings, and the mine has switched to a total recycle system (Hallam, pers. comm.).

The final producing mine in the Skeena drainage is the Cronin Mine, located on Cronin Creek near Smithers, and presently owned by Hallmark Resources Limited. This mine, producing since 1969, removes gold, silver, lead, zinc, and cadmium (B.C. Dept. Mines, Petrol. Res., 1972). The mine was originally owned by Kindrat Mines Ltd., and at this time, mine tailings were released directly to Cronin Creek. Large fish kills occurred in 1971, resulting in the installation of crude tailings impoundments. However, these proved inadequate. The new owners have done much to improve the pollution abatement facilities, installing a seepage reclaim system, with new and better tailings impoundments. These enclosures are, however, only good for two years (Hallam, *et al.*, 1975).

Table 11.1 summarizes the types and quantities of ore produced annually by these three mines.

In addition to these producing mines, four other mines, with a possible production of over 5,000 tons/day each, have been proposed in the Skeena drainage system. These are Sustut Copper on the Sustut River, Glacial Gulch on the Bulkley River, Equity Mining Capital Ltd. on the Bulkley system, and Morrison Copper on the Morrison River (Hallam, pers. comm.).

The pollution hazards inherent in the mine wastes include dissolved metals and metallic salts which are often toxic to biota, turbidity of receiving waters due to suspended solids which inhibit photosynthesis by reducing available light, and smother benthic life when the suspended particles finally settle out of solution, and in, in some cases, discolouration of the receiving waters.

The detrimental effects of mine pollution were dealt

Table 11.1. Producing mines of the Skeena drainage basin together with pertinent information on annual production (B.C. Dept. Mines, Petrol. Res., 1972).

Mine	Location	Owner	Ore Shipped (Tons/yr)	Product	Au (oz.)	Ag (oz.)	Cu (lb.)	Pb (lb.)	Zn (lb.)	Cd. (lb.)
Cronin	Cronin Creek near Smithers	Hallmark Resources Ltd.	700	Lead concentrates: 76 Tons. Zinc concentrates: 82 Tons.	10	8,865	-	99,089	105,034	1,228
Granisle	McDonald Island, Babine Lake	Granisle Copper Ltd.	2,537,138	Copper concentrates: 35,648 Tons	12,234	121,810	24,909,713	-	-	-
Bell (Newman)	Newman Peninsula, Babine Lake	Noranda Mines Ltd. (Bell Copper Division)	767,270	Copper concentrates 11,823 Tons	3,630	-	6,397,979	-	-	-

with in detail in the Squamish River estuary report (Hoos and Vold, 1975) in relation to Britannia Mine in Howe Sound. Although the mines of the Skeena system are all located on fresh water, the effects on the environment would be very similar. At present, two of the three producing mines are self-contained. This should also be the case with the four proposed mines, thus reducing the possibility of more fish kills similar to those documented at the Cronin site.

9. CEMENT OPERATIONS:

Ocean Cement Northern Ltd. operates a cement plant on the banks of the Skeena at Terrace, British Columbia. Although they do use a settling pond to remove much of the suspended particles in their rinse water (from the ready-mix process), a certain amount remains and is discharged to the river.

As noted in the Squamish River estuary report (Hoos and Vold, 1975), the deleterious effects of such a discharge are the same as those for any suspended solid - turbidity, loss of photosynthetic ability due to reduced light, smothering of benthos, clogging of gills, etc. Whether or not the cement operation is having these effects on the receiving area is not presently known.

11 (ii) AIR POLLUTION

As the entire area of the Skeena district, covering over 6,000 sq. mi., had an estimated population of only 15,500 in 1969, it is highly unlikely that the emissions from domestic, automobile, and diesel fuels, sewage, or refuse could be significant (B.C. Research, 1970). However, industrial emissions, particularly from the Canadian Cellulose pulp mills, could be quite the opposite. One is referred to the Climatology section of this report for the atmospheric conditions required for air pollutants to become hazardous.

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The most visible air pollution problem at Prince Rupert is the Prince Rupert Forest Products Ltd. sawmill burner. Hydrocarbons, carbon monoxide, and particulates are released through the burning of material in the "wigwam" burner, reported to be one of the largest in Canada. In addition, sander dust and sawdust are emitted, along with noise and odors (B.C. Research, 1970). Similar pollution problems can be expected at other sawmill operations throughout the Skeena drainage basin.

Other industrial sources of particulate emissions include a concrete mix plant at Terrace (Ocean Cement Northern Ltd.), and an asphalt plant and grain elevator at Prince Rupert. The grain elevator has recently come under public attack with respect to its dust emissions, and efforts are presently being expended on control measures (Wituschek, pers. comm.).

The fish processing operations and, in particular, the herring reduction plants, regularly emit very strong, obnoxious odors which can be almost nauseating on a warm, calm day (Hoos, pers. comm.). In addition to the odor, fish processing plant emissions are characterized by containing carbon monoxide, carbon dioxide, sulphur dioxide, nitrite particulates, and water vapour. Appendix 11.3 contains a list of the PCB emission permits for fish processing plants of the estuary area.

Probably the most environmentally deleterious sources of air pollution on the estuary are the pulp mills located on Watson Island. Between the two mills, Canadian Cellulose has eighteen discharge outlets for air emissions (see Appendix 11.3). The types of substances released include fly ash, carbon dioxide, water vapour, sodium sulphate, sodium chloride, hydrogen sulphide, sulphur dioxide, CH_3SH , Me_2S , Me_2S_2 , MeSH , CaO_2 , chlorine, ClO_2 , pulp fibre, and caustic. In addition, the gases being released may be heated to as high as 323°F (Environ. Prot. Serv., 1975). Such emissions can cause corrosion, reduced visibility, damage to vegetation, irritation to the eyes and/or nose, and can generally

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be considered a health hazard (B.C. Research, 1970).

No information is available concerning the emissions from the mines operating in the Skeena drainage system. As noted by B.C. Research (1970), the main product would be dust from blasting, drilling, transport, crushing, and grinding. Gaseous emissions may contain sulphur compounds, blasting gases, and hydrocarbons from machinery.

12. PROPOSED PORT DEVELOPMENT

Prince Rupert is Canada's most northern and western port. It is serviced by the Canadian National Railway and provincial highway number 16, both of which pass through a vast area of forest and mineral wealth comprising the Skeena River drainage basin. With growing industrialization of this area, and increased demand for Canadian raw materials by Japan and other nations, much interest has been generated in the development of Prince Rupert as a major port for the handling of both bulk and general cargoes.

Needless to say, such development would require a large area of land. The environmental effects of such a project have caused concern amongst public and private citizens alike, and have formed the basis of various reports on the subject.

12 (i) HISTORICAL PERSPECTIVE

As far back as 1903, the future of Prince Rupert as a bustling seaport was envisaged by C.M. Hays, the "father of Prince Rupert". It was his dream to see a city of 50,000 inhabitants grow out of his plan to build the Grand Trunk Pacific Railway. However, the large city failed to materialize, and during the following half century the city nearly became a ghost town on several occasions.

In 1965, C.B.A. Engineering Ltd. was commissioned by the Canadian National Railway to do a feasibility study into the possibility of developing Ridley Island as a bulk terminal. The report, written for the study, indicated that the northwest side of the island was a suitable site for development from a land-availability point of view, although a considerable amount of rock cut and fill would be required to make the initial 60 acres, and

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eventual 80 to 100 acres, useable. However, due to its exposed location, the report recommended that more hydrological data be obtained before proceeding. As well, a Port Authority was needed to provide overall guidance for the port redevelopment and in-harbour operation, including business promotion (C.B.A. Engineering Ltd., 1969).

Shortly thereafter, the City of Prince Rupert Port Development Commission was established. In 1969, this body contracted C.B.A. Engineering Ltd. to do a follow-up study to the initial feasibility work. The second report (C.B.A. Engineering Ltd., 1969) confirmed their earlier findings. Since the commodity to be shipped was unknown, the plans emphasized flexibility.

Coal was used as a base commodity, the idea being that, if the port could handle coal shipping, it could also handle iron ore, potash, or any other similar cargo. The development was based on coal being shipped to the port in unit trains approximately 5,000 feet long. This would require a rail loop of 10,000 feet, centered around a railroad car-dumper.

No breakwater was to be built. A support structure for a shiploader would be constructed, along with a buoy-type anchoring system for two berths.

A branch rail-line would be extended from the Canadian National line to convey the cargo to the loading area. As well, a road connecting with Highway 16 would be built to accommodate large trucks loaded with bulk cargo.

A water supply would be required, along with a power line from the B.C. Hydro facilities in the Port Edward area. Finally, the red liquor discharge pipe from the Canadian Cellulose pulp mill on Watson Island would have to be moved, as it would cut through the middle of the proposed site.

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The feasibility of the entire project relied on obtaining land fill at a cheaper price than that required for excavating rock. The source was to have been the sand flats of the Skeena River estuary (C.B.A. Engineering, 1969).

For some reason the entire project was shelved. In 1971, a private firm, Maui Enterprises Ltd., produced a report proposing to develop the Kitson Island - Flora Bank area as a bulk loading port facility. The project would ultimately have taken more than 3,000 acres of Skeena estuary. This caused concern amongst the regulatory agencies over-seeing the harbour, with the result that, in 1972, Prince Rupert was declared a national port, falling under the jurisdiction of the National Harbours Board. The port boundaries were established such that the Kitson Island site fell within the Board's control, and the private project was effectively stopped (Dept. Environ., 1973a and b).

The National Harbours Board then hired Wright Engineers Limited (1972) to review and up-date the previous studies and to recommend changes to the port to meet the needs of the present and foreseeable future. In making their recommendations, Wright Engineers relied on two reports, one by Hedlin Menzies and Associates Ltd. (1970) and a second by M.W. Menzies Group Ltd. (1971), for cargo volume projections and information on expansion of rail facilities. Among the conclusions and recommendations contained in the Wright Engineers' report were the following points.

The major potential for Prince Rupert's economy was in the mineral and forest resources of the north. To develop these resources, an expansion of transportation infrastructure was essential. The predicted movement of commodities (in long tons per year) was 2,287,000 by 1975, and 8,580,000 by 1985. In addition, a projected tonnage of 440,000 tons was possible for northern pipeline construction. The port and associated industrial development in the area would generate an additional

direct personal income greater than \$7 million per annum.

The report stressed the need for two separate deep-sea terminals in the area - one for bulk cargoes and the other for general commodities. The most urgent of these was the general terminal, which would consist of a 40-acre marginal wharf with a marshalling yard. The wharf would provide 1,400 feet of berthing space, with a water depth of 45 feet. Expansion of the wharf to 2,000 feet on 68 acres could be expected.

Four sites were indicated as potential locations for port development, including the Prince Rupert drydock, Fairview, Ridley Island, and Kitson Island. The first two of these were projected as general cargo terminal sites, while the final two were viewed as bulk loading terminal sites. The Fairview site was indicated as the best location for the general terminal; while Ridley Island was proposed for the bulk facility, which, it was speculated, would not be required until 1980.

The Fairview general cargo facility is presently under construction (Swan Wooster, 1974).

Shortly after Wright Engineers released their report, Rathie (1972), of the National Harbours Board, carried out a comparison study of the Prince Rupert-Ridley Island bulk site with that of the Squamish River estuary, which was also being discussed as a potential port location for a coal terminal (Hoos and Vold, 1975). The study was based on the premise that the Sukunka coal fields were to be opened up, and concluded that the Prince Rupert site would be the most efficient and economical destination for the coal.

No exact site has yet been determined for the bulk loading facility.

12 (ii) ENVIRONMENTAL STUDIES

When the first Kitson Island - Flora Bank proposal became known, the federal Fisheries Service (1972) did a cursory survey of the biological productivity of the Skeena River estuary. Their results indicated that Flora Bank supported between 50 and 60 percent of the total eelgrass of the estuary. It was also an important feeding and resting area for fish stocks of the Skeena system, and as such, was very important to the fishing industry of the region.

At about the same time as the Wright Engineers' study was completed in 1972, the Fisheries Service (Higgins and Schouwenburg, 1973) concluded a much more detailed study of the Skeena River estuary fish populations to identify the interrelationships between the fish species and their estuary habitats, in the hope that the impact of port development on the fisheries could be determined.

Subsequently, F.F. Slaney and Company (1973) was contracted by the Department of the Environment to compile data on other aspects of the biota of the potential port sites, with the same goal in mind - to determine the effects of port development on the ecosystems involved.

The two reports were released under one cover by the Department of Environment (1973b and c). Some of their results and recommendations regarding sites within the Skeena estuary follow.

Development of the Ridley Island site would require the removal of shoreline vegetation and soils, and the excavation of part of the bedrock scarp immediately behind the shore. Any construction in the middle of the island would require the boggy land to be filled. The shoreline vegetation is not heavily utilized by wildlife, while the deer population is the only community

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of large enough size in the bog area to warrant concern. Therefore, the researchers did not feel the environmental effects of loss of this habitat would be substantial in terms of the entire estuary, should the port be constructed on Ridley Island.

The result was similar for the aquatic environment off the Ridley Island site. Intertidal biota were found to be sparse, so that the filling and dredging required for the port facilities would not be destroying any vital organisms. It was felt that the effects on fish and waterfowl would also be minimal, except in the case of possible water contamination by oil, toxic chemicals, dust, etc.

Air pollution was thought to be a significant cause for concern. Combined with the already substantial emissions from the Watson Island pulp mills, coal dust could become a serious problem. However, it was felt that the implementation of dust control measures could overcome this difficulty.

Kitson Island was indicated as being a potential site for future recreational development in conjunction with the Flora Bank fishery resource. This was determined to be completely incompatible with port development.

The biggest concern, however, was the construction of a causeway from Lelu Island, across Flora Bank, to Kitson Island. Large segments of the banks would be unreachable by fish larvae, which presently use the abundant eelgrass of the area for feeding and protection. Flushing action of the Skeena across parts of the bank would be eliminated, while the usual current and tidal flow patterns would be disrupted. These flow changes would also cause the salinity regime to be altered such that the water north of the causeway would become more saline, while on the south side it would be less saline. As well, patterns of sedimentation would be disrupted. Needless to say, all of these physical environmental changes would have biological

ramifications throughout the estuary ecosystem.

The third proposed site for a bulk terminal was at Fairview, located on the southern edge of Prince Rupert, and already being developed as a general cargo terminal. The area remaining was considered too small to support the bulk facility and still provide sufficient back-up land for expansion. Before construction could even begin, a segment of shoreline would have to be completely stripped of vegetation and surface soils, resulting in the loss of some wildlife habitat (particularly for bald eagles), disruption of surface drainage patterns, increase in landslide potential, and the disruption of the scenery of the area.

The aquatic changes at Fairview would include bathymetry alterations offshore due to filling, increased turbidity due to dredging and runoff, and destruction of benthic communities due to smothering. A greater threat would be that of possible oil spills after the port was operational.

The report by F.F. Slaney (1973) contains a step-by-step outline of port construction at each site, and the possible effects each stage might have on various aspects of the area's environment. The reader is referred to the original report for these details.

12 (iii) PRESENT STATUS

Prompted by these environmental studies, the provincial government hired H. Paish and Associates Limited to appraise the work done to date (Paish, *et al.*, 1973). The federal government was dissatisfied with Paish's report, and on the advice of a Department of Environment Steering Committee on Prince Rupert, proposed that a federal-provincial committee be established to deal with the entire question of a site for the bulk terminal.

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The result, in the summer of 1974, was the formation of a four-member joint Federal-Provincial Committee on Prince Rupert Port Study.

In August, 1974, the joint committee contracted Swan Wooster Engineering to undertake phase I of the project, to select possible bulk terminal sites for environmental analysis, based on engineering data (Swan Wooster, 1974). Three factors to be taken into account in site location were land transportation (access by rail and road), ocean transportation (easy access and room for three or more berths with water depths of 65 ft. and 45 ft.), and site development (reasonably level ground of about 100 acres, measuring 800-1200 ft. wide by 5400-3600 ft. long).

Using these criteria, three zones were designated by topography - the Skeena River, Work Channel, and the outer coast. The Skeena River zone was ruled out because of the high sediment load carried by the river, which would require constant dredging to maintain channels deep enough for vessels to move easily.

Work Channel was eliminated owing to the very narrow channel entrance and strong tidal currents in the area. The long, restricted channel would make safe navigation to the port very difficult. As well, the grade would be too steep for railway lines along the channel.

The outer coastal zone was sub-divided into three regions, including the area from the northern tip of the Tsimpsean peninsula to Digby Island, Prince Rupert Harbour, and the area between Digby and Smith islands. The northern-most section was eliminated, except in the area of Port Simpson, because of poor accessibility from both land and sea. The other two sections were deemed to be possible bulk terminal sites.

Within the entire coastal zone, ten possible terminal

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sites were designated. These were Port Simpson, Smith Island, Kitson Island (Flora Bank), Ridley Island, Digby Island, Melville Arm, Bacon Cove, Schreiber Point, Pethick Point, and Osborne Cove. After careful scrutiny, only three proposed sites met all of the criteria for port development - Port Simpson, Kitson Island, and Ridley Island.

These three sites were then further analyzed to determine "present worth values", based on the four criteria of land transportation, ocean transportation, site development, and materials handling. When considering the last of these, it was proposed that Fairview Point be added to the above list as a site for handling commodities other than coal, while coal products would be handled from either a Ridley or Kitson Island site.

The final cost analysis and final conclusion, from an engineering standpoint, was that a Ridley Island site alone, or a Ridley Island - Fairview Point split site, was preferable over the other possibilities.

The second phase of the federal-provincial port study was contracted to B.R. Hinton and Associates, who headed a group of sixteen consulting firms known as the Northcoast Environmental Analysis Team (NEAT). The team undertook to identify the possible physical, sociological, and environmental ramifications of port development at each of the ten possible sites indicated in the phase I engineering study, and to then rate each site for development suitability. As well, they attempted to evaluate the capital cost for development of highly rated locations, and recommended mitigating measures and specific investigations required on highly rated sites. The results and recommendations were compiled into five volumes - a main report containing general information on the overall study and the team's ratings and recommendations, and four appendices on the detailed studies carried out. A sixth volume containing maps and a reprint of the

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initial engineering report (Swan Wooster, 1974) make a total of seven documents assessing the possible port sites.

The findings of the individual NEAT members have been discussed throughout this report under their appropriate topics. The following presents the conclusions of the entire project, as found in the main report, by B.R. Hinton and Associates (1975a). The reader is referred to the original six documents for details of the studies on which these recommendations are made.

The engineering report initially ruled out sites in Work Channel, along the Skeena River, and along the outer coast of the Tsimpsean peninsula. Based on land access, ocean access, and cost, Ridley Island was singled out as the preferred site in phase I of the study.

The environmental studies indicated that development of Kitson Island and adjacent Flora Bank would have a detrimental effect on important anadromous fish and waterfowl populations, and, therefore, these areas were judged environmentally unacceptable.

From a regional environmental value standpoint, the most sensitive and valuable areas were located around Flora Bank (salmon and waterfowl habitats), in the western end of Prince Rupert Harbour, and along the west coast of the Tsimpsean peninsula (herring, waterfowl, and possibly salmon habitats).

Local impacts of development at Ridley Island or Port Simpson were felt to be small and about equal, but the probability of pollution related problems at the Ridley sites were much greater than those at Port Simpson. No matter which of these two sites was developed, large ships entering the ports at the southern sites would have to use Port Simpson for anchorage. As well, development of the Ridley sites would mean that large ships would be moving in and out of Chatham Sound just off the

most ecologically valuable part of the study area. Ships going to a development at Port Simpson, on the other hand, would probably approach via the north end of Chatham Sound, thus avoiding the ecologically-sensitive areas of Kitson Island, Flora Bank, Big Bay and Pearl Harbour. It was indicated that any surface water pollution originating at or near Ridley or Kitson islands would be carried northward towards Venn Passage, Big Bay, and Pearl Harbour, with resulting destruction of waterfowl and herding habitats. However, surface pollution from a port at Port Simpson would be carried westward, out to sea.

Consideration of available land indicated that Port Simpson was the best site for major port development, despite high costs for access. The higher land development prices of southern sites balanced with Port Simpson access costs, when the large scale of the development was taken into account.

The final conclusion of the study was that Port Simpson would be the best site for a bulk-loading development on purely environmental grounds. When all relevant factors were weighed, Ridley and Port Simpson were felt to be about equal. NEAT recommended that the choice of a site not be made until industrial development studies were completed. For the Prince Rupert area, the probable site for a combined port and industrial complex would, in all likelihood, be Port Simpson. Should no heavy industry be envisioned for the region, the site choice would depend on local opinions after all of the options had been explained. In this case, the working assumption was indicated to be that Ridley Island was the site of choice for a bulk-loading facility alone.

Based on the engineering and environmental data gathered for phases I and II of this study, and the regional plans of the province for development and urbanization of the north coast, it is hoped that a sound decision regarding the location of the bulk terminal site will be made.

13. CONCLUSION

The Skeena River forms the most northerly and westerly estuary of Canada's Pacific mainland coast. Located within its zone of influence is the city of Prince Rupert. This is the southern-most terminus of the Alaska Ferry System, and the northern-most terminus of the British Columbia Ferry Authority. As well, it is the closest port to the abundant forest and mineral resources of British Columbia's northland, and services one of the province's largest fishing fleets.

As such, the Skeena region has come under increased pressure for greater industrial development. For example, a large general cargo loading facility is presently under construction in the area, while various other sites are being scrutinized for possible bulk-loading terminal development. These are only two of the many recent proposals for changes in the estuary area.

However, like the other estuaries analyzed for this report series (Hoos and Packman, 1974; Hoos and Vold, 1975), that of the Skeena also supports valuable fish populations, which, in turn, form the backbone of the region's fishing industry. The fish rely on the eelgrass and mudflats for food and protection during various life-cycle stages, while other forms of life depend on both the fish and the vegetation for their existence.

To date, the flora and fauna of the Skeena estuary area have been relatively unaffected by the manmade alterations to their habitats. The glaring exceptions are the region of Ridley Island receiving red liquor wastes, and Porpoise Harbour and Wainwright Basin, into which other Canadian Cellulose pulp mill effluents are released. It is, therefore, increasingly important that further development of the estuary vicinity only

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proceed after much detailed study of the possible detrimental environmental effects has been done.

As indicated in the text of this report and others of this series, it should be possible to make use of the Skeena drainage basin and estuary in another manner that does not harm the natural inhabitants of the region - that is, recreationally. The abundant fish, diverse wildlife, and rugged scenic beauty of the area make it an ideal recreational resource. The use of these resources will gain in importance as the human populations of British Columbia have more leisure time, mobility, and income and grow to recognize the potential of the Skeena River region for consumptive and non-consumptive recreational pursuits.

14. APPENDICES

187. Appendices - Sources

Appendix 1.1. Sources of Information.

The references and data used in this summary of environmental information on the Skeena estuary were gathered from many sources, particularly the members of the Estuary Working Group. The following is a list of other people and agencies that aided in the compilation of literature and/or provided advice and moral support to the author of this report:

(i) Environment Canada (DOE)

1. Environmental Protection Service: Mr. R. Hoos and Mr. R. Hallam provided a variety of information, much of it not yet published.
2. Fisheries and Marine Service, Northern Operations Branch: Mr. W. Schouwenburg and the service library provided valuable information and data.
3. Pacific Environment Institute: Dr. M. Waldichuk and Dr. C. Levings provided information and advice. The PEI library and files were also useful resources.
4. FRB Biological Station, Nanaimo: the publications section provided many reports.
5. Ocean and Aquatic Affairs: Dr. L. Giovando gave helpful advice and information.
6. Atmospheric Environment Service: Mr. G. Schaefer and other staff members compiled the Climatology section for this report.
7. Inland Waters Directorate: various people provided unpublished data and advice on hydrology and water quality.

(ii) Other Sources

1. Geological Survey of Canada: Dr. J. Luternauer wrote much of the geology section of this report. He and Mr. K. Ricker (who compiled the bibliography for the Geology section) also gave helpful advice, while the GSC library and publication service provided various reports.
2. University of British Columbia: all of the libraries were used extensively for a wide variety of subjects.

188. Appendices - Sources

Appendix 1.1. (cont'd).

3. British Columbia Government

- (a) Fish and Wildlife Branch: Mr. B. Pendergast provided advice.
- (b) Environment and Land Use Secretariate: Mr. W. Wolfersten provided valuable information.
- (c) Provincial Museum: Mr. W. Campbell provided information and advice.
- (d) Pollution Control Branch: Dr. L. Regan and Mr. W. Drinnan provided valuable information.

189. Appendices - On-going research

Appendix 1.2. On-going Research of the Skeena River and Its Estuary.

(i) Geology

Dr. J. Clague: Geological Survey of Canada studies of terrestrial sediment distribution and landslide potential along the Skeena River and environs.

Dr. J. Luternauer (Geological Survey of Canada): further analysis of delta sediment samples and seismic profiles, taken during 1974, to discern sediment dispersal routes, areas of sediment deposition, the influence of river discharge/wave climates on delta front erosion-accretion rates, trace metal base levels, etc.

(ii) Climatology

continual monitoring of meteorological data at the various stations located on the Skeena estuary, by the Atmospheric Environment Service.

(iii) Hydrology, Water Quality, and Pollution

continual monitoring of water flow rates and water quality characteristics at various stations on the Skeena River system, by Inland Waters Directorate.

continual monitoring of effluent sources of Prince Rupert and environs, and the Skeena River system, by the Environmental Protection Service and British Columbia Pollution Control Branch.

monitoring of the dissolved oxygen, temperature, salinity, pH, turbidity, tannin and lignin, and total organic carbon at twelve locations (2-8 depths) in the Prince Rupert area this summer by the Pollution Control Branch.

(iv) Biology

Dr. C. D. Levings (P.E.I.): on-going research on amphipod (*Anisogammarus* spp.) ecology in disrupted environments such as in the Port Edward vicinity.

Dr. J. G. Stockner: continued research into primary production in the Babine system.

British Columbia Pollution Control Branch: continued research into the effects of pollutants from industries

190. Appendices - On-going research

Appendix 1.2 (cont'd).

(iv) Biology (cont'd)

in the Prince Rupert region on biotic communities, including periphyton plates (quarterly biomass at 16 locations), chlorophyll (monthly at 12 locations, 2 depths), zooplankton diversity (monthly at 12 locations, 2 depths), effluent bioassays (quarterly on major effluent discharges), benthos (diversity and biomass annually at 6 locations), and intertidal biology (macro-algae diversity annually at 25 locations).

Fisheries and Marine Service and the Biological Station, Nanaimo: continued research into various aspects of the Babine system in relation to salmon production.

(v) General Studies

various feasibility and environmental impact assessments with respect to industrial development of the estuary and environs, including:

- a. Joint Federal-Provincial Committee on Prince Rupert Port Study: contracted Swan Wooster Engineering Company Limited, Vancouver, and B. R. Hinton and Associates Limited, Vancouver, to determine possible bulk-loading facility sites from both engineering and biological/ecological points of view. A final decision regarding this development will depend heavily on this project.
- b. Nippon Kokan K.K.: feasibility study regarding possible development of an integrated steel mill in the Prince Rupert vicinity.
- c. Federal-Provincial General Development Agreement Program: for development of environment and resource inventories in British Columbia, in particular, the northwestern part of the province.

Appendix 4.1.

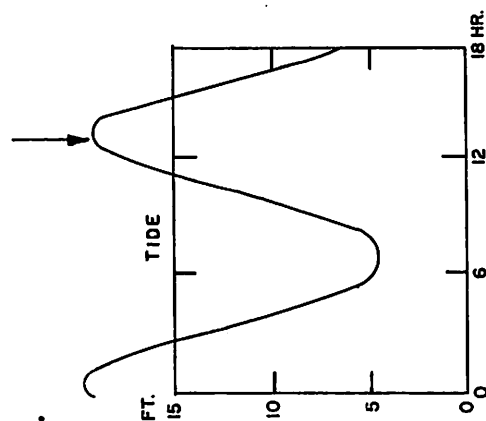
Skeena River Estuary Available Streamflow Data
(Water Survey of Canada, Ottawa).

NAME	GAUGE LOCATION	DISCHARGE RECORD (Stage only *) (Misc. Meas. #)
Skeena River at Usk 0	54 ⁰ 37' 50" 128 ⁰ 25' 40"	28-31, 36-49 50-72
Zymoetz River above O.K. Creek (formerly near Terrace)	54 ⁰ 29' 00" 128 ⁰ 19' 50"	63-72
Zymoetz River near Terrace	54 ⁰ 32' 10" 128 ⁰ 27' 15"	51# 52-64
Kitsumkalum River near Terrace	54 ⁰ 34' 55" 128 ⁰ 39' 37"	28# 29-52
Zymagotitz River near Terrace	54 ⁰ 31' 07" 128 ⁰ 43' 40"	60-72
Lakelse River near Terrace	54 ⁰ 23' 30" 128 ⁰ 31' 40"	48-50 54-55
Williams Creek near Terrace	54 ⁰ 24' 55" 128 ⁰ 31' 59"	49-50#, 53# 54
Schulbuckland Creek near Terrace	54 ⁰ 21' 15" 128 ⁰ 33' 50"	53-55
Exchamsiks River near Terrace	54 ⁰ 21' 47" 129 ⁰ 18' 41"	62-72
Khtada River near Kwinitza	54 ⁰ 09' 53" 129 ⁰ 34' 39"	28-31
Big Falls River near Port Essington	53 ⁰ 59' 02" 129 ⁰ 43' 53"	28-30
Brown Creek near Port Essington	54 ⁰ 01' 37" 129 ⁰ 50' 29"	28-32

Appendix 5.1. Oceanographic Data for Inverness Passage to the Mouth of the Skeena River, on April 18, 1962 (Waldichuk, *et al.*, 1968).

Station: P-28
 Time: 1242
 Date: 18/IV/62
 Lat: 54° 11.7' N
 Long: 130° 15.9' W
 Depth: 92 ft.
 B.T. Ser. No. 36

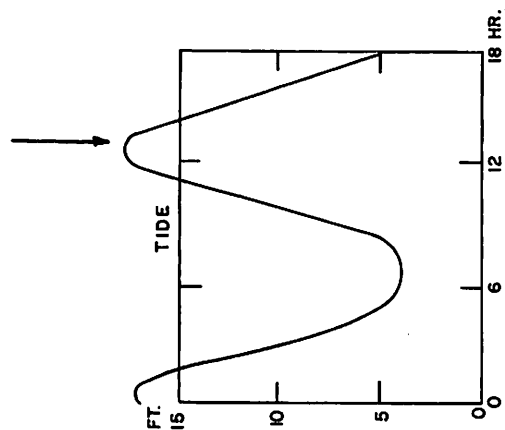
Weather: Clear
 Cloud: Type Cc Amt. 1
 Wind: Dir. 240 OT Spd. 2 mph.
 Sea: 0 Swell: 0
 Air Temp: D. 49 °F. W. 45 °F.
 Baro: 1015 mb.
 Secchi: 6.5 ft. Col: Muddy; green



Depth (m)	T (°C)	S (°/°°)	δt	Dissolved oxygen (mg/l) % sat.	pH	Alkalinity Total Carb.
0	7.2	25.24	19.75	9.94	7.94	1.95
2	6.47	27.42	21.56	9.33	7.93	1.94
4	6.35	28.26	22.21	9.82	7.87	1.98
6	6.28	28.73	22.60	9.57	7.87	1.98
10	6.24	29.15	22.93	8.69	7.87	1.99
15	6.19	29.37	23.11	9.02	7.90	1.99
20	6.15	29.61	23.30	9.11	7.94	2.02
25	6.07	30.14	23.73	9.50	7.96	2.08
						2.04

Appendix 5.1. (cont'd).

Station: P-29
 Time: 1335
 Date: 18/IV/62
 Lat: 54° 10.7' N
 Long: 130° 11.25' W
 Depth: 33 ft.
 B.T. Ser. No. 38
 Weather: Mostly clear
 Cloud: Type Cc Amt. 2
 Wind: Dir. 295 °T Spd. 5 mph.
 Sea: 0 Swell: 0
 Air Temp: D. 50 °F. W. 47 °F.
 Baro: 1015 mb.
 Secchi: 6.5 ft. Col: Green

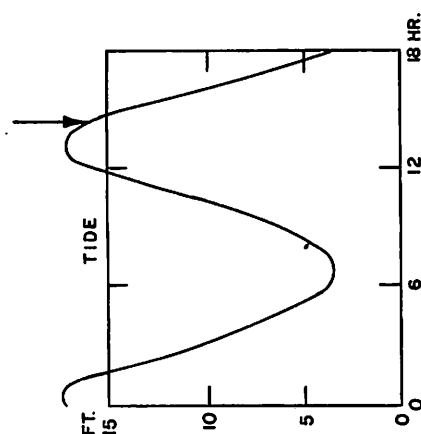


Depth (m)	T (°C)	S (°/°°)	δt	Dissolved oxygen (mg/l) % sat.	pH	Alkalinity Total Carb.
0	8.0	25.12	19.57	10.43	7.92	1.71
2	6.43	26.43	20.78	10.28	7.93	1.79
4	6.35	26.82	21.09	10.28	7.94	1.81
6	6.26	27.03	21.27	10.23	7.93	1.76
8	6.20	27.32	21.50	10.20	7.96	1.73
10	6.16	27.61	21.73	10.14	7.95	1.71
						1.67
						1.68
						1.76
						1.78
						1.73
						1.69
						1.67

Appendix 5.1. (cont'd).

Station: P-30
 Time: 1430
 Date: 18/IV/62
 Lat: 54° 8.0' N
 Long: 130° 6.8' W
 Depth: 69 ft.
 B.T. Ser. No. 37

Weather: Partly cloudy
 Cloud: Type Cc Amt. 5
 Wind: Dir. 295 oT Spd. 5 mph.
 Sea: 0 Swell: 0
 Air Temp: D. 47 °F. W. 45 °F.
 Baro: 1014 mb.
 Secchi: 3 ft. Col: Muddy; green

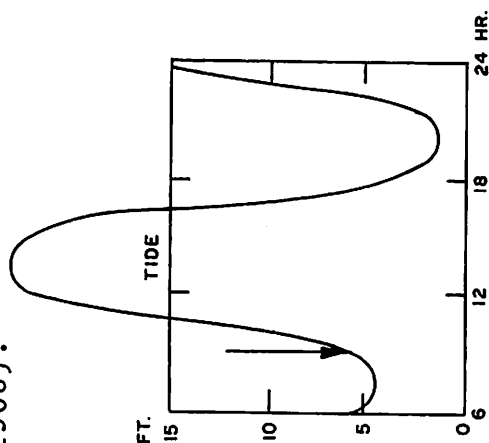


Depth (m)	T (°C)	S (°/∞)	δt	Dissolved oxygen (mg/l) % sat.	pH	Alkalinity Total Carb.
0	7.1	20.21	15.83	11.03	7.94	1.10
2	6.42	21.88	17.20	10.79	7.97	1.27
4	6.26	23.06	18.14	10.68	8.07	1.30
6	6.15	23.99	18.88	10.57	7.96	1.40
10	6.13	24.32	19.16	10.43	7.97	1.47
15	6.11	24.78	19.51	10.26	7.99	1.59
20	6.14	26.96	21.23	10.20	7.98	1.63
						1.00
						1.24
						1.27
						1.37
						1.43
						1.54
						1.59

Appendix 5.2. Oceanographic Data for Inverness Passage to the Mouth of the Skeena River, on October 22, 1964 (Waldichuk, *et al.*, 1968).

Station: P-28
 Time: 0905
 Date: 22/X/64
 Lat.: 54° 11.80' N
 Long: 130° 16.00' W
 Depth: 30 ft.
 B.T. Ser. No. 22

Weather: Rain
 Cloud: Type Ns-Ac Amt. 10
 Wind: Dir. 095 OT Spd. 10 mph.
 Sea: 0 Swell: 0
 Air Temp: D. 48°F. W. 48°F.
 Baro: 1021.5 mb.
 Secchi: 1 ft. Col: Silty; brown

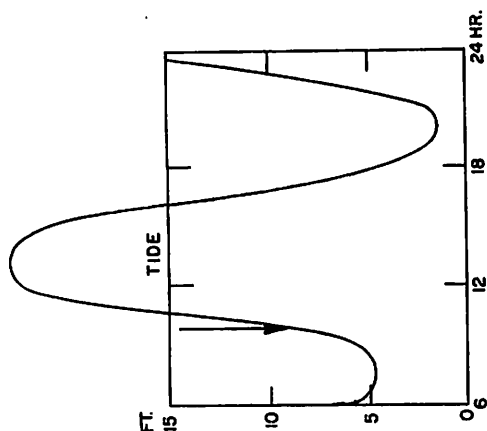


Depth (m)	T (°C)	S (°/‰)	δt	<u>Dissolved oxygen</u> (mg/l) % sat.	pH	<u>Alkalinity</u> Total Carb.
0	7.5	4.06	3.13	11.30 99.6	7.61	0.55 0.53
2	7.28	4.01	3.10	11.29 98.9	7.63	0.55 0.53
4	7.54	6.56	5.11	10.97 98.2	7.71	0.58 0.56
6	7.72	8.11	6.30	10.75 97.5	7.65	0.67 0.65
8	8.01	10.51	8.16	10.65 98.9	7.85	0.88 0.85

Appendix 5.2. (cont'd).

Station: P-29
 Time: 0959
 Date: 22/X/64
 Lat: 54° 10.70' N
 Long: 130° 11.20' W
 Depth: 18 ft.
 B.T. Ser. No. 23

Weather: Rain
 Cloud: Type Ns Amt. 10
 Wind: Dir. 095 OT Spd. 3 mph.
 Sea: 0 Swell: 0
 Air Temp: D. 47 OF. W. 47 OF.
 Baro: 1022 mb.
 Secchi: 0.8 ft. Col: Silty; grey

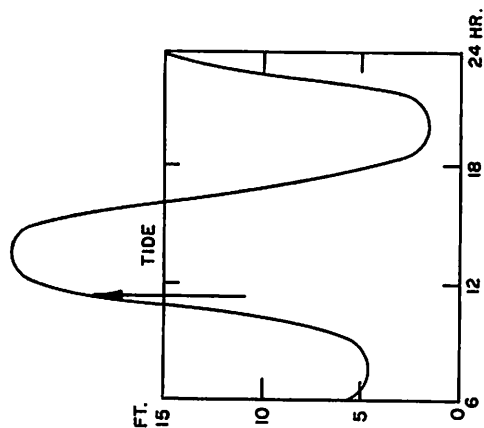


Depth (m)	T (°C)	S (°/°°)	δt	Dissolved oxygen (mg/l) % sat.	pH	Alkalinity Total Carb.
0	7.3	2.93	2.25	11.39 99.2	7.56	0.36 0.34
2	7.22	3.55	2.74	11.33 99.2	7.64	0.55 0.53
4	7.32	4.26	3.30	11.19 98.3	7.57	0.59 0.57
6	7.44	5.63	4.37	11.03 98.0	7.65	0.77 0.75

Appendix 5.2. (cont'd).

Station: P-30
 Time: 1139
 Date: 22/X/64
 Lat: 54° 08.00'N
 Long: 130° 06.80'W
 Depth: 30 ft.
 B.T. Ser. No. 24

Weather: Rain
 Cloud: Type Ns Amt. 10
 Wind: Dir. 095 OT Spd. 5 mph.
 Sea: 0 Swell: 0
 Air Temp: D.47 °F. W. 47°F.
 Baro: 1022.5 mb.
 Secchi: 0.8 ft. Col: Silty; grey



Depth (m)	T (°C)	S (°/‰)	δt	Dissolved oxygen (mg/l) % sat	pH	Alkalinity Total Carb.
0	6.8	0.32	0.22	11.79	7.47	0.32
2	6.69	0.57	0.42	11.72	7.47	0.32
4	6.70	0.76	0.58	11.43	7.50	0.32
6	6.71	0.83	0.62	11.94	7.27	0.36
8	6.72	0.94	0.71	11.89	7.53	0.32

198. Appendices - invertebrates

Appendix 6.1.

List of Freshwater and Marine Benthic Invertebrate Organisms
of the Skeena River System and Estuary, as Compiled from the
Available Literature.

PHYLUM PORIFERA

Halichondria sp.

Spongilla sp.

unidentified encrusting species

unidentified species

PHYLUM CNIDARIA

Class Anthozoa

Tealia sp.

Virgularia sp.

Class Hydrozoa

unidentified species

PHYLUM NEMERTEA

unidentified species

PHYLUM PLATYHELMINTHES

unidentified species

PHYLUM NEMATODA

marine, terrestrial, and freshwater unidentified species

PHYLUM BRYOZOA

unidentified species

PHYLUM ANNELIDA

Class Oligochaeta

marine and freshwater unidentified species

Class Polychaeta

unidentified species

199. Appendices - invertebrates

Appendix 6.1 (cont'd).

Subclass Errantia

Dorvillea pseudorubrovittata

Drilonereis falcata minor

Eteone longa

E. pacifica

E. spetsbergensis

Eulalia bilineata

E. sp.

Eunicidae unidentified species

Eunoe nodosa

Exogone lourei

Glycera capitata

G. sp.

Glyceridae unidentified species

Glycinde picta

Goniada brunnea

Holosynda brevisetosa

Harmathoe lunulata

Hesperonoe sp.

Lumbrinereis bicirrata

L. luti

L. sp.

Nephtydidae unidentified species

Nephtys ferruginea

N. punctata

N. sp.

Nereidae unidentified species

Nereis sp.

Ninoe gemmea

Odontosyllis phosphorea

Onuphius sp.

Peisidice aspera

Pholoe minuta

Phyllodoce sp.

200. Appendices - invertebrates

Appendix 6.1 (cont'd).

Phyllodocidae unidentified species

Pilargis berkeleyae

Polynoidae unidentified species

Sphaerodoropsis sphaerulifer

Sphaerodorum papillifer

Sphaerosyllis sp.

Syllidae unidentified species

Syllis heterochaeta

S. sp.

Subclass Sedentaria

Ammochares fusiformis

Ammotrypane aulogaster

Ampharete acutifrons

Ampharetidae unidentified species

Amphicteis mucronata

A. scaphobranchiata

Anobothrus gracilis

Arenicola pusilla

Aricidea minuta

A. quadrilobata

A. ramosa

Ariciidae unidentified species

Artacama conifera

Capitella capitata

Capitellidae unidentified species

Chaetozone setosa

Cirratulidae unidentified species

Cirratulus cirratus spectabilis

Cossura sp.

Crucigera irregularis

Decamastus gracilis

Eudistyla sp.

Idanthyrus armatus

Laonice cirrata

201. Appendices - invertebrates

Appendix 6.1 (cont'd).

Laonome kroyeri
Maldane glebifex
Maldanidae unidentified species
Mediomastus capensis
Melinna cristata
Myriochele oculata
Ophelidae unidentified species
Paraonis gracilis
Pectinaria belgica
P. granulata
Pectinariidae unidentified species
Pherusa plumosa
Phyllochaetopterus prolifica
Pista sp.
Polycirrus sp.
Polydora socialis
Potamilla neglecta
Praxillella affinis var. *pacifica*
P. gracilis
Prionospio malmgreni
P. steenstrupi
Proclea graffi
Rhodine bitorquata
Sabella crassicornis
Sabellaria cementarium
Sabellariidae unidentified species
Sabellidae unidentified species
Scalibregma inflatum
Scalibregmidae unidentified species
Scoloplos acmeceps
S. armiger
S. pugettensis
Serpulidae unidentified species
Spio cirrifer

202. Appendices - invertebrates

Appendix 6.1 (cont'd).

Spiochaetopterus costarum
Spionidae unidentified species
Spiophanes berkeleyorum
Sternaspidae unidentified species
Sternaspis fossor
S. scutata
Stylarioides papillata
Terebellidae unidentified species
Terebellides stroemi
Tharyx sp.
Thelepus setosus
Travisia brevis
unidentified species

Class Hirudinea
unidentified species

PHYLUM MOLLUSCA

Class Amphineura
Katherina tunicata
Lepidozona sp.
Mopalia hindsii
M. imporcata
M. sp.
Tonicella lineata
Trachydermon sp.
unidentified species

Class Gastropoda
Acmaea digitalis
A. pelta
A. persona
A. scutalata
A. scutum
Acmaeidae unidentified species
Acteocina eximia

203. Appendices - invertebrates

Appendix 6.1 (cont'd).

Amphissa columbiana

Calliostoma ligatum

Ceratostoma sp.

Cidarina cidarina

Fusitriton sp.

Lacuna marmorata

Littorina sitkana

L. sp.

Margarites sp.

Mitrella gouldii

Ocenebra tenuisculpta

Planorbis sp.

Polinices pallida

Puncturella cucullata

P. multistriata

Searlsia dira

Thais emarginata

T. lamellosa

T. sp.

Tonicella lineata

Trichotropis cancellata

unidentified dorid nudibranch

unidentified species

Class Bivalvia

Acila castrensis

Astarte alaskensis

A. compacta

Axinopsida serricata

Cardiidae unidentified species

Cardiomya pectinata

Cardita ventricosa

Chlamys hastata henricia

C. rubida

Clinocardium californiense

204. Appendices - invertebrates

Appendix 6.1 (cont'd).

Clinocardium fucanum
C. nuttalli
Compsomya subdiaphana
Crassostrea gigas
Cyclocardia ventricosa ventricosa
Hiatella gallicana
Macoma eliminata
M. inconspicua
M. irus
M. nasuta
Mya arenaria
M. sp.
Mytilus californianus
M. edulis
Nucula tenuis
Nuculana miniata
N. pernula
Nuculanidae unidentified species
Phyasira bisecta
Pisidium sp.
Protothaca staminea var. *runderata*
Psephidia lordi
Saxidomus giganteus
S. sp.
Solamen sp.
Solen sicarius
Sphaerium sp.
Tellina nukuloides
Tellinidae unidentified species
Thyasira bisecta
Transennella tantilla
Ungulinidae unidentified species
Venericardia ventricosa
Veneridae unidentified species

205. Appendices - invertebrates

Appendix 6.1 (cont'd).

Venerupis japonica

Yoldia amygdalea

unidentified species

Class Scaphopoda

Dentalium sp.

Class Cephalopoda

unidentified octopod species

unidentified squid species

PHYLUM ARTHROPODA

Class Arachnida

Hydracarina spp.

unidentified mite species

unidentified spider species

Class Insecta

Order Plecoptera

unidentified Chloroperlid nymphs

unidentified Perlodid nymphs

unidentified species

Order Ephemeroptera

Ephemera sp.

unidentified Baetid nymphs

unidentified Heptageniid nymphs

unidentified species

Order Trichoptera

unidentified Rhyacophilid larvae

unidentified species

Order Coleoptera

unidentified Elmid species

unidentified species

Order Diptera

unidentified species

Family Helidae

206. Appendices - invertebrates

Appendix 6.1 (cont'd).

unidentified species
Family Chironomidae
unidentified larvae
Family Deuterophlebiidae
unidentified species
Family Empididae
unidentified species
Family Simuliidae
unidentified species
Family Tendipedidae
unidentified species
Family Rhagionidae
unidentified species
Family Dolichopodidae
unidentified species
Order Hymenoptera
unidentified species
Order Hemiptera
unidentified species
Order Odonata
unidentified species
Order Neuroptera
unidentified species
Class Crustacea
Byblis sp. (further classification not given)
Heterophoxus oculatus (further classification not given)
Melita sp. (further classification not given)
Subclass Cirripedia
Order Thoracica
Balanus balanus
B. cariosus
B. sp.
Subclass Branchiopoda
Order Diplostraca

207. Appendices - invertebrates

Appendix 6.1 (cont'd).

Suborder Cladocera
 unidentified species

Subclass Ostracoda
 unidentified species

Subclass Copepoda
 Order Harpacticoida
 unidentified species

Subclass Malacostraca
 Order Mysidacea
 Archaeomysis sp.
 unidentified species

 Order Cumacea
 unidentified species

 Order Isopoda
 Cirolana kinkaidi
 C. sp.
 Idoteidae unidentified species
 Idothea wosensenski
 I. sp.
 Ligia sp.
 Pentidotea resecata
 Symidotea sp.

 Order Amphipoda
 Ampelisca sp.
 Amphithoe sp.
 Anisogammarus confervicolus
 A. locustoides
 A. pugettensis
 Corophidae unidentified species
 Corophium sp.
 Gammarus sp.
 Hyalella sp.
 Isaeidae unidentified species
 Orchestia sp.

208. Appendices - invertebrates

Appendix 6.1 (cont'd).

Vedicerotidae unidentified species
unidentified species

Order Decapoda

Suborder Natantia

Callinassa californiensis

Crago alaskensis

C. franciscorum

Lebbeus polaris

Pandalopsis dispar

Pandalus borealis

P. danae

P. goniurus

P. jordani

P. platyceros

Sergestes similis

unidentified species

Suborder Reptantia

Section Anomura

Lopholithodes foraminatus

Paguridae unidentified species

Pagurus sp.

unidentified species

Section Brachyura

Cancer magister

C. productus

C. sp.

Hemigrapsus nudus

H. sp.

Oregonia sp.

Pugettia sp.

unidentified species

209. Appendices - invertebrates

Appendix 6.1 (cont'd).

PHYLUM BRACHIOPODA

Class Articulata

Lacqueus californianus
Terebratalia transversa
Terebratulina unguicula
unidentified species

PHYLUM ECHINODERMATA

Class Holothuroidea

Cucumaria miniata
Eupentacta pseudoquinquesemita
Molpadia intermedia
Parastichopus californicus
Psolidium ballatum
unidentified species

Class Echinoidea

Strongylocentrotus droebachiensis
S. franciscanus

Class Ophiuroidea

Amphipholis squamata
Diamphiodia occidentalis
Ophiura lutkeni
O. maculata
unidentified species

Class Asteroidea

Ctenodiscus crispatus
Evasterias troschelli
Henricia sp.
Leptasterias aequalis
Pisaster ochraceous
unidentified species

210. Appendices - invertebrates

Appendix 6.1 (cont'd).

PHYLUM CHORDATA

Class Ascidiacea

unidentified species

211. Appendices - invertebrates

Appendix 6.2.

List of Freshwater and Marine Zooplanktonic Organisms of the Skeena River System and Estuary, as Compiled from the Available Literature.

PHYLUM PROTOZOA

Evadne sp.
Noctiluca sp.
Podon sp.
unidentified species

PHYLUM CNIDARIA

unidentified hydrozoans
unidentified medusae

PHYLUM CTENOPHORA

Pleurobrachia bachei
unidentified species

PHYLUM CHAETOGNATHA

Sagitta elegans
unidentified species

PHYLUM ANNELIDA

Class Polychaeta
unidentified species

PHYLUM MOLLUSCA

Class Gastropoda
Limacina sp.
unidentified pulmonate species
unidentified species
Class Bivalvia
unidentified species

212. Appendices - invertebrates

Appendix 6.2 (cont'd).

PHYLUM CHORDATA

Class Larvacea

Oikopleura sp.

unidentified species

Class Pisces

unidentified fish larvae

PHYLUM ARTHROPODA

Class Insecta

unidentified species

Class Crustacea

Subclass Branchiopoda

Order Diplostraca

Suborder Cladocera

Bosmina longispina

B. sp.

Daphnia longispina

D. sp.

Polyphemus pediculus

unidentified freshwater and marine species

Subclass Ostracoda

unidentified freshwater and marine species

Subclass Copepoda

Order Calanoida

Acartia longiremus

A. sp.

Allorchestes angustus

Calanus glacialis

C. sp.

Centropages abdominalis

Diaptomus sp.

Eurytemora pacifica

Hetercope septentrionalis

H. sp.

213. Appendices - invertebrates

Appendix 6.2 (cont'd).

Metridia sp.

Pseudocalanus minutus

P. sp.

Tortanus discaudatus

T. sp.

unidentified species

Order Cyclopoida

Cyclops sp.

Oithona sp.

unidentified species

Order Harpacticoida

unidentified species

copepod nauplii

copepod copepodites

Subclass Cirripedia

unidentified nauplii

unidentified cypris larvae

Subclass Malacostraca

Order Mysidacea

unidentified species

Order Euphausiacea

Euphausia pacifica

unidentified nauplii

unidentified species

Order Amphipoda

Anisogammarus pugettensis

unidentified species

Order Isopoda

unidentified species

Order Cumacea

unidentified species

Order Decapoda

unidentified zoea larvae

unidentified megalops larvae

unidentified species

APPENDIX 7.1.

Skeena River Anadromous Fish Escapement

Data (1962-1974) (Fisheries Service, 1972; Zyblut, pers. comm.).

Species	Years of Enumeration	Average Annual Escapement (1962-1972)	Date & Size of Max. Escapement Min. Escapement	Period of Spawning (peak under- lined)	Downstream Timing
Sockeye	1962-1972	705,807	1964 905,780	1966 453,599	-- May & June (1968): 30.9 mill. (1967): 16.6 mill. (1973): 89.0 mill. Peak: May 10- May 30
Chinook	1962-1972	21,570	1969 30,375	1966 13,500	-- --
Pink	1962-1972	1,084,273	1972 1,653,000	1967 565,000	July-Aug.- Sept. Peak: mid- May - mid- June
Chum	1968-1974	16,077	1972 37,321	1971 4,757	Aug.-Sept.- Oct. --

Appendix 7.2.

List of Fish Species of the Skeena River System and Estuary,
Including Trawl Species, as Compiled from the Available
Literature.

1. *Acipenser medirostris* (green sturgeon)
2. *A. transmontanus* (white sturgeon)
3. *Agonus acipenserinus* (sturgeon poacher)
4. *Alosa sapidissima* (American shad)
5. *Ammodytes hexapterus* (needlefish or Pacific sandlance)
6. *Anarrhichthys ocellatus* (wolf-eel)
7. *Anoplopoma fimbria* (sablefish)
8. *Apristurus brunneus* (brown cat shark)
9. *Artedius fenestralis* (padded sculpin)
10. *Atheresthes stomias* (turbot or arrowtooth flounder)
11. *Aulorhynchus flavidus* (tube-snout)
12. *Blepsias cirrhosus* (silverspotted sculpin)
13. *Bothragomus swanii* (deep-pitted poacher)
14. *Brosmophycis marginata* (red brotula)
15. *Careproctus melanurus* (blacktail snailfish)
16. *Catostomus catostomus* (longnose sucker)
17. *C. commersoni* (white sucker)
18. *C. macrocheilus* (largescale sucker)
19. *Chrosomus eos* (redbelly dace)
20. *Citharichthys sordidus* (mottled sanddab)
21. *Clinocottus acuticeps* (sharpnose sculpin)
22. *C. embryum* (calico sculpin)
23. *Clupea harengus pallasii* (Pacific herring)
24. *Coregonus clupeaformis* (lake whitefish)
25. *Cottus aleuticus* (coastrange sculpin)
26. *C. asper* (prickly sculpin)
27. *Couesius plumbeus* (lake chub)
28. *Cymatogaster aggregata* (shiner perch)
29. *Damalichthys vacca* (pile perch)
30. *Delolepis gigantea* (giant wrymouth)

216. Appendices - fish

Appendix 7.2 (cont'd).

31. *Engraulis mordax* (anchovy)
32. *Enophrys bison* (buffalo sculpin)
33. *Entosphenous tridentatus* (Pacific lamprey)
34. *Eopsetta jordani* (petrale sole or brill)
35. *Eumicrotremus orbis* (spiny lumpsucker)
36. *Gadus macrocephalus* (Pacific cod)
37. *Galeorhinus galeus* (soupfin shark)
38. *Gasterosteus aculeatus* (threespine stickleback)
39. *Glyptocephalus zachirus* (rex sole)
40. *Gobiosoma masandricus* (flathead clingfish)
41. *Hexagrammos decagrammus* (kelp greenling)
42. *H. stelleri* (white-spotted greenling)
43. *Hippoglossoides elassodon* (flathead sole)
44. *Hippoglossus stenolepis* (Pacific halibut)
45. *Hydrolagus collieri* (ratfish)
46. *Hypomesus pretiosus* (surf smelt)
47. *Inopsetta ischrya* (hybrid sole)
48. *Isopsetta isolepis* (butter sole)
49. *Lampanyctus richardsoni* (western brook lamprey)
50. *Lepidopsetta bilineata* (rock sole)
51. *Leptocottus armatus* (staghorn sculpin)
52. *Limanda aspera* (yellowfin sole)
53. *Liparis fucensis* (slipskin snailfish)
54. *Lota lota* (burbot)
55. *Lycodopsis pacifica* (blackbelly eelpout)
56. *Lyopsetta exilis* (slender sole)
57. *Mallotus villosus* (capelin)
58. *Merluccius productus* (Pacific hake)
59. *Microgadus proximus* (Pacific tomcod)
60. *Microstomus pacificus* (Dover sole)
61. *Mylocheilus caurinus* (peamouth chub)
62. *Myoxocephalus polyacanthocephalus* (great sculpin)
63. *Nectoliparis pelagicus* (tadpole snailfish)
64. *Oncorhynchus gorbuscha* (pink salmon)

217. Appendices - fish

Appendix 7.2 (cont'd).

65. *Oncorhynchus keta* (chum salmon)
66. *O. kisutch* (coho salmon)
67. *O. nerka* (sockeye salmon)
68. *O. n. kennerlyi* (kokanee)
69. *O. tshawytscha* (chinook salmon)
70. *Ophiodon elongatus* (lingcod)
71. *Osmerus mordax* (rainbow smelt)
72. *Parophrys vetulus* (lemon sole)
73. *Platichthys stellatus* (starry flounder)
74. *Pleuronichthys coenosus* (C-0 sole)
75. *P. decurrens* (curlfin sole)
76. *Porichthys notatus* (midshipman)
77. *Poroclinus rothrocki* (whitebarred prickleback)
78. *Prosopium coulteri* (pygmy whitefish)
79. *P. williamsoni* (mountain whitefish)
80. *Psettichthys melanostictus* (sand sole)
81. *Ptychocheilus oregonensis* (northern squawfish)
82. *Radulinus taylori* (spinynose sculpin)
83. *Raja binoculata* (big skate)
84. *R. rhina* (longnose skate)
85. *R. stellulata* (starry skate)
86. *Rhamphocottus richardsoni* (grunt sculpin)
87. *Rhinichthys cataractae* (longnose dace)
88. *Richardsonius balteatus* (redside shiner)
89. *Salmo clarki clarki* (coastal cutthroat trout)
90. *S. gairdneri* (rainbow trout)
91. *S. gairdneri* (steelhead trout)
92. *Salvelinus malma* (dolly varden)
93. *S. namaycush* (lake trout)
94. *Scorpaenichthys marmoratus* (cabezon)
95. *Sebastes aleutianus* (blackthroat rockfish)
96. *S. alutus* (Pacific ocean perch)
97. *S. brevispinis* (silvergray rockfish)
98. *S. caenaematicus* (shortraker rockfish)

218. Appendices - fish

Appendix 7.2 (cont'd).

- 99. *Sebastes caurinus* (copper rockfish)
- 100. *S. crameri* (blackmouth rockfish)
- 101. *S. diploproa* (splitnose rockfish)
- 102. *S. elongatus* (greenstripe rockfish)
- 103. *S. entomelas* (widow rockfish)
- 104. *S. flavidus* (yellowtail rockfish)
- 105. *S. helvomaculatus* (rosethorn rockfish)
- 106. *S. maliger* (quillback rockfish)
- 107. *S. melanops* (black rockfish)
- 108. *S. paucispinis* (bocaccio)
- 109. *S. pinniger* (orange rockfish)
- 110. *S. proriger* (redstripe rockfish)
- 111. *S. reedi* (yellowmouth rockfish)
- 112. *S. ruberrimus* (red snapper)
- 113. *S. rubrivinctus* (flag rockfish)
- 114. *S. zacentrus* (sharpfin rockfish)
- 115. *Sebastolobus alascanus* (spinycheek rockfish)
- 116. *Spirinchus thaleichthys* (longfin smelt)
- 117. *Squalus suckleyi* (Pacific dogfish)
- 118. *Thaleichthys pacificus* (eulachon)
- 119. *Theragra chalcogramma* (whiting, bigeye, or walleye pollock)
- 120. *Torpedo californica* (Pacific electric ray)
- 121. *Trichodon trichodon* (sandfish)
- 122. *Zaprora silensus* (prowfish)

Appendix 8.1.

List of Floral Species of the Skeena River System, Its Estuary, and Its Terrestrial Habitats, as Compiled from the Available Literature.

(i) ALGAE

Cyanophyceae

Anabaena sp.
Chroococcus sp.
Gloeocapsa sp.
Merismopedia sp.
Oscillatoria sp.
unidentified species

Pyrrhophyceae

Ceratium sp.
Gymnodinium sp.
Peridinium sp.
unidentified species

Cryptophyceae

Cryptomonas sp.
unidentified species

Chlorophyceae

Ankistrodesmus sp.
Cladophora albida
C. seriaca
Closterium sp.
Cosmarium sp.
Enteromorpha clathrata var. *crinata*
E. compressa
E. intestinalis
E. i. var. *clindracea*
E. linza
E. prolifera
E. sp.
Euglena sp.

220. Appendices - flora

Appendix 8.1 (cont'd).

- *Gloeocystis* sp.
- Golenkiniopsis* sp.
- Monostroma fuscum*
- Nostroma fuscum*
- Oocystis* sp.
- Prasiola meridionalis*
- Quadrigula* sp.
- Raphidonema* sp.
- Rhizoclonium riparium*
- Spongomorpha coalita*
- S. saxatilis*
- Staurastrum* sp.
- Thorea* sp.
- Ulva fenestrata*
- U. lactuca*
- U. rigida*
- U. scagelii*
- U. sp.*

Volvocales sp.

unidentified freshwater and marine species

Chrysophyceae

- Chromulina* sp.
- Chrysocapsa* sp.
- Chrysochromulina* sp.
- Dinobryon* sp.
- Mallomonas* sp.
- Synura* sp.

unidentified species

Bacillariophyceae

- Achnanthes* sp.
- Asterionella formosa*
- Cocconeis* sp.
- Coscinodiscus* spp.
- Cyclotella bodanica*

221. Appendices - flora

Appendix 8.1 (cont').

Cyclotella compta
C. ocellata
C. stelligera
Cymbella spp.
Diatoma sp.
Epithemia spp.
Fragilaria construens
F. crotonensis
Gomphonema sp.
Hannaea arcus
Melosira distans
M. italica
Meridion circulare
Navicula spp.
Nitzschia spp.
Rhizosolenia longiseta
R. sp.
Rhopalodia spp.
Stephanodiscus astrea
S. sp.
Synedra sp.
Tabellaria fenestrata
T. flocculosa
unidentified species

Phaeophyceae

Alaria marginata
A. tenuifolia
A. sp.
Fucus distichus
F. gardneri
Halosaccion gladiforme
Laminaria groelandica
L. saccharina
L. sp.

222. Appendices - flora

Appendix 8.1 (cont'd).

Nereocystis luetkeana

Pylaiella littoralis

unidentified species

Rhodophyceae

Aghardiella tenera

Antithamnion dendroideum

Bangia tenuis

Callithamnion biseriatum

C. bisporum

C. pikeanum

Cryptosiphonia woodii

Delesseria decipiens

Dilsea californica

Endocladia muricata

Gelidium sp.

Gigartina papillata

G. sp.

Gloiopeltis furcata

Gracilariopsis sjoestedtii

Halosaccion glandiforme

Iridea cordata

Lithothamnion sp.

Microcladia borealis

Odonthalia floccosa

Phycodrys setchellii

Polyneura latissima

Polysiphonia hendryi

P. pacifica

P. urceolata

P. sp.

Porphyra miniata

P. perforata

P. umbilicalis

Prionitis lanceolata

223. Appendices - flora

Appendix 8.1 (cont'd).

Pterosiphonia bipinnata

Ptilota tenuis

Ralfsia sp.

Rhodoglossum affine

R. roseum

Rhodomela larix

Rhodymenia palmata

Rhycodrye setchellii

unidentified species

Anthophyceae

Phyllospadix scouleri

Zostera marina

(ii) BRYOPHYTES AND LICHENS

Alectoria jubata

A. sarmentosa

Antitrichia curtipendula

Bazzania ambigua

B. denudata

B. tricrenata

Blepharostoma trichophyllum

Brachythecium washingtonianum

Calliergonella schreberi

Calypogeia neesiana

C. trichomanis

Cephalozia bicuspidata

C. lammersiana

C. media

Cetraria glauca

C. herrei

C. scutata

Cladonia bellidiflora

C. crispata

C. furcata

Appendix 8.1 (cont'd).

Cladonia gracilis
C. impexa
C. mitis
C. ochrochlora
C. rangiferina
C. squamosa
C. sylvatica
C. uncialis
Claopodium bolanderi
C. crispifolium
Conocephalum conicum
Dicranum fuscescens
D. majus
D. scoparium
D. strictum
Drepanocladus aduncus
Eurhynchium oreganum
Fontinalis kindbergii
Frullania nisquallensis
Heterocladium heteropteroides
H. macouni
H. procurrens
Hookeria lucens
Hylocomium splendens
Hypnum circinale
H. subimponens
Icmadophila ericetorum
Lepidozia reptans
Lobaria pulmonaria
Lophocolea heterophylla
Lophozia incisa
Lycopodium annotinum
L. clavatum
L. lucidulum

Appendix 8.1 (cont'd).

Metzgeria conjugata
M. pubescens
Mnium insigne
M. menziesii
M. punctatum
M. venustum
Monotropha lanuginosa
M. uniflora
Mylia taylori
Neckera douglasii
N. menziesii
Oligotrichum aligerum
O. parallelum
Orthotrichum lyellii
Parmelia enteromorpha
Pellia columbiana
P. neesiana
Philonotis americana
P. fontana
Pilophoron hallii
Plagiochila asplenoides
Plagiothecium denticulatum
P. elegans
P. silesiacum
P. undulatum
Pogonatum alpinum
P. contortum
Polytrichum formosum
Porella navicularis
P. platyphylla
Pseudisothecium stoloniferum
Radula bolanderi
R. complanata
Ramalina reticulata

Appendix 8.1 (cont'd).

Rhacomitrium heterostichum

R. lanuginosum

R. varium

Rhytidiadelphus loreus

R. triquetrus

Rhytidiopsis robusta

Riccardia palmata

R. sinuata

Scapania bolanderi

Schistostega pennata

Selaginella oregona

Siphula ceratitis

Sphagnum capillaceum

S. compactum

S. fimbriatum

S. fuscum

S. imbricatum

S. magellanicum

S. palustre

S. papillosum

S. recurvum

S. robustum

S. rubellum

S. squarrosum

S. tenellum

S. teres

S. warnstorffii

Tetraphis pellucida

Ulota megalospora

Usnea ceratina

U. hirta

U. longissima

Verrucaria maura

V. sp.

Appendix 8.1 (cont'd).

unidentified species

(iii) FERNS AND HERBACEOUS PLANTS (including aquatics)

Achillea millefolium (yarrow)
Actaea arguta
Adenocaulon bicolor (silver green)
Adiantum pedatum (northern maidenhair)
Agrostis aequivalvis (slender bentgrass)
A. diegoensis (bentgrass)
A. exarata (bentgrass)
A. idahoensis (Idaho bentgrass)
Alisma plantago var. *aquatica* (water plantain)
Andromeda polifolia (bog rosemary)
Angelica lucida (sea-watch)
Apargidium boreale (bog dandelion)
Aquilegia formosa (columbine)
Arabis hirsuta (hairy rockcress)
Arceuthobium tsugense
Asarum caudatum
Aster subspicatus (aster)
Athyrium filix-femina (lady fern)
Atriplex patula (orache)
Blechnum spicant (deer or hard fern)
Boykinia elata
Bromus pacificus (Pacific brome)
B. vulgaris (brome)
Cakile edentula (sea rocket)
Calamagrostis canadensis (Canada bluejoint)
C. nutkaensis (Nootka or Pacific bluejoint)
Callitriche anceps (waterstar)
C. stagnalis (waterstar)
Caltha biflora (marsh or twinflower marigold)
Carex hendersonii
C. kelloggii

Appendix 8.1 (cont'd).

Carex laeviculmis

C. leptalea

C. leptapoda

C. livida

C. lyngbyei (Lyngbye's sedge)

C. mertensii

C. obnupta (slough sedge)

C. pauciflora

C. pluriflora

C. saltuensis

C. sitchensis (sitka sedge)

C. stygia

C. vesicaria

Castilleja unalaschoensis (yellow paintbrush)

Cerastium vulgatum (chickweed)

Chimaphila menziesii (Prince's pine or pipsissewa)

Cicuta douglasii (water hemlock)

Cinna latifolia (nodding reedgrass)

Circaea alpina (enchanter's nightshade)

Claytonia sibirica (Siberian miner's lettuce)

Clintonia uniflora (Queen cup)

Cocklearia officinalis (scurvy grass)

Conioselinum pacificum (hemlock parsley)

Coptis asplenifolia (fern-leaved or boreal goldthread)

C. trifolia (goldthread)

Corallorhiza maculata (spotted coral-root)

Cornus canadensis (dwarf dogwood)

Deschampsia caespitosa (tufted hairgrass)

Dicentra formosa (bleeding heart)

Disporum smithii (large-flowered fairy bell)

D. oreganum (Hooker's fairy bell)

Draba hyperborea (sea mustard)

Drosera rotundifolia (round-leaf sundew)

Dryopteris austriaca (spiny or mountain wood fern)

Appendix 8.1 (cont'd).

Dulichium arundinaceum
Eleocharis acicularis (needle spike rush)
E. palustris (spike rush)
Elymus hirsutus (hairy ryegrass)
E. mollis (limegrass)
Epilobium adenocaulon
E. angustifolium (fireweed)
E. glandulosum (common willow weed)
Equisetum arvense (horsetail)
E. fluviatile (horsetail)
Eriophorum angustifolium (cottongrass)
E. chamissonis (cottongrass)
Fauria crista-galli (deer cabbage)
Festuca rubra (red fescue)
F. subulata (bearded fescue)
Fragaria chiloensis (strawberry)
Franseria chamissonis (silver bur sage)
Fritillaria camschatcensis (chocolate lily)
Galium trifidum (bedstraw)
G. triflorum (small or sweet bedstraw)
Gentiana douglasiana (white gentian)
G. spectrum
Glehnia littoralis (beach carrot)
Glyceria elata (tall mannagrass)
G. occidentalis (mannagrass)
G. pauciflora
G. striata (fowl mannagrass)
Goodyera oblongifolia (green-leaved rattlesnake orchid)
Gymnocarpium dryopteris (oak fern)
Habenaria saccata (slender bog or green rein orchid)
Heuchera micrantha (small-flower alumroot)
Hierochloa odorata (holygrass)
Hippuris vulgaris (mare's tail)
Holcus lanatus (velvet grass)

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Appendix 8.1 (cont'd).

Honkenya peploides (sea purslane)
Hordeum brachyantherum (sea barley)
Hypericum anagalloides (bog St. John's wort)
Hypochaeris radicata (hairy cat's ear)
Juncus balticus (Baltic rush)
J. bufonius (toad rush)
J. effusus (common rush)
J. ensifolius (dagger-leaved rush)
J. oreganus (amphibious rush)
Lactuca biennis (tall blue lettuce)
Lathyrus japonicus (beach pea)
Ligustichum scoticum (beach lovage)
Lilaea scilloides (flowering quillwort)
Lilium columbianum (Columbia or tiger lily)
Limosella aquatica (mudwort)
Linnaea borealis (twinflor)
Listera caurina (northwest twayblade)
L. convallaroides (broad-lipped twayblade)
L. cordata (heart-leaved twayblade)
Lonicera involucrata (black twinberry)
Luzula multiflora (woodrush)
L. parviflora (woodrush)
Lysichitum americanum (yellow skunk cabbage)
Maianthemum dilatatum (false lily-of-the-valley or two-leaved Solomon's seal)
Melica subulata (Alaska oniongrass)
Menyanthes trifoliata (bog bean)
Menziesia ferruginea (false azalea)
Mertensia maritima (sea bluebells)
Mitella ovalis
M. pentandra (five-point mitrewort)
Moneses uniflora (single delight)
Myriophyllum spicatum (coontail)
Nuphar polysipalum (yellow water lily)
Oenanthe sarmentosa (water parsley)

Appendix 8.1 (cont'd).

Osmorhiza chilensis (cecily)
O. purpurea (sweet cecily)
Petasites frigida (alpine coltsfoot)
Phyllospadix scouleri (bracketgrass)
Plantago macrocarpa (large-fruited plantain)
P. maritima (sea plantain)
Poa annua (annual bluegrass)
P. spp. (bluegrass)
Polypodium glycyrrhiza (licorice fern)
P. scouleri (leathery polypody)
P. vulgare var. *occidentale* (common polypody or lico-
rice fern)
Polystichum andersonii (Anderson's holly fern)
P. munitum (sword fern)
Potamogeton natans (pond weed)
Potentilla pacifica (silverweed)
P. villosa (woody cinquefoil)
Prenanthes alata (white lettuce)
Puccinellia nutkaensis (Alaska alkaligrass)
P. pumila (alkaligrass)
Pyrola asarifolia var. *bracteata* (large pyrole)
P. picta (white-vein pyrole)
P. secunda (one-sided wintergreen)
Ranunculus aquatilis (aquatic buttercup)
R. cymbalaria (buttercup)
R. flammula (small creeping buttercup)
R. uncinatus var. *parviflorus*
Rhynchospora alba (white beakrush)
Rumex acetosella (sheep sorrel)
R. occidentalis (western dock)
Ruppia maritima (widgeon grass)
Sagina maxima (pearlwort)
Sagittaria latifolia (wapato)
Salicornia pacifica (pickleweed)

Appendix 8.1 (cont'd).

Sanguisorba officinalis (burnet)
Saxifraga ferruginea (rusty saxifrage)
Scirpus caespitosus (tufted clubrush)
S. microcarpus (small-fruited bulrush)
S. validus (American great bulrush)
Sedum roseum (red stonecrop)
Senecio triangularis (giant ragwort)
Sium suave (water parsnip)
Smilacina racemosa (false spikenard)
S. stellata (star-flowered Solomon's seal)
Sparganium angustifolium (bur reed)
S. emersum
S. minimum
Spergularia marina (sea spurry)
Stachys mexicana (great hedge nettle)
Stellaria crispa (crisped starwort)
S. humifusa (trailing chickweed)
S. sitchana
Streptopus amplexifolius (twisted stalk)
S. roseus (simple-stemmed twisted stalk)
S. streptopoides (small twisted stalk)
Suaeda maritima (seablite)
Thalictrum occidentale (meadow rue)
Thelypteris phegopteris (long beech or wood fern)
Tiarella trifoliata (foam flower)
Trientalis arctica (upland starflower)
T. latifolia
Trifolium wormskjoldii (Pacific clover)
Triglochin maritimum (sea arrowgrass)
Trilium ovatum (trillium or western wake robin)
Trisetum cernuum (nodding false-oat)
Urtica lyallii (stinging nettle)
Urtricularia sp. (bladderwort)
Veratrum viride (green false hellebore)

Appendix 8.1 (cont'd).

Veronica americana (speedwell)
V. scutellata
Vicia gigantea (giant vetch)
Viola glabella (yellow violet)
V. orbiculata (violet)
Zannichellia palustris (horned pondweed)
unidentified species

(iv) SHRUBS

Acer circinatum (vine maple)
Empetrum nigrum (crowberry)
Gaultheria shallon (salal)
Juniperus communis (spreading juniper)
Kalmia polifolia (swamp or pale laurel)
Ledum groenlandicum (Labrador tea)
Loiseluria procumbens (dwarf azalea)
Lonicera involucrata (honeysuckle or black twinberry)
Mahonia nervosa (Oregon grape)
Menziesia ferruginea (rusty menziesia)
Myrica californica (wax myrtle)
M. gale (sweet gale)
Oplopanax horridum (devil's club)
Osmaronia cerasiformis (Indian plum, Oso-berry)
Oxycoccus quadripetalus
Physiocarpus capitatus (ninebark)
Rhododendron macrophyllum (rhododendron)
Ribes bracteosum (stink or blue currant)
R. lacustre (prickly currant or gooseberry)
Rosa gymnocarpa (dwarf or woodland rose)
Rubus chamaemorus (cloudberry)
R. leucodermis (black raspberry)
R. parviflorus (thimbleberry)
R. pedatus (trailing blackberry)
R. spectabilis (salmonberry)
R. ursinus (trailing blackberry or bramble)

Appendix 8.1 (cont'd).

Rubus vitifolius (blackberry)
Spiraea douglasii (meadowsweet hardhack)
Symphoricarpos albus (snowberry or waxberry)
Taxus brevifolia (Pacific yew)
Vaccinium alaskaense (Alaska huckleberry)
V. caespitosum (dwarf huckleberry)
V. membranaceum (big huckleberry)
V. ovalifolium (tall blue huckleberry)
V. ovatum (evergreen huckleberry)
V. oxycoccos (bog cranberry)
V. parvifolium (red huckleberry)
V. uliginosum (bog blueberry)
V. vitis-idaea (lingonberry)
Viburnum edule (squashberry)
unidentified species

(v) TREES

Abies amabilis (balsam or lovely fir)
A. lasiocarpa (Pacific silver or alpine fir)
Acer glabrum (Douglas maple)
A. macrophyllum (broadleaf maple)
Alnus rubra (red alder)
A. sinuata (sitka alder)
Betula papyrifera (white birch)
Chamaecyparis nootkatensis (yellow cedar)
Cladothamnus pyrolaeiflorus (copperbush)
Cornus nuttallii (flowering dogwood)
C. sericea (dogwood)
Crataegus douglasii (Douglas or black hawthorn)
Malus diversifolia (Pacific or wild crabapple)
Picea sitchensis (sitka spruce)
Pinus contorta (lodgepole or shore pine)
P. monticola (western white pine)
Populus tremuloides (aspen poplar)

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Appendix 8.1 (cont'd).

Populus trichocarpa (northern black cottonwood)
Prunus emarginata (bitter cherry)
Pseudotsuga menziesii var. *menziesii* (Douglas fir)
Pyrus fusca (western crabapple)
Rhamnus purshiana (cascara)
Salix hookeriana (Hooker's willow)
S. lasiandra (Pacific or peachleaf willow)
S. scouleriana (Scouler's willow)
S. sitchensis (sitka willow)
Sambucus pubens (elder)
Sorbus sitchensis (sitka or mountain ash)
Thuja plicata (western red cedar)
Tsuga heterophylla (western hemlock)
T. mertensiana (mountain hemlock)
unidentified species

Appendix 9.1.

Species Lists of Birds, Mammals, Amphibians and Reptiles of the Skeena River Estuary and Lower Skeena Valley, as Compiled from the Available Literature.

(i) BIRDS

1. *Gavia immer* (common loon)
2. *G. adamsii* (yellow-billed loon)
3. *G. arctica* (Arctic loon)
4. *G. stellata* (red-throated loon)
5. *Lunda cirrhata* (tufted puffin)
6. *Fratercula corniculata* (horned puffin)
7. *Podiceps grisegena* (red-necked grebe)
8. *P. auritus* (horned grebe)
9. *Aechmophorus occidentalis* (western grebe)
10. *Oceanodroma furcata* (fork-tailed storm petrel)
11. *Phalacrocorax auritus* (double-crested cormorant)
12. *P. pelagicus* (pelagic cormorant)
13. *Ardea herodias* (great blue heron)
14. *Botaurus lentiginosus* (American bittern)
15. *Olor columbianus* (whistling swan)
16. *O. buccinator* (trumpeter swan)
17. *Branta canadensis* (Canada goose)
18. *B. leucopareia* (lesser Canada goose)
19. *B. minima* (cackling goose)
20. *B. bernicla nigricans* (black brant)
21. *Anser albifrons* (white-fronted goose)
22. *Chen caerulescens* (snow goose)
23. *Anas platyrhynchos* (mallard)
24. *A. strepera* (gadwall)
25. *A. acuta* (pintail)
26. *A. crecca carolinensis* (green-winged teal)
27. *A. discors* (blue-winged teal)
28. *A. penelope* (European wigeon)

237. Appendices - wildlife

Appendix 9.1 (cont'd).

29. *Anas americana* (American wigeon)
30. *A. clypeata* (northern shoveler)
31. *Aythya americana* (redhead)
32. *A. collaris* (ring-necked duck)
33. *A. valisineria* (canvasback)
34. *A. marila* (greater scaup)
35. *A. affinis* (lesser scaup)
36. *Bucephala clangula* (common goldeneye)
37. *B. islandica* (Barrow's goldeneye)
38. *B. albeola* (bufflehead)
39. *Clangula hyemalis* (oldsquaw)
40. *Histrionicus histrionicus* (harlequin duck)
41. *Melanitta deglandi* (white-winged scoter)
42. *M. perspicillata* (surf scoter)
43. *M. nigra* (black scoter)
44. *Lophodytes cucullatus* (hooded merganser)
45. *Mergus merganser* (common merganser)
46. *M. serrator* (red-breasted merganser)
47. *Haliaeetus leucocephalus* (bald eagle)
48. *Circus cyaneus* (marsh hawk)
49. *Falco peregrinus* (peregrine falcon)
50. *Dendragapus obscurus* (blue grouse)
51. *Bonasa umbellus* (ruffed grouse)
52. *Lagopus lagopus* (willow ptarmigan)
53. *Grus canadensis* (sandhill crane)
54. *Haematopus bachmani* (black oystercatcher)
55. *Charadrius semipalmatus* (semipalmated plover)
56. *C. vociferus* (killdeer)
57. *Pluvialis dominica* (American golden plover)
58. *P. squatarola* (black-bellied plover)
59. *Aphriza virgata* (surfbird)
60. *Arenaria interpres morinella* (ruddy turnstone)
61. *A. melanocephala* (black turnstone)
62. *Capella gallinago* (common snipe)

Appendix 9.1 (cont'd).

63. *Numenius phaeopus* (whimbrel)
64. *Actitis macularia* (spotted sandpiper)
65. *Tringa solitaria* (solitary sandpiper)
66. *T. melanoleuca* (greater yellowlegs)
67. *T. flavipes* (lesser yellowlegs)
68. *Heteroscelus incanus* (wandering tattler)
69. *Calidris canutus* (red knot)
70. *C. ptilocnemis* (rock sandpiper)
71. *C. acuminata* (sharp-tailed sandpiper)
72. *C. melanotos* (pectoral sandpiper)
73. *C. bairdii* (Baird's sandpiper)
74. *C. minutilla* (least sandpiper)
75. *C. alpina* (dunlin)
76. *C. pusillus* (semipalmated sandpiper)
77. *C. mauri* (western sandpiper)
78. *C. alba* (sanderling)
79. *Limnodromus griseus* (short-billed dowitcher)
80. *L. scolopaceus* (long-billed dowitcher)
81. *Stercorarius parasiticus* (parasitic jaeger)
82. *Larus hyperboreus* (glaucous gull)
83. *L. glaucescens* (glaucous-winged gull)
84. *L. argentatus* (herring gull)
85. *L. canus* (mew gull)
86. *L. philadelphia* (Bonaparte's gull)
87. *Rissa tridactyla* (black-legged kittiwake)
88. *Xema sabini* (Sabine's gull)
89. *Sterna paradisaea* (Arctic tern)
90. *Uria aalge* (common murre)
91. *Cephus columba* (pigeon guillemot)
92. *Brachyramphus marmoratus* (marbled murrelet)
93. *Synthliboramphus antiquus* (ancient murrelet)
94. *Ptychoramphus aleuticus* (Cassin's auklet)
95. *Cerorhinca monocerata* (rhinoceros auklet)
96. *Columba fasciata fasciata* (band-tailed pigeon)

239. Appendices - wildlife

Appendix 9.1 (cont'd).

97. *Otus asio* (screech owl)
98. *Bubo virginianus* (great horned owl)
99. *Glaucidium gnoma* (pygmy owl)
100. *Strix varia* (barred owl)
101. *S. nebulosa* (great grey owl)
102. *Asio flammeus* (short-eared owl)
103. *Aegolius acadicus* (saw-whet owl)
104. *Chordeiles minor* (common nighthawk)
105. *Cypseloides niger* (black swift)
106. *Chaetura vauxi* (Vaux' swift)
107. *Selasphorus rufus* (rufous hummingbird)
108. *Colaptes auratus* (common flicker)
109. *C. a. borealis* (boreal flicker)
110. *Dryocopus pileatus* (pileated woodpecker)
111. *Dendrocopos villosus* (hairy woodpecker)
112. *D. pubescens* (downy woodpecker)
113. *Asyndesmus lewis* (Lewis' woodpecker)
114. *Sphyrapicus varius ruber* (northern red-breasted
sapsucker)
115. *Picoides arcticus* (black-beaked three-toed woodpecker)
116. *Tyrannus tyrannus* (eastern kingbird)
117. *Empidonax flaviventris* (yellow-bellied flycatcher)
118. *E. traillii* (willow flycatcher)
119. *E. t. alnorum* (alder flycatcher)
120. *E. hammondi* (Hammond's flycatcher)
121. *E. wrightii* (gray flycatcher)
122. *Tachycineta thalassina* (violet-green swallow)
123. *Iridoprocne bicolor* (tree swallow)
124. *Stelgidopteryx ruficollis* (rough-winged swallow)
125. *Hirundo rustica* (barn swallow)
126. *Perisoreus canadensis* (Canada or gray jay)
127. *Cyanocitta stelleri* (Steller's jay)
128. *C. s. annectens* (black-headed jay)
129. *Pica pica* (black-billed magpie)
130. *Corvus corax* (common raven)

240. Appendices - wildlife

Appendix 9.1 (cont'd).

131. *Corvus brachyrhynchos* (American or common crow)
132. *C. caurinus* (northwestern crow)
133. *Parus atricapillus* (black-capped chickadee)
134. *P. gambeli* (mountain chickadee)
135. *P. hudsonicus* (boreal chickadee)
136. *P. rufescens* (chestnut-backed chickadee)
137. *Troglodytes aedon* (house wren)
138. *T. troglodytes* (winter wren)
139. *Telmatodytes palustris* (long-billed marsh wren)
140. *Dumetella carolinensis* (catbird)
141. *Turdus migratorius* (American robin)
142. *Ixoreus naevius* (varied thrush)
143. *Catharus guttatus* (hermit thrush)
144. *C. ustulatus* (Swainson's thrush)
145. *Hylocichla minima* (gray-cheeked thrush)
146. *H. guttata* (Alaska hermit thrush)
147. *Sialia currucoides* (mountain bluebird)
148. *Myadestes townsendi* (Townsend's solitaire)
149. *Regulus satrapa* (golden-crowned kinglet)
150. *R. calendula* (ruby-crowned kinglet)
151. *R. c. grinnelli* (sitka kinglet)
152. *Anthus spinoletta* (water pipit)
153. *Bombycilla garrulus* (Bohemian waxwing)
154. *B. cedorum* (cedar waxwing)
155. *Lanius excubitor* (northern shrike)
156. *Vireo olivaceus* (red-eyed vireo)
157. *V. gilvus* (warbling vireo)
158. *Vermivora celata lutescens* (orange-crowned warbler)
159. *V. peregrina* (Tennessee warbler)
160. *Dendroica petechia* (yellow warbler)
161. *Seiurus noveboracensis notabilis* (northern water-thrush)
162. *Geothlypis trichas* (common yellowthroat)
163. *Setophaga ruticilla* (American redstart)
164. *Agelaius phoeniceus* (red-winged blackbird)

241. Appendices - wildlife

Appendix 9.1 (cont'd).

165. *Euphagus carolinus* (rusty blackbird)
166. *Molothrus ater* (brown-headed cowbird)
167. *Piranga ludoviciana* (western tanager)
168. *Hesperiphona vespertina* (evening grosbeak)
169. *Carpodacus purpureus* (purple finch)
170. *Pinicola enucleator* (pine grosbeak)
171. *Leucosticte tephrocotis littoralis* (Hepburn rosy finch)
172. *Spinus pinus* (pine siskin)
173. *Loxia curvirostra minor* (American crossbill)
174. *L. leucoptera* (white-winged crossbill)
175. *Passerculus sandwichensis* (savannah sparrow)
176. *P. s. anthinus* (Kodiak savannah sparrow)
177. *Junco hyemalis* (slate-coloured junco)
178. *J. h. connectens* (Cassiar junco)
179. *J. h. oregonus* (Oregon junco)
180. *J. h. shufeldti* (Shufeldt junco)
181. *Spizella passerina* (chipping sparrow)
182. *Zonotrichia atricapilla* (golden-crowned sparrow)
183. *Z. albicollis* (white-throated sparrow)
184. *Z. leucophrys* (intermediate sparrow)
185. *Z. nuttalli* (Nuttall sparrow)
186. *Passerella iliaca* (fox sparrow)
187. *Melospiza lincolni* (Lincoln's sparrow)
188. *M. melodia* (song sparrow)
189. *M. m. caurina* (Yakutat song sparrow)
190. *M. m. morphna* (rusty song sparrow)
191. *Calcarius lapponicus alascensis* (Alaska longspur)
192. *C. pictus* (Smith longspur)
193. *C. ornatus* (chestnut-collared longspur)

(ii) MAMMALS

Order Insectivora (shrews)

Sorex cinereus (cinereous shrew)

242. Appendices - wildlife

Appendix 9.1 (cont'd).

Sorex palustris (navigator shrew)

S. vagrans (wandering shrew)

Order Chiroptera (bats)

Myotis californicus (Californian myotis)

M. lucifugus (little brown myotis)

M. volans longicrus (long-legged myotis)

M. yumanensis (Yuma myotis)

Order Rodentia

Family Sciuridae (squirrels, chipmunks, marmots)

Eutamias amaensis (northwestern chipmunk)

E. minimus (least chipmunk)

Glaucomys sabrinus (northern flying squirrel)

Marmota caligata (hoary marmot)

M. monax (woodchuck)

Tamiasciurus hudsonicus (red squirrel)

Family Castoridae (beavers)

Castor canadensis (Canadian beaver)

Family Cricetidae (new world rats and mice)

Clethrionomys gapperi caurinus (redback vole)

Lemmus sibericus helvulus (Siberian or brown
lemming)

Microtus longicaudus (long-tailed vole)

M. pennsylvanicus drummondi (meadow vole)

Mus musculus domesticus (house mouse)

Neotoma cinerea occidentalis (bushy-tailed
wood rat)

Ondatra zibethica (muskrat)

Peromyscus maniculatus (deer or white-footed
mouse)

Synaptomys borealis (northern bog lemming)

Family Zapodidae (jumping mice)

Zapus hudsonius hudsonius (meadow jumping
mouse)

Z. princeps saltator (western jumping mouse)

Family Erethizontidae (American porcupines)

Erethizon dorsatum nigrescens (porcupine)

243. Appendices - wildlife

Appendix 9.1 (cont'd).

Order Cetacea (whales and dolphins)

- Balaenoptera acutorostrata* (pike or Minke whale)
- B. physalus* (fin or finback whale)
- Delphinus bairdi* (Baird dolphin)
- Eschrichtius robustus* (gray whale)
- Grampus griseus* (gray or Risso's dolphin)
- Lagenorhynchus obliquidens* (Pacific striped dolphin)
- Megaptera novaeangliae* (humpback whale)
- Mesoplodon* sp. (beaked whale)
- Orcinus orca* (Pacific killer whale)
- Phocoena phocoena* (harbour porpoise)
- Phocoenoides dalli* (Dall porpoise)
- Physeter catodon* (sperm whale)

Order Carnivora

Family Canidae (dog-like flesh-eaters)

- Canis latrans* (coyote)
- C. lupus* (wolf)
- Vulpes fulva* (red fox)

Family Ursidae (bears)

- Ursus americanus* (black bear)
- U. arctos horribilis* (grizzly bear)

Family Procyonidae (raccoons)

- Procyon lotor* (raccoon)

Family Mustelidae (weasel-like flesh-eaters)

- Gulo luscus* (wolverine)
- Lutra canadensis* (Canadian river otter)
- Martes americana* (marten)
- M. pennanti* (fisher)
- Mephitis mephitis* (striped skunk)
- Mustela erminea* (ermine or short-tailed weasel)
- M. vison* (mink)

Family Felidae (cat-like flesh-eaters)

- Felis concolor* (cougar)
- Lynx canadensis canadensis* (Canada lynx)

244. Appendices - wildlife

Appendix 9.1 (cont'd).

Order Pinnipedia (seals, sea-lions, walruses)

Callorhinus ursinus (northern fur seal)

Eumetopias jubata (northern or Steller sea-lion)

Phoca vitulina richardi (Pacific harbour or hair seal)

Order Artiodactyla (cloven-hoofed ungulates)

Alces americana (moose)

Cervus canadensis (elk or wapiti)

Odocoileus hemionus hemionus (mule deer)

O. h. sitkensis (sitka deer)

Oreamnos americanus (mountain goat)

Ovis dalli stonei (stone sheep)

Rangifer tarandus caribou (caribou)

R. t. montanus (mountain caribou)

(iii) AMPHIBIANS AND REPTILES

Ambystoma gracile decorticatum (British Columbia salamander)

Bufo boreas boreas (northwestern toad)

Rana pretiosa pretiosa (western spotted frog)

R. sylvatica (northern wood frog)

Taricha granulosa granulosa (Pacific coast newt)

Thamnophis elegans vagrans (wandering garter snake)

Appendix 11.1. (a) Water Pollution Sources in the Skeena River and Its Estuary (Environmental Protection Service, 1975).

1. SEWAGE

PCB I.D. #	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01815	The Canadian Fishing Co. Ltd., Port Edward	Inverness Passage	500	Typical septic tank effluent	
PE-1816-4	The Canadian Fishing Co. Ltd., Rupert Harbour	Prince Rupert Harbour	(1) 300 Feb.-Dec. (2) 400	Typical septic tank effluent	Possible public health problem.
PE-00215	Standard Oil Bulk Station	Prince Rupert Harbour	30	Typical septic tank effluent	Possible public health problem.
PE-00246	Prince Rupert Fisherman's Co-operative Ass. Cold Storage Plant	Fairview Bay, Prince Rupert Harbour	5,000	Typical septic tank effluent	Possible public health problem.
PE-00272	City of Prince Rupert	Prince Rupert Harbour	2,690,000	Typical of combined domestic, commercial and storm sewage, i.e. BOD ₅ 170 mg/l; SS 190 mg/l; TS 650 mg/l; pH 6.5 - 8.5; temp. 55-65°; coliforms 40 M/100 ml.	Possible public health problem. Possible aesthetic problem.

Appendix 11.1. (a) (cont'd).

PCB I.D. #	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01810A	Cassiar Packing Co. Ltd.	Inverness Passage	2,000	Typical septic tank effluent	
PE-01812F	Canada Fishing Co. Ltd., Oceanside Plant Sewage	Prince Rupert Harbour	2,000	Typical septic tank effluent	
PE-01862-2	Royal Fisheries Ltd.	Prince Rupert Harbour	600 5 day week, May 1-Sept. 3	Typical domestic septic tank discharge	Possible public health problem.
AE-02498	Prince Rupert Fisherman's Co-operative Association	Fairview Bay, Prince Rupert Harbour	1,000	Typical septic tank discharge	Possible public health problem.
PE-2615	Province of B.C.-Transport and Communication Ferry Terminal	Fairview Bay, Prince Rupert Harbour	5,000	pH 5.5 SS 60 mg/l BOD ₅ 45 mg/l	Present treatment includes a packaged sewage treatment plant and chlorination facilities.
Registered Seal Cove Sea Plane Base		Prince Rupert Harbour	2,050	Typical domestic septic tank discharge	Possible public health problem.
PE-2603	Rivtow Strait Ltd.	Prince Rupert Harbour	100	Typical domestic septic tank discharge	Possible public health problem.

Appendix 11.1. (a) (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01827-2	British Columbia Packers Ltd.	Prince Rupert Harbour	1,000	Typical septic tank effluent	Possible public health problem.
PE-01828-5	British Columbia Packers Ltd., Port Edward Plant	Porpoise Harbour	4,000 June 15- Oct. 31	Typical domestic septic tank discharge	Possible public health problem.
Registered	Prince Rupert Forest Products Ltd.	Prince Rupert Harbour	1,000	Typical domestic sewage	Possible public health problem. Possible aesthetic problem.
PE-01812C and D	Canadian Fishing Co. Ltd., Ocean-side Reduction Plant & Exhaust Scrubber	Prince Rupert Harbour	62,000	BOD ₅ 0.4 lbs/ 1000 lbs. raw fish SS 0.6 lbs/ 1000 lbs. raw fish	
PE-01812E	Canadian Fishing Co. Ltd., Oceanside Plant Unloading Siphon	Prince Rupert Harbour	5,000	BOD ₅ 2.4 lbs/ 1000 lbs. fish unloaded SS 1.2 lbs/ 1000 lbs. fish unloaded	

Appendix 11.1. (a) (cont'd).

PCB I.D. #	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01862	Royal Fisheries Ltd.	Prince Rupert Harbour	67,600	BOD ₅ 224 mg/l pH 6.5 - 8.5 SS 179 mg/l temp. 50-80° F	Possible aesthetic problems. Present treatment consists of waste collection, coarse screening, and sub-surface outfall. Fine screening will be installed by June 15, 1975. Same discharge all year round.
AE-02498	Prince Rupert Fisherman's Co-operative Fish Processing & Reduction Plant	Fairview Bay, Prince Rupert Harbour	480,000 Feb.-Nov.	BOD ₅ 1400 ppm TS 890 ppm SS 850 ppm temp. 80° F pH 8.5 Chlorine content unknown	Present treatment of waste collection and coarse screening; fine screening by July, 1975. Chlorine is added to processing water for washdown in the plant.
PE-01827	B.C. Packers Ltd.	Prince Rupert Harbour	201,000	BOD ₅ 1.6 lbs/1000 lbs. product SS 1.2 lbs/1000 lbs product	Treatment collection system - coarse screening to July, 1974; then fine screening.

Appendix 11.1. (a) (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01828	B.C. Packers Ltd., Edward Plant	Porpoise Har- bour	1,640,000 (June 15 - Oct. 31)	BOD ₅ 1100-8200 mg/l SS 640-480 mg/l pH 6.5 - 8.5 temp. 50-80° F	Treatment collection system. Fine screen- ing for salmon can- ning, boat unload- ing and herring water. 1975 stick- water evaporation system.

Appendix 11.1 (a) (cont'd).

2. CHEMICAL INDUSTRY

PCB I.D. #	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
AE-03645	Canadian Occidental Petroleum Ltd. - Hooker Chemical Division, Watson Island	Porpoise Harbour	1,400-1 day per week	Effluent results from the catalytic decomposition of a sodium hypochlor- ite chloride & oxygen. SS 20 mg/l TS 250,000 mg/l Sodium Hypochlorite 5000 mg/l Sodium Chloride 225,000 mg/l Sodium Hydroxide 20,000 mg/l Chlorine 200-300 IGD	Sodium hypochlorite to be reduced to 0.5 mg/l residual chlorine content by 1975. Excess chlorine bubbled in- to a water tank.

Appendix 11.1 (a) (cont'd).

3. FOREST INDUSTRY

PCB I.D. #	DISCHARGER	LOCATION OF DISCHARGE	Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-3063	Prince Rupert Forest Products Ltd.	Prince Rupert Harbour	400,000	BOD ₅ 4.0 lbs/cunit SS 4.0 lbs/cunit settleable solids= 2.5 mg/l pH 6.5 - 8.5 Toxicity (TLM 96)= 50% in 12.5% effluent concen- tration	Treatment is via a settling pond.
AE-1157-A	Canadian Cellulose Company Ltd. Watson Island Woodroom	Porpoise Harbour	2,300,000	SS 13 lb/cunit BOD ₅ 2.1 lb/cunit pH 4.6 - 6.5 temp. 40-70° F	Present treatment includes collection of floor drains, screening to reduce SS. Contributes to fibre deposits and DO depletion in Porpoise Harbour.
AE-1157-B	Canadian Cellulose Company Ltd. Sulphite Mill, Watson Island	Porpoise Harbour	32,000,000	BOD ₅ 125 ppm SS 65 ppm TS 3,000 ppm pH 6.5 - 8.5 temp. 50-95° F	Treatment includes settling in effluent lagoons. Contributes to fibre deposits and DO depletion in Porpoise Harbour.

Appendix 11.1 (a) (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
AE-1157-C	Canadian Cellulose Company Ltd. Kraft Mill, Watson Island	Porpoise Harbour	29,000,000	SS 100 lb/ADTON BOD ₅ 75 lb/ADTON pH 4.5 - 9.0 Toxicity (TLM 96)= 30%	Contributes to fibre deposits and DO de- pletion in Porpoise Harbour.
AE-1157-D	Canadian Cellulose Company Ltd. Red Liquor Line	Chatham Sound	3,600,000	SS 375 mg/l TS 7300 mg/l BOD ₅ 2256 mg/l pH 4.5 - 6.5 temp. 50-130° F	Line has broken in the past and re- sulted in red liquor discharge into Por- poise Harbour, has caused fish kills; difficulty in con- trolling and dis- persing of this ef- fluent may force closure of this plant. The Chatham Sound discharge cove has been denuded of normal floral and faunal populations due to the toxicity of this effluent.

Appendix 11.1 (a) (cont'd).

4. FISH PROCESSING

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01815	The Canadian Fishing Co., Port Edward	Inverness Passage	(1) 9,000 (2) 17,000	SS 50,000 mg/l pH 6.3 temp. high (?)	(1) stickwater (2) herring processing water.
PE-1816	The Canadian Fishing Co. Ltd., Rupert Harbour	Prince Rupert Harbour	(1) 97,800* (2) 72,400 depending on season	(1) SS 435 mg/l BOD ₅ 690 mg/l (2) SS 140 mg/l BOD ₅ 260 mg/l	This plant will be used for fillet operation until March, 1975; washing (salmon, herring, halibut) & freezing until 1977; after which it will only be used for freezing.
PE-1816-3	The Canadian Fishing Co. Ltd.	Prince Rupert Harbour	12,000	Engine-cooling water for freezers	
PE-01810B	Cassiar Packing Co. Ltd.	Inverness Passage	100,000 June-Sept. 10,000 Feb.-April	Waste from fish processing SS 3,000 mg/l BOD ₅ 5,000 mg/l pH 6.5 - 7.5 temp. 500 - 80° F	Treatment by coarse screening.

*= combined cooling and processing

Appendix 11.1. (a) (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01812A	Canadian Fishing Co. Ltd., Oceanside Plant (salmon pro- cessing)	Prince Rupert Harbour	433,000 June - Oct.	BOD ₅ 27 lb/1000 lb. product SS 11 lb/1000 lb. product	Treatment by coarse screening.
PE-01812B	Canadian Fishing Co. Ltd., Oceanside Plant (herring roe processing)	Prince Rupert Harbour	21,000	BOD ₅ 4 lb/1000 lb. raw fish processed SS 3 lb/1000 lb. raw fish processed	

Appendix 11.1 (cont'd).

(b) Water Pollution Sources Upstream of the Skeena River Estuary
(Environmental Protection Service, 1975).

1. SEWAGE

PCB I.D. #	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-00446	Totem Marina Ltd. (mobile home park & resort)	Topley Babine Lake	11,000	SS 55 ppm BOD ₅ 45 ppm	Treatment includes an extended aeration package treatment plant and chlorina- tion.
PE-01507	Village of Granisle Municipal Sewage System	Babine Lake	120,000	SS 120 ppm TS 400 ppm BOD ₅ 120 ppm pH 6.5 - 7.5 temp. 33 - 70° F	Present treatment includes activated sludge treatment plant, chlorination facilities, a pol- ishing lagoon and a sludge lagoon.
PE-01556	New Hazelton Municipal Sewage	Waterfall Creek, ultimately into Skeena River	50,000	BOD ₅ 45 ppm SS 60 ppm TS 320 ppm pH 6.5 - 7.5 temp. 45 - 65° F	Present treatment facilities include an aerated lagoon with subsequent settling and chlor- ination of effluent.
PE-01594	District of Terrace Do- mestic Sew- age System	Skeena River	2,000,000	Typical of domestic sewage	Primary treatment now. Must complete secondary treatment facilities by 1980.

Appendix 11.1. (b) (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-1900	Skogland Hot- Springs Hotel and Resort	Into Lakelse Lake which flows into Lakelse River which flows into Skeena River	10,000	BOD ₅ 45 mg/l SS 60 mg/l	Present treatment includes extended aeration package treatment plant and chlorination.
Registered	Winck Memor- ial, Hazelton	Skeena River	25,000	Typical domestic septic tank dis- charge	Possible public health problem.
Registered	Houston	Bulkley River	340,000	SS 40 ppm BOD ₅ 50 ppm pH 6.8 - 7.2	Aerated lagoon fol- lowed by chlorina- tion
PE-1594	District of Terrace	Skeena River	2,000,000	Typical of raw domestic sewage	Must complete sec- ondary treatment plant, chlorination facilities, and out- fall by 1980.
	Village of Hazelton	Skeena River	40,000	SS 400 mg/l BOD ₅ 270 mg/l pH 6.5 - 7.5 temp. 45 - 70° F Coliform (mpn per 100 ml) = 5 x 10 ⁷	Planning on second- ary treatment, chlorination and sludge drying beds.

Appendix 11.1. (b) (cont'd).

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
	Smithers	Bulkley River	625,000	SS 100 mg/l BOD ₅ 75 mg/l Coliform 5,000 mpn/100ml	Activated sludge; secondary treatment followed by chlor- ination.

Appendix 11.1. (b) (cont'd).

2. INDUSTRIAL

PCB I.D.#	DISCHARGER	LOCATION OF DISCHARGE	I Gal/Day	PRESENT EFFLUENT QUALITY	COMMENTS
PE-01608	Granisle Copper Ltd.	Babine Lake	8,100,000 much of which is recycled	Pit Water: Cu 0.18 mg/l Zn 0.06 mg/l Supernatant: SS 52 mg/l pH 0.08 mg/l Zn 0.01 mg/l CH 0.02 mg/l	Tailings pond super- natants used as pro- cess make-up water, providing the tail- ings pond remains stable. Pit water is discharged into the lake. Since the mine is located on an island, land for disposal of tail- ings is scarce.
Registered	Ocean Cement Northern Ltd., Terrace	Skeena River	600	Rinse water from ready-mix operation	Presently have a settling pond.

Appendix 11.2. Mining Claims (to 1972) in the Skeena River Drainage Basin, Falling Within the Omineca and Skeena Mining Districts (B.C. Dept. Mines, Petrol. Res., 1972).

Property Name	Location	Owner	Date of Claim	Metal
Pond	south of Eutsuk Lake	Adastral Mining Corporation Ltd.	1971	copper
Jam, Bob, Ron Fab	Mt. Preston Coles Creek	Denison Mines Limited Amax Potash Limited	1971 1971	copper copper, molybdenum
Rea, TL	Tahtsa Lake	Bethlehem Copper Corporation Limited	1969	copper, molybdenum, silver
Hit	between Comb & Whiting Creeks	J. Todd & R.R. Blusson	1971	--
Len (Huckleberry)	near Sweeney Lake	Kennco Explorations, (Western) Limited	1971	copper, molybdenum
Whit	Whiting Creek	Kennco Explorations, (Western) Limited	1965	molybdenum, copper
DW, Corb, Cup, Fen	Nanika Lake	Silver Cup Mines Ltd., & Aston Resources Ltd.	1968	copper, molybdenum
OVP,MK	south of Troitsa Lake	Aston Resources Ltd.	1971	copper, molybdenum
MO	head of Horetzky Creek	Charta Mines Limited	1906	copper, molybdenum, silver
Berg	south of Kidprice Lake	Kennco Explorations, (Western) Limited	1971	copper, molybdenum

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
Bergette	south of Smoke Mountain	G.O.M. Stewart & R. Blusson	1971	copper, molybdenum
Sib	southwest of Twinkle Lake	K.W. Livingstone	1971	molybdenum
Nadi, Ida	Nadina Lake	Jorex Limited	1970	copper, molybdenum
L & H	Johnny David Lake	Canex Placer Limited	--	copper, molybdenum
Dual (Con)	north of Nadina Lake	K.W. Lingstone	1971	copper, molybdenum
Geo	Horseshoe Lake	Granges Exploration AB	--	--
Helen	north of Tahtsa junction	International Visual Systems Ltd.	--	--
Godot	northeast of Tetachuck Lake	Noranda Exploration Company, Limited	1971	copper, molybdenum
WT	north of Chelaslie Arm	Noranda Exploration Company, Limited	1971	copper, molybdenum
E,O	south of Fraser Lake	Rio Tinto Canadian Exploration Limited	1971	copper, molybdenum
MJM, Mint, Lode	Nihti Mountain	Nithex Exploration and Development Ltd.	1966	molybdenum
Nihti	Nihti Mountain	Marvin Sherman	1966	molybdenum
Marv	east of Babine	Jorex Limited	--	--
Code, Fen	south of Morice River	Anaconda American Brass Limited	1965	silver, lead, zinc

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
Hagas	southeast of Morice River	Perry, Knox, Kaufman, Inc. & Sun Oil Company	--	zinc, copper
Lori	northwest of Morice Lake	El Paso Mining and Drilling Company	--	copper
R	north of Morice Lake	Amoco Canada Petroleum Company, Ltd.	--	--
Mo	Gosnell Creek	El Paso Mining & Drilling Company	--	copper, molybdenum
Red	south-southwest of Smithers	Amoco Canada Petroleum Company Ltd.	--	copper
Fog	southwest of Smithers	The Swiss Aluminum Company of Canada Ltd.	--	copper
Tel	Telkwa River	Tyee Lake Resources Ltd.	1969	copper, silver
War Eagle	south of Howson Creek	Pathfinder Resources	--	copper, silver
Tom	south of Scallon Creek	Maharaja Minerals, Limited	--	copper
Joe	west of Houston	Lobell Mines Limited	1970	silver, copper, lead, zinc
Rock	west of Houston	Noranada Mines Limited	1971	copper, molybdenum
Dominion	Denys Creek	Maharaja Minerals, Limited	1969	copper

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
JW	northwest of Houston	Bethlehem Copper Corporation Ltd.	--	--
Star, Klondike (Hot, Chief)	southeast of Houston	R. Blusson	1965	copper, molybdenum
Deer	Mud Lake	Rio Tinto Canadian Exploration Limited	--	copper, zinc, fluorite
Red Top, Beaver Dam	north of Topley	Ducanex Resources Limited	1926	copper, molybdenum, silver, gold
Thezar	southwest of Topley Landing	Amax Potash Limited	1971	copper
Fly	southwest of Topley Landing	Cities Service Minerals Corporation	1972	--
Day	north of Houston	Bethlehem Copper Corporation Ltd.	--	--
SK	east of Smithers	Amoco Canada Petroleum Company Ltd.	1967	gold, silver, lead, zinc, copper
Lava	south of Telkwa	Maharaja Minerals, Limited	1969	copper, molybdenum
HB,AJ	south of Smithers	Hunter Basin Mines Ltd.	1971	gold, silver, copper

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
HOS	southwest of Smithers	Branta Explorations Ltd.	1971	copper (gold, silver)
Janet, Stock, Lorne (Copper Queen)	Winfield Creek	Copper Queen Explorations Limited	1970	copper, silver
Guy	west of Smithers	Delbrook Mines Limited	1970	--
Glacier Gulch	northwest of Smithers	Climax Molybdenum Corporation of British Columbia, Limited	1966	molybdenum, tungsten
BC	east of Smithers	Bethlehem Copper Corporation Limited	--	--
Drift	Harvey Creek	Driftwood Mines Ltd.	1971	copper, silver
Cronin Mine	Cronin Creek	Hallmark Resources Limited	1969	gold, silver, lead, zinc, cadmium
A	near Debuture Creek	Amoco Canada Petroleum Company Ltd.	--	--
Hal	west of Babine Lake	W.R. Bacon	1970	copper
Full	north of Fulton Lake	Cities Service Minerals Corporation	--	--
M	northeast of Smithers	Amoco Canada Petroleum Company Ltd.	--	copper

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
Del, Lou	west of Babine Lake	W.R. Bacon	1970	copper
W	northeast of Smithers	Amoco Canada Petroleum Company Ltd.	--	--
Blow	northeast of Topley Landing	W.R. Bacon	--	--
Granisle Mine	north of Topley Landing	Granisle Copper Limited	1966	copper (silver, gold)
Tonja, Bab	Babine Lake	Quintana Minerals Corporation	1966	--
Trek	Babine Lake	Canadian Superior Exploration Limited	1967	copper
Bell Mine (Newman)	Babine Lake	Noranda Mines, Limited	1965	copper (gold)
Off, Raid, DDT	northeast of Smithers	Wesfrob Mines Limited	1966	copper, molybdenum
WASP	west of Smithers Landing	Selco Mining Corporation Limited	1968	copper
Brunswick	south of Hazelton	Arcadia Explorations Ltd.	1952	silver, lead, zinc
Hot, Haz	south of New Hazelton	J.H. Sargent	--	--
Loudel (Cap, Golden Wonder)	southwest of New Hazelton	Chapparal Mines Ltd.	1971	copper, tungsten, silver, gold

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
Sunrise	northeast of Hazelton	Sunrise Silver Mines	1971	silver, lead, zinc, antimony
Hot	north of Smithers	Cobre Exploration Limited	--	copper, molybdenum
Daisy	east of Hazelton	Twin Peak Resources Ltd. & Selco Mining Corporation Limited	1971	copper, molybdenum
Ro	north-northwest of Smithers	Canadian Superior Exploration Limited	1971	--
Lynn	northeast of Smithers	Ducanex Resources Limited	1971	copper
Friday	Sinta Creek	David Minerals Ltd., Ducanex Resources Limited, & Twin Peak Resources Ltd.	--	--
Brian, Add	northeast of Hazelton	Earl Dodson and A.J. MacDonald	1971	copper, molybdenum
7A	Thomlinson Creek	The Granby Mining Company Limited	1971	copper, molybdenum
Carr	Takla Lake	Canadian Superior Exploration Limited	--	copper, molybdenum
Nalcus	north of Takla Lake	Wesfrob Mines Limited	--	copper, molybdenum
ND	Takla Lake	Nithex Exploration and Development Ltd.	--	--

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
Ban	Banks Island	Quested Mining Corporation Ltd.	--	copper, molybdenum
Blue Jay	head of Porcher Inlet on Porcher Island	Five Star Petroleum & Mines Ltd.	--	molybdenum
Lady Luck	Mount Johnstone	Cree Lake Mining Ltd.	1970	copper, zinc, lead, iron, molybdenum
Porph	Zymoetz River	R.H. Bates	--	copper, silver
Northwest	east of Salmon Run Creek	R.J. MacNeill	1914	copper
WB	west of Salmon Run Creek	Metron Explorations Ltd.	--	--
Croesus	Kleanza Mountain	Kendal Mining & Exploration Ltd.	1967	copper, silver, gold, lead, zinc
KDL	Kendal Creek	Kendal Mining & Exploration Ltd. and R.H. Bates	1971	copper, molybdenum, silver, lead, zinc
Hope Silver	north of Terrace	Kendal Mining & Exploration Ltd.	1971	gold, silver, lead, zinc
Rega, Jackal, Mag. Niilo	near Cedarvale	Magnetron Mining Ltd.	1969	copper, lead, zinc, silver
Dominion	southeast of Stewart	McIntyre Porcupine Mines Ltd.	1927	copper, lead, zinc

Appendix 11.2. (cont'd).

Property Name	Location	Owner	Date of Claim	Metal
Little Joe, Gypsy	north of Stewart	Starbird Mines Ltd.	1968	silver, gold
Black Hill, Nellie, Blue Grouse	Glacier Creek	Lehto Resources Ltd.	1928	lead, zinc, silver, gold

Appendix 11.3. Air Pollution Sources on the Skeena River Estuary (Environmental Protection Service, 1975).

PCB ID #	DISCHARGER & TYPE OF OPERATION (T.O.)	LOCATION OF EMISSION	TOTAL FLOW RATE (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
AA-3547	CANADIAN CEL- LULOSE COMPANY LIMITED:	Watson Island 1 mile			
	Bleached Kraft Pulp Mill:				
	Number 3 Power Boiler		52,300	fly ash, CO ₂ , water. temp 290°F	The firm proposes treatment via a scrubber, which is to be installed by 1978.
	Number 4 Power Boiler		197,000	fly ash, CO ₂ , water. temp 323°F	The firm proposes treatment via a scrubber, which is to be installed by 1978.
	Recovery Boiler		256,000	Na ₂ SO ₄ , NaCl, CO ₂ , H ₂ S, SO ₂ , CH ₃ SH. temp 280°F	The firm proposes treatment via the installation of a scrubber on Recov- ery stack gases by the end of 1976.

Appendix 11.3. (cont'd).

PCB ID #	DISCHARGER & T.O.	LOCATION OF		TOTAL FLOW RATE (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
		EMISSION				
	Recovery Boiler (cont'd).					This emission now produces a significant odor problem. A strong Black Liquor oxidation system is to be installed by 1978 and another recovery precipitator unit by the end of 1980.
	Brown Stock Washer Vent			19,245	H ₂ S, Me ₂ S, water. temp 104°F	Proposed treatment is a scrubber installed by the end of 1975. This emission produces a significant odor problem.
	Weak Black Liquor Oxidation System			6,480	TRS, Me ₂ S, Me ₂ S ₂ , water. temp 187°F	Proposed treatment is a scrubber and a packed tower with installation in 1975.

Appendix 11.3. (cont'd).

PCB ID #	DISCHARGER & T.O.	LOCATION OF EMISSION	TOTAL FLOW RATE (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
	Weak Black Liquor Vent		76	Me ₂ S, Me ₂ S ₂ , H ₂ S, MeSH, water. temp 187°F	
	Evaporator Seal Tank Vent		133	H ₂ S, CH ₃ SH, Me ₂ S, Me ₂ S ₂ , water. temp 52°F	Proposed treatment involves direction of this emission into the lime kiln. Equipment installa- tion is proposed for the end of 1975.
	Lime Kiln		21,600	CaO, CO ₂ , H ₂ S, water. temp 164°F	Present treatment is via Venture scrubber. Pro- posed treatment is via Peabody scrub- ber.
	Recover Smelt Dissolving Tank		38,500	Na ₂ CO ₃ , H ₂ S, CH ₃ SH, water. temp 155°F	Proposed treatment is showers in stack.
	Slaker		350 4 hours per day	CaO, water. temp 207°F	

Appendix 11.3. (cont'd).

DISCHARGER & T.O.		LOCATION OF EMISSION	TOTAL FLOW RATE (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
PCB ID #					
	Digester Non-Condensable Vent	CANADIAN CEL- LULOSE COMPANY LIMITED: Watson Island 1 mile north- west of Port Edward	35	H ₂ S, CH ₃ SH, Me ₂ S, Me ₂ S ₂ , water. temp 100°F	Treatment proposed is via stripping and incineration.
	Strong Black Liquor Vents		250	TRS, Me ₂ S, H ₂ S, Me ₂ S ₂ , MeSH. temp 212°F	Treatment proposed is incineration.
AA-3763					
	Sulfite Dis- solving Pulp Mill:				
	Number 1 Boiler		6,560	CO ₂ , water vapour. temp 290°F	
	Number 2 Boiler		65,600	CO ₂ , water vapour. temp 290°F	
	Sulfite Di- gester Vomit Stack		23,200 20 minutes - 2-3 times daily	SO ₂ . temp 102°F	Treatment via scrubber proposed.
	Sulfite Mill Chlorine Di- oxide Plant Exhaust		710	Cl ₂ , ClO ₂ . temp 70°F	Treatment via scrubber proposed.

Appendix 11.3. (cont'd).

PCB ID #	DISCHARGER & T.O.	LOCATION OF EMISSION	TOTAL FLOW RATE (SCFM)	EMISSION CHARACTERISTICS	COMMENTS
	Sulfite Pulp Dryers (3)		91,800 (total) for 1 hr. once daily	water. temp 120°F	Treatment via heat recovery systems proposed.
	Sulfite Mill Stacks (53)		304,790 (total)	water, trace amounts of SO ₂ , Cl ₂ , pulp fibre, caustic.	No treatment pro- posed.
Regis- tered 18-24-20	CANADIAN FISHING COMPANY: Oceanside Can- nery Drying Operation	Prince Rupert Harbour Waterfront	8,000 8-20 hr/day July/Sept. 5-12 hr/day Oct/ June	steam laden air (no more inform.)	Present treatment is waterspray scrubbing tower.
Regis- tered 18-24-21	CANADIAN FISHING COMPANY: Oceanside Can- nery Proces- sing & Reduc- tion Plant	Prince Rupert Harbour Waterfront	3,600 8-12 hrs July/ Sept. 900 SCFM - 5/12 hrs. Oct/June	CO ₂ , water vapour, particulate, SO ₂ , CO, NO ₂ .	

Appendix 11.3. (cont'd).

PCB ID #	DISCHARGER & T.O.	LOCATION OF EMISSION	TOTAL FLOW RATE (SCFM)	EMISSION		COMMENTS
				CHARACTERISTICS		
Regis- tered 18-24-19	CASSIAR PACKING CO. (1962) LTD.: Boiler	Port Edwards Waterfront	8 hrs. June/ Sept.	Particulate.		
Regis- tered 18-24-18	CASSIAR PACKING CO. (1962) LTD.: Electric Generator	Port Edwards Waterfront	24 hr. from April/Oct.	Diesel exhaust.		
Regis- tered 18-24-22	CANADIAN FISHING COMPANY LTD.: Atlin Plant	Waterfront Prince Rupert Harbour	70-150 8-12 hrs. July/Sept. 5-12 hrs. Oct./June	Steam laden air.		
Regis- tered 18-24-23	CANADIAN FISHING COMPANY LTD.: North Pacific Plant	Inverness Slough	1400 Jan.-April 5-6 day/ week	Fuel oil combustion gases, particulate SO ₂ , carbon, water vapour.		

Appendix 11.3. (cont'd).

PCB ID #	DISCHARGER § T.O.	LOCATION OF EMISSION	EMISSION		COMMENTS
			TOTAL FLOW RATE (SCFM)	CHARACTERISTICS	
Regis- tered 18-24-24	CANADIAN FISHING COMPANY LTD.: North Pacific Plant Boiler		3100-3200 Jan.-April 5-6 day/ week	NO ₂ , carbon, water vapour, particulate SO ₂ , CO.	

15. GLOSSARY

GLOSSARY INDEX

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GLOSSARY

(i) GENERAL TERMS

1. *bank*: a raised shelf of ground, slope, or elevation in a sea or river bed; or, the sloping margin of a river.
2. *bar*: a sand bank or shoal at the mouth of a river or estuary; or, any of various elongate offshore ridges, banks, or mounds of sand, gravel, or other unconsolidated material, submerged at least at high tide, and built up by the action of waves or currents on the water bottom, especially at the mouth of a river or estuary.
3. *biota*: the flora and fauna of an area; or, the living part of a system.
4. *community*: a naturally occurring group of different organisms inhabiting a common environment, interacting with each other, and relatively independent of other groups; or, an assemblage of closely tied niches.
5. *delta*: the low, nearly flat, alluvial tract of land deposited at or near the mouth of a river, commonly forming a triangular or fan-shaped plain of considerable size, enclosed and crossed by many distributaries of the main river, perhaps extending beyond the general trend of the coast, and resulting from the accumulation (in a wider body of water) of sediment supplied by the river in such quantities that it is not removed by tides, waves, or currents.
6. *detritus*: an accumulation of decaying debris, both organic and inorganic.
7. *ecology*: the study of the interrelationships between organisms and their environment.
8. *ecosystem*: an ecological unit consisting of both the biotic and abiotic (i.e. non-living) environment, interacting to produce a stable system.
9. *estuary*: the seaward end, or the widened funnel-shaped tidal mouth, of a river valley, where fresh water mixes with, and measurably dilutes, sea water, and where tidal effects are evident.

10. *food hierarchy*: based on the principal that, with each step along a food chain, there is less energy available to the consumer, and therefore, there are usually fewer and fewer consumers as one advances up the ladder; the result is a pyramid, with primary producers most abundant and on the bottom, and tertiary consumers least abundant and at the top.
11. *freshet*: a sudden increase or rise in river flow or level because of melting snow and/or heavy rain.
12. *headwaters*: the streams and creeks that are the sources of a river or other water body.
13. *niche*: the way in which an organism uses the factors in its environment; that is, an organism's "role".
14. *nutrient*: a substance necessary to maintain life and promote growth.
15. *shoal*: a shallow place or submerged sand bank, especially one that is exposed at low water, and which may act to impede navigation.
16. *Skeena*: derived from the Tsimpsean Indian word "K-shian", meaning "water of the clouds".
17. *topography*: the surface features of a region, including its relief and rivers, lakes, etc., and such man-made features as canals, bridges, roads, etc.
18. *turbid*: muddy or cloudy owing to sediment particles in suspension in a liquid.

(ii) GEOLOGICAL AND SOIL TERMS

1. *alluvial fan or deposit*: a gradually sloping mass of clay, or sand, or other unconsolidated material (which has been gradually deposited by moving water) that widens out like a fan from the place where the velocity of the flow decreases as it enters a plain, etc.
2. *almadine amphibolite facies*: metamorphic rocks formed by regional dynamothermal metamorphism under high to very high pressures (>5,000 to 6,000 bars) and temperatures of 450°-700°C. Characteristic index minerals include kyanite and, less commonly, andalusite, but not cordierite.

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3. *apophyses*: outgrowth; or, a tongue of intruding rock.
4. *bedrock*: the solid, rock core of the earth which underlies the soil and all superficial rock.
5. *border facies*: the marginal portion of an igneous intrusion which differs in texture and composition from the main body of the intrusion, possibly due to more rapid cooling or assimilation of material from the country rock.
6. *clay*: firm, fine-grained (<0.004 mm) earth which is plastic when wet, composed chiefly of hydrous aluminum silicate minerals; is produced by the chemical decomposition of rocks or the deposit of fine rock particles in water.
7. *colluvial deposit*: an accumulation of rock fragments, sand, etc. on a steep slope or at the foot of a cliff; or, alluvium deposited by unconcentrated surface runoff or sheet erosion, usually at the base of a slope.
8. *dyke*: igneous rock that solidified as a tabular body in a more or less vertical fissure.
9. *fault*: a surface, or zone, of rock fracture along which there has been displacement, from a few centimeters to a few kilometers in scale.
10. *floored*: underlain by, as in "the sediment was floored by bedrock".
11. *foliated*: divided into thin layers.
12. *folisol*: shallow organic soils made up primarily of foliar debris and rotting wood.
13. *glacio-marine till*: unsorted and unstratified marine sediment drift, generally unconsolidated, deposited by and underneath a glacier without subsequent reworking by water from the glacier, and containing a heterogeneous mixture of clay, sand, gravel and boulders varying widely in size and shape.
14. *gravel*: a loose mixture of pebbles and rock fragments coarser than sand (>2.00 mm).
15. *hillocks*: small, low hills; mounds.
16. *hummocky*: refers to a topography having rounded conical knolls, mounds, hillocks, or other small elevations, generally of equidimensional shape, and not ridge-like.

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17. *inner facies*: a term applied to the environment in which a rock was found or to the environment recorded by a rock body.
18. *intrusion*: the invasion, as of liquid magma (i.e. molten rock; which upon cooling solidifies to form igneous rock), into or between solid rock; or, the body of rock resulting from such invasion.
19. *isoclinally folded*: rock layers which have been bent or pressed over one another, by pressure, such that all dip in the same direction. They occur in homogeneous rocks such as slates, and are characteristic of strong deformation.
20. *knob*: a knoll; or, a rounded hill or mountain.
21. *lithic fibrisol*: poorly decomposed organic material from sphagnum mosses, underlain directly by bedrock.
22. *lowland*: land that is lower (i.e. closer to sea level) than that surrounding it; or, of, in or from such a region.
23. *mafic content*: the quantity of igneous rock (containing magnesium, iron, and small amounts of silica) in a rock formation, sediment, etc.
24. *massive*: occurring in thick beds, without minor joints and lamination; said of some stratified rocks.
25. *megaripples*: large sand waves or ripple-like features having a wavelength greater than 1 m, or a ripple height greater than 10 cm, composed of sand, and formed in very shallow water in a fluvial, tidal, or marine environment.
26. *mesic fibrisol*: deep, poorly decomposed sphagnum material, underlain by a layer of partially decomposed sphagnum material.
27. *metamorphism*: the mineralogical and structural adjustment of solid rocks to physical and chemical conditions which have been imposed at depth, below the surface zones of weathering and cementation, and which differ from the conditions under which the rocks in question originated.
28. *plastic clay*: clay in which strain produces continuous, permanent deformation without rupture.
29. *plutonic*: pertaining to igneous rocks formed at great depth, under great heat and pressure, and with slow cooling.

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- 30. *podzol*: leached, mineral soil; or, a type of light-coloured, relatively infertile soil, poor in lime and iron; found typically in coniferous forests in cool, humid areas.
- 31. *relief*: the differences in height, collectively, of land forms in a particular area; or, these differences as shown by lines, colours, raised areas, etc., on a map.
- 32. *sand*: loose, gritty particles of worn or disintegrated rock, varying in diameter from 0.063 mm to 2.00 mm, usually deposited along the shores of bodies of water, in river beds, on deltas, etc.
- 33. *scarp*: a steep slope; that is, an escarpment or cliff extending along the edge of a plateau, mesa, etc.; or, a line of cliffs produced by faulting or erosion.
- 34. *seismic profile*: the data resulting from a single series of observations made at one geographic location with a linear arrangement of seismometers.
- 35. *silt*: fine-grained (0.063 mm to 0.004 mm), unconsolidated sediment with particles intermediate in size between very fine sand and clay, carried or laid down as sediment by moving water.
- 36. *slump*: the slippage or sliding of a mass of unconsolidated sediment down a sub-marine or sub-aqueous slope.
- 37. *stocks*: a rarely used term for a chimneylike orebody; or, an igneous intrusion that is less than 40 sq. mi. in surface exposure, is usually but not always discordant, and resembles a batholith except in size.
- 38. *strata*: layers of sedimentary rock separated from each other by discrete changes in character of material deposited or by sharp physical breaks in deposition, or by both.
- 39. *surficial deposits*: unconsolidated and residual, alluvial, or glacial deposits lying on bedrock or occurring on or near the Earth's surface; they are generally unstratified and represent the most recent of geologic deposits.
- 40. *tightly folded*: a fold, the limbs of which have been so compressed that they are parallel. The structure contour lines of such a fold form a closed loop.

41. *tsunami*: a long-period sea wave caused by a submarine disturbance such as an earthquake or volcanic eruption.

(iii) CLIMATOLOGICAL TERMS

1. *atmospheric pressure*: the pressure exerted by the atmosphere as a consequence of gravitational attraction exerted upon the column of air lying directly above the point in question. Normal sea-level atmospheric pressure is equal to 14.69 lb./sq. in. (or 29.92 in. of mercury as indicated on a mercury barometer).
2. *evaporation*: the physical process by which a liquid is transformed to a gas, or, in general, the amount of water evaporated.
3. *maritime climate*: a regional climate which is under the predominant influence of the sea, and which is characterized by small diurnal and annual ranges of temperature.
4. *modified maritime climate*: a maritime climate that has attained a degree of continentality owing, for example, to occasional intrusions of cold arctic air.
5. *temperature inversion*: an increase in air temperature with an increase in altitude (also, the layer through which this condition prevails), which results in stable stratification and prevents the vertical mixing normally associated with conditions of decreasing temperature with increasing height.

(iv) HYDROLOGICAL TERMS

1. *"cedar" water*: water containing high concentrations of dissolved tannin and humic acids.
2. *glacial flour*: finely ground rock formed by the movement or grinding of glacial ice over a rock surface; carried as fine particles in suspension by streams and rivers, and deposited, with other sediment, on deltas.
3. *hydrograph*: a graph showing changes in water flow over a period of time.

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4. *lignin*: an amorphous, organic substance which acts as a binder for the cellulose fibres in wood and certain plants, and which adds strength and stiffness to cell walls.
5. *Pearl-Benson index*: a method used to measure the concentration of lignin sulphonates in a liquid, particularly red liquor pulpmill wastes. The results are expressed in terms of the equivalent concentration of a standard sulfite waste liquor comprised of 10% solids.
6. *plume*: sediment suspension carried by fresh water, which flows out over the surface of a saltwater body, and appears as a muddy fan on the sea water's surface.
7. *salt wedge*: an intrusion, in a tidal estuary, of sea water in the form of a wedge, characterized by a pronounced increase in salinity from surface to bottom.
8. *tannin*: a yellowish, astringent substance ($C_{14}H_{10}O_9$) derived from oak bark, etc., and used in tanning, medicine, etc.; or, any of a number of similar substances.

(v) OCEANOGRAPHIC TERMS

1. *barometric pressure*: the pressure of the atmosphere as indicated on a barometer (that is, on an instrument consisting of an evacuated, graduated glass tube in which a column of mercury rises or falls as the atmospheric pressure increases or decreases); on a mercury barometer it averages 29.92 inches of mercury at sea level.
2. *cable length*: a unit of nautical measure variously equal to 720 feet (120 fathoms), 600 feet (100 fathoms), or, in the British navy, 607.6 feet (1/10 of a nautical mile).
3. *Coriolis force*: the inertial force caused by the earth's rotation that deflects a moving body to the right in the Northern Hemisphere and to the left in the Southern Hemisphere; this deflection is produced by the acceleration of any body moving at a constant speed above the earth with respect to the surface of the rotating earth.
4. *current*: a horizontal movement of water.

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5. *diurnal*: daily; recurring once a day, having a period or cycle of approximately one tidal day.
6. *driftpole observations*: observations of water currents made by following the movements of a weighted pole.
7. *ebb tide*: outgoing or falling tide.
8. *eddy*: a turbulent circular movement of water usually formed where currents pass obstructions, between two adjacent counter-flowing currents, or along the edge of a permanent current.
9. *fetch*: the reach or longest distance over which the wind can sweep unobstructed.
10. *flocculate*: process of aggregation or precipitation of small lumps formed by precipitation.
11. *flood tide*: rising or incoming tide.
12. *homogeneity*: property of all parts being uniform, similar, and/or equal in structure, quantity, kind, etc.
13. *hydrography*: the study, description, and mapping of oceans, lakes, and rivers, especially with reference to their navigational and commercial uses.
14. *mixed tide*: type of tide in which a diurnal wave produces large inequalities in heights and/or durations of successive high and/or low waters.
15. *physiography*: the description of the features and phenomena of nature; or, the science which deals with the nature and origin of the earth's topographic features.
16. *rip*: an extent of rough, broken water caused by the meeting of cross currents or tides.
17. *salinity*: a measure of the quantity of dissolved salts in sea water; the total amount of dissolved solids in sea water in parts per thousand (‰) by weight, when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter is completely oxidized.
18. *stratification*: the state of a fluid that consists of two or more horizontal layers arranged according to their density, the lightest layer being on top, and the heaviest on the bottom.

(vi) BIOLOGICAL TERMS

1. *anadromous*: a form of fish life cycle in which maturity is attained in salt water, and the adults enter fresh water to spawn.
2. *angler-day*: a day on which a fisherman participates in a sport fishery for any reasonable length of time.
3. *benthic algae*: a group of mainly aquatic plants, variously one-celled, colonial, or filamentous, containing chlorophyll and/or other pigments (especially reds and browns), and having no vascular system, which live in or on the bottom sediment of a water body.
4. *benthos*: organisms living in or on the bottom sediment of a body of water; can be broken into three size groups - macro (greater than 1.0 mm), meio (1.0 mm to 0.5 mm), and micro (less than 0.5 mm).
5. *biogeoclimatic zone*: a zone which is named either by its most characteristic plants or by their geographic (latitudinal or longitudinal) distribution, in relation to the areas macroclimatic and zonal-soil features.
6. *bog*: a wet, spongy area characterized by a very high water table, poor drainage, very acid, organically rich soils, and specially adapted plants, particularly sphagnum mosses, heaths, lichens, and various members of the blueberry family.
7. *consumptive wildlife*: wild animals which are destroyed by man; refers to game animals hunted for food or sport.
8. *copepodite*: a development stage in the life cycle of copepods.
9. *cyprid larva*: a larval stage in the life cycle of barnacles, in which the entire body is encased in a bi-valve carapace; the cyprid has a pair of sessile compound eyes and six pairs of thoracic appendages. It is this stage which settles on the substrate and cements itself, prior to metamorphosis to the adult form.
10. *desiccation*: dried completely; preserved by drying.
11. *diving ducks*: ducks which obtain their food by diving below the surface.

12. *echinoderm*: a phylum of deuterostome invertebrates, all of which are marine and dwell on the bottom, having pentamerous radial symmetry, an internal skeleton, a water-vascular system used in locomotion, feeding, respiration, etc., dioecious reproduction and no excretory system. The group is comprised of the starfish, brittlestars, sea urchins, sand dollars, sea cucumbers, and sea lillies.
13. *epifaunal*: benthic organisms which live on the surface of the substrate.
14. *epiphyte*: a plant that grows on another plant, but is not a parasite, and produces its own food by photosynthesis (such as orchids, lichens, etc.); or, a plant growing on the external surface of an animal's body.
15. *fauna*: animal life of a specific region or time.
16. *filamentous alga*: a group of mainly aquatic plants which grow in long, threadlike strings, containing chlorophyll and/or other pigments (especially reds and browns), and having no vascular system.
17. *fry*: the young fish of a year.
18. *groundfish*: a group of laterally flattened fish, especially adapted to living on or near the bottom: one side of the body assumes the characteristics of the normal ventral surface, the eye and other body parts having rotated to lie on the top surface. The upper surface is often colour camouflaged for protection.
19. *hauling-out site*: an area of low reef or a ledge, with ready access to water, used by seals for resting, mating, giving birth, etc.
20. *hermit crab*: crustaceans of the Order Decapoda, Suborder Reptantia (lobsters, crayfish and crabs); the body is unusual in that the abdomen is not flexed beneath the cephalothorax, but is modified to fit within the spiral chamber of a snail shell. The abdomen is asymmetrically developed, with a thin, soft, non-segmented cuticle, and the pleopods on at least the short side have been lost.
21. *hydroid*: a member of the Phylum Cnidaria, Class Hydrozoa. The life cycle may be polypoid (the sessile form), medusoid (free-swimming form), or both, but all forms are united by three characteristics - the mesoglea is never cellular, the gastrodermis lacks nematocysts, and the gonads are epidermal, or if gastrodermal, the sex cells are shed directly to the outside, not into the gastrovascular cavity.

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22. *infaunal*: benthic organisms which live buried in, or beneath, the surface of the sediment.
23. *intertidal zone*: that area of shore bounded by the levels of high and low tide.
24. *kokanee*: a sockeye salmon (*Oncorhynchus nerka*) which does not migrate to the sea, but spends its entire life in fresh water.
25. *larvacean*: specialized tunicates (Class Larvacea) which are tiny transparent animals living in the plankton of the oceans. The adults are neotonic, having retained some of the characteristics of the juvenile. A tail is present, the entire animal resembling an ascidian tadpole larva bent into a "U". The body is enclosed or attached to a gelatinous mass (as opposed to the usual cellulose tunic) which is continually being shed and replaced. This gelatin consists of a series of cavities and filters used in respiration and feeding. Reproduction is always sexual, the tadpole larva undergoing metamorphosis without settling.
26. *littoral*: that zone of shore having light penetration to the bottom and experiencing wave action; in the case of the oceans, usually above 200 m.
27. *mummify*: to preserve by natural means or by a special embalming process.
28. *nauplius*: the first larval stage in the development of certain crustaceans; typically unsegmented, with only three pairs of appendages, all on the head, and an unpaired median eye.
29. *nemertean*: elongated, usually flattened worms having a proboscis apparatus used in defense and to capture food. Most are marine bottom-dwellers, usually living under rocks, shells, etc., or in burrows in mud and sand. All are carnivorous.
30. *non-consumptive wildlife*: wild animals which are not destroyed by man's use of them, examples being bird-watching, nature photography, etc.
31. *party-day*: a day or reasonable part of a day stayed in a region by a group of people travelling in a single vehicle.
32. *photosynthesis*: the process whereby the energy from sunlight, in the presence of chlorophyll, is used to manufacture carbohydrate from carbon dioxide and water; the general reaction is $\text{CO}_2 + \text{H}_2\text{O} \longrightarrow (\text{CH}_2\text{O}) + \text{O}_2 + \text{H}_2\text{O}$.

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33. *phytoplankton*: plant life, mostly microscopic, found floating or drifting in the oceans or large bodies of water; forms the base of most aquatic food chains as the main primary producer.
34. *plankton*: plant and animal life, mostly microscopic, drifting or floating freely in the water column of oceans and bodies of fresh water.
35. *primary productivity*: the amount of organic matter synthesized by organisms from inorganic substances in unit time in a unit volume of water, or in a column of water of unit area cross section and extending from the surface to the bottom.
36. *pteropod*: shelled or naked planktonic opisthobranch (have one auricle and one kidney; are hermaphroditic) gastropods having large parapodial fins for swimming.
37. *raptorial bird*: a bird of prey, usually having a strong, notched beak and sharp talons (e.g. eagles, hawks, owls, vultures).
38. *red tide*: a reddish discolouration of sea water caused by a population explosion or "bloom" of red flagellates (especially *Gymnodinium* and *Gonyaulax*) which produce a substance that is toxic to fish and other marine life, and may be stored in the tissues of some organisms such as shellfish.
39. *shorebird*: any of a number of birds that feed (usually by wading) or nest on the shores of oceans, rivers, etc.; examples are sandpipers, snipes, etc.
40. *smolt*: usually, a yearling salmonid (that is, older than a fry), when it first leaves fresh water and descends to the ocean.
41. *spat*: the spawn of a bivalve mollusc, such as that of an oyster.
42. *sublittoral*: below that zone of shore having light penetration to the bottom and experiencing wave action; in the case of the oceans, usually below 200 m.
43. *taxonomy*: a system of arranging animals and plants into natural, related groups based on some factor common to each, such as structure, embryology, biochemistry, etc.
44. *terrestrial vegetation*: plants which grow on land as opposed to water.
45. *trawl*: to fish by dragging a large bag-like net along the bottom of a fishing bank.

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46. *troll*: to fish with a moving line, especially one with a revolving lure, trailed behind a moving boat.
47. *ungulate*: belonging to a group of mammals, all of which have hooves.
48. *vascular plant*: a plant whose tissues contain vessels for conducting fluid.
49. *waterfowl*: birds that live on, or near, water, especially swimming game birds like geese and ducks.
50. *zone 1 vegetation*: applied to the Skeena estuary area as the normal forest cover of the region, consisting of western red cedar and hemlock, and an understory of salal, *Rubus* spp. and *Vaccinium* spp. It occurs on undisturbed, well to imperfectly drained sites with podzolic and/or folisolic soils.
51. *zone 2 vegetation*: applied to the Skeena estuary area as areas where normal vegetative cover has been disturbed, and red alder is found growing together with normal zone 1 vegetation.
52. *zone 3 vegetation*: applied to the Skeena estuary area as a bog zone consisting of stunted lodgepole pine, low-growing shrubs of red cedar, yellow cedar and juniper, along with labrador tea and *Vaccinium* spp. and a ground cover of mosses and lichens. This zone occurs on very poorly drained sites of deep organic mesic fibrisols.
53. *zone 4 vegetation*: applied to the Skeena estuary area as a transition zone consisting of small zone 1 species (western red cedar and hemlock) and lodgepole pine of medium height, with an understory of salal, *Vaccinium* spp., and labrador tea, and a ground cover of mosses and lichens. Sites are poorly drained, medium-depth lithic fibrisols and mesic fibrisols.

(vii) LAND USE AND DEVELOPMENT TERMS

1. *base commodity*: an article of commerce, (anything which is bought or sold) which is a staple or is fundamental in the economy.
2. *breakwater*: a barrier to break the force of waves before they reach the shore, as in front of a harbour.

3. *dory*: a small, flat-bottomed fishing boat with high, outward-curving sides.
4. *Gitekshan*: the Tsimpsean Indian word for "people who live up the K-shian", or Skeena.
5. *grease trail*: a path blazed through the wilderness between the Nass and Skeena river drainages by the local Indian tribes, used in the transport of eulachon oil, a staple commodity early in the Indian economy.
6. *infrastructure*: a substructure or underlying foundation; especially, the basic installations and facilities on which the continuance and growth of a community, etc., depend (such as roads, schools, transportation, communication systems, etc.).
7. *Tsimpsean*: derived from the language of northern Indian tribes meaning "people of the mouth of the K-shian" or Skeena.

(viii) POLLUTION TERMS

1. *bilge*: the rounded, lower part of a ship's hull; this area acts as a "catch-basin" for any water, oil, etc. leaking or spilling into the ship.
2. *black liquor*: the residual solution obtained from the Kraft process of alkaline digestion of woodchips, using sodium hydroxide, sodium sulfate, and sodium sulfide.
3. *blanch*: to make white; or, to scald.
4. *caustic*: common term referring to sodium hydroxide.
5. *centrifuge*: a machine using or causing centrifugal force (that is, the force tending to pull something outward when it is rotated rapidly around a center) to separate particles of varying density, or to draw off moisture.
6. *corrosion*: being corroded, that is, being eaten into or worn away gradually as by a chemical reaction; or, causing to deteriorate.
7. *dressed*: used in relation to fish processing to mean the removal of viscera and gills.

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8. *effluent*: the waste outflow from something, such as from a sewer, pulp mill, etc.
9. *emission*: in pollution work, refers to gaseous or vaporized wastes, as opposed to liquid wastes which are called effluents.
10. *fillet*: process of removing the bone from fish; or, the end product from such a process.
11. *fletched*: refers to pieces of fish which have had the bone and skin removed and which weigh 5 to 20 pounds each.
12. *offal*: waste parts (such as viscera, heads, gills, etc.), oil and blood from fish, resulting from fish processing procedures.
13. *red liquor*: the wood-sugar-rich effluent from sulphite pulp mills resulting from the digestion of wood chips under high pressure and temperature by a cooking liquor often containing calcium bisulphite.
14. *reduction plant*: a fish processing plant where fish offal is separated, by a series of procedures, into dry solids and oil.
15. *rendering*: the processes (including heating, drying, pressing, and centrifuging) whereby fish processing wastes are converted to meal, pet food, fertilizer, animal oil, and/or edible oil.
16. *residue*: matter remaining after a process is completed, such as after evaporation, centrifugation, combustion, filtration, etc.
17. *retort*: a vessel in which a substance is distilled or separated into its component parts by heat and pressure.
18. *roe*: fish eggs, especially when still massed in the ovarian membrane.
19. *spent sulphite liquor*: a waste product, high in organic compounds, from the sulphite pulp mill process of cooking wood-chips with sulfurous acid and lime or magnesium.
20. *stickwater*: the residue obtained from centrifuging oily offal wastes. It may contain up to 6% organic solids, and may undergo evaporation to produce condensed fish solubles.

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21. *tailings*: finely ground waste rock discharged from mine milling processes where metals are released and removed from the ore.
22. *toxic*: poisonous.

A NEW DISTRIBUTION

Let $X_1, X_2, \dots, X_n$ be independent random variables with common distribution function $F(x)$ and density function $f(x)$. Let $Y_1, Y_2, \dots, Y_n$ be independent random variables with common distribution function $G(y)$ and density function $g(y)$. Let $Z_1, Z_2, \dots, Z_n$ be independent random variables with common distribution function $H(z)$ and density function $h(z)$.

THEOREM 1. Let

$$X_1, X_2, \dots, X_n \sim G(y), \quad Y_1, Y_2, \dots, Y_n \sim H(z), \quad Z_1, Z_2, \dots, Z_n \sim F(x).$$

$$X_1, X_2, \dots, X_n \sim G(y), \quad Y_1, Y_2, \dots, Y_n \sim H(z), \quad Z_1, Z_2, \dots, Z_n \sim F(x).$$

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