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THE NANAIMO RIVER ESTUARY

STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1976

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THE NANAIMO RIVER ESTUARY

STATUS OF

ENVIRONMENTAL KNOWLEDGE TO 1976

REPORT OF THE ESTUARY WORKING GROUP

DEPARTMENT OF THE ENVIRONMENT

REGIONAL BOARD PACIFIC REGION

By

LEONARD M. BELL and RONALD J. KALLMAN

Under the Direction of Dr. M. Waldichuk

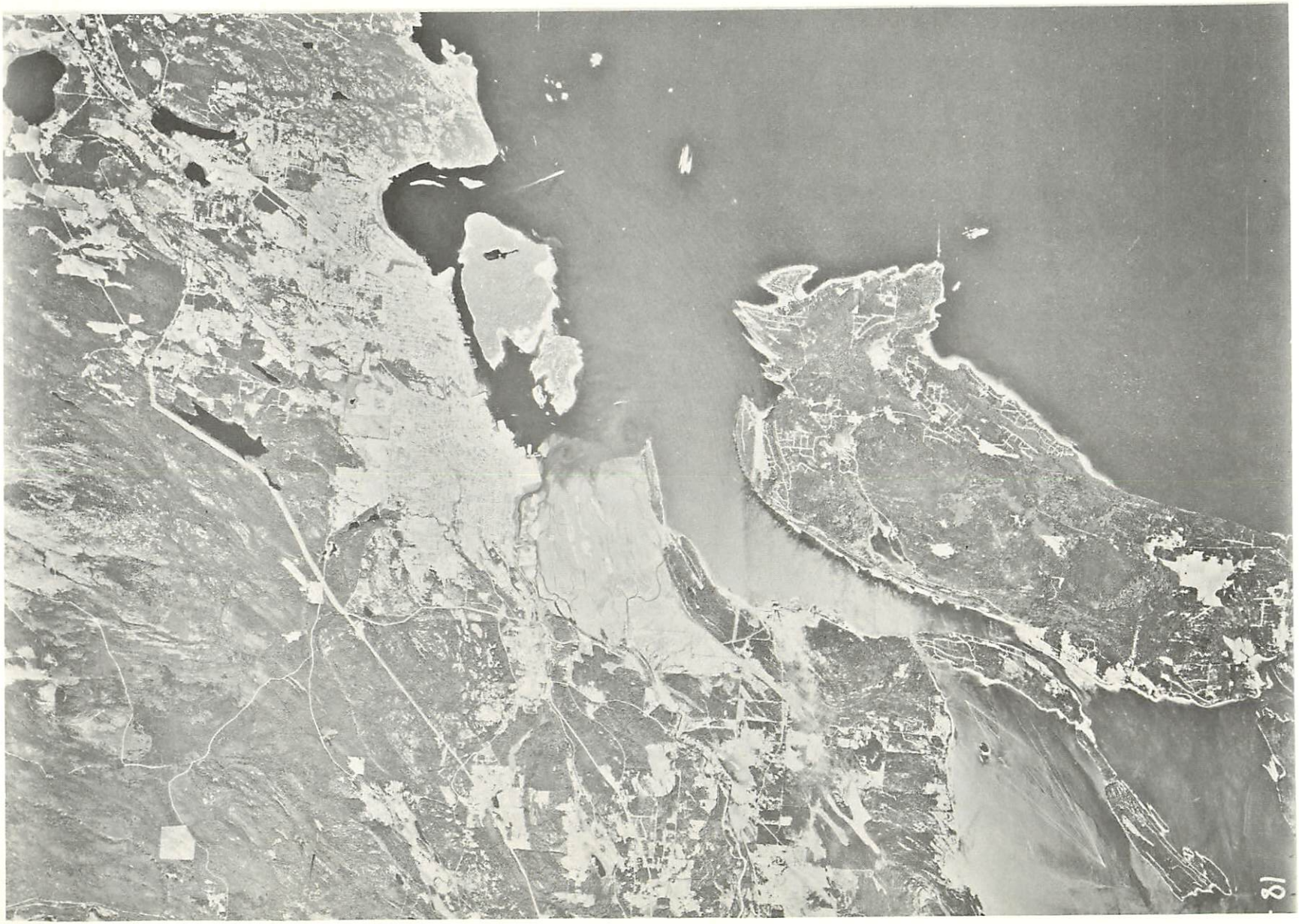
Fisheries and Marine Service

Pacific Environment Institute

West Vancouver, B.C.

SPECIAL ESTUARY SERIES No. 5

JULY 31, 1976



Aerial photograph of the Nanaimo River estuary, August 1972.

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ABBREVIATIONS AND SYMBOLS

asl	above sea level
ac.	acre(s)
A.L.R.	Agricultural Land Reserve
A.R.D.A.	Agricultural and Rural Development Act
ADT	air dry ton
et al.	and others
Atmos. Environ. Serv. (AES)	Atmospheric Environment Service
av.	average
BOD	biochemical oxygen demand
B.C.	British Columbia
B.C.L.I.	British Columbia Land Inventory
C.L.I.	Canada Land Inventory
CNAV	Canadian Naval Auxiliary Vessel
CPR	Canadian Pacific Railway
cm	centimetre(s)
cm/s (cm/sec)	centimetres per second
cont'd	continued
cfs	cubic feet per second
m^3(cu.m)	cubic metre(s)
m^3/s (cms)	cubic metres per second
dm^3	cubic decimetre(s)
^oC	degrees Celsius (centigrade)
^oF	degrees Fahrenheit
σ_τ	density (sigma-τ)
E	east
ed.	editor or edition
EEB	Environmental Emergency Board
ELUCS	Environment and Land Use Committee Secretariat
EPS	Environmental Protection Service
pH	expression for acidity or alkalinity of a solution
fm	fathom(s)

ABBREVIATIONS AND SYMBOLS (cont'd).

ft.	foot (feet)
e.g.	for example
gal.	gallon(s)
g	gram(s)
g/m^2	grams per square metre
GSC	Geological Survey of Canada
>	greater than
ha	hectare(s)
h.(hr.)	hour(s)
ID	identification
IGD	Imperial gallons per day
in.	inch(s)
Ibid.	in the same place
IOUBC	Institute of Oceanography, University of British Columbia
km	kilometre(s)
km/hr.	kilometre(s) per hour
KME	kraft mill effluent
Lat.	latitude
<	less than
l	litre(s)
Long.	longitude
MS	manuscript
max.	maximum
mem.	memoir
m	metre(s)
µg	microgram(s)
mi.	mile(s)
m.p.h.	miles per hour
meq/l	milliequivalents per litre
mg/l	milligrams per litre
mm	millimetre(s)
MMbm	million board feet
Mm^3	million cubic metres

ABBREVIATIONS AND SYMBOLS (cont'd).

Mdm^3	million cubic decimetres
min.	minimum
m.(')	minute
misc.	miscellaneous
n.mi.	nautical mile(s)
N	north
No.(#)	number
oz.	ounce
PBS	Pacific Biological Station
PEI	Pacific Environment Institute
Pac. Reg.	Pacific Region
p.	page or pages
pp.	pages
ppm	parts per million
$^{o}/_{oo}$	parts per thousand
%	percent
PCB	Pollution Control Branch
lb(s)	pound(s)
Reg. Bd.	Regional Board
rept.	report
sat.	saturated
ser.	series
S	south
spec.	special
sp.	species (singular)
spp.	species (plural)
cm^2	square centimetres
sq.ft.	square feet
m^2	square metre(s)
sq.mi.	square mile(s)
STD(std.)	standard
SCF	standard cubic foot (air pollution)
SCFM	Standard cubic foot per minute (air pollution)

ABBREVIATIONS AND SYMBOLS (cont'd).

SS	suspended solids
temp.	temperature
i.e.	that is
Mbm	thousand board feet
TDS	total dissolved solids
TIC	total inorganic carbon
TOC	total organic carbon
TS	total solids
TSS	total suspended solids
UBC	University of British Columbia
U.S.	United States(of America)
U.Vic	University of Victoria
var.	variety (biology), variance (statistics), variation (navigation)
vol.	volume
W	west
yr.	year

PREFACE

This is the fifth in the series of reports of the Estuary Working Group (Preface Table (i)) of the Regional Board Pacific Region of Environment Canada on the 18 estuaries considered critical in British Columbia. The four previous reports covered the Fraser (No. 1), Squamish (No. 2), Skeena (No. 3), and the Cowichan and Chemainus River estuaries (No.4). Priority for the sixth, seventh and eighth estuary systems to be covered will be given to the Kitimat, Courtenay-Campbell and Somass Rivers, respectively. The remaining nine estuaries are those of the Indian, Homathko and Bella Coola rivers on the mainland, and of the Quatze, Salmon, Nitinat, Gold, Wannock and Nimpkish rivers on Vancouver Island.

These reports are not intended to provide substantive new information on the estuaries concerned. However, it is hoped that they succeed in bringing together in one place all the available references relevant to the environmental aspect of the chosen estuaries. At the same time, an effort has been made to summarize pertinent information and to provide lists on plant and animal life, to give the reader some idea of the ecological characteristics, especially if further work on the estuary is planned.

The shores of Nanaimo Harbour and Departure Bay have been a preferred area for human settlement long before the advent of the white man. The remnants of Indian middens along the shores of Departure Bay and Gabriola Island are mute testimony to the richness of the nearby coastal waters in living resources. The petroglyphs south of Nanaimo reflect in art form the close association of the Indians with their source of livelihood from the sea.

The Nanaimo area has had a comparatively long history of industrial development since the white man entered the scene,

having celebrated 100 years of coal mining in 1949. The main asset of its coastal waters was for the shipment of coal, with Departure Bay serving as one of the early coal-shipping points. Vestiges of rock jetties remain in Departure Bay, originally formed by ballast discharged from early sailing ships taking on coal for distant points. Many of the beach areas still exhibit fragments and fines from the old coal mining and shipping days. Beneath the waters of Nanaimo Harbour, and the urban section of the city of Nanaimo, extensive tunnels were bored into the substratum as miners sought coal from the many underlying seams. There are remnants of old mine shafts virtually within the confines of the city and in more outlying areas, including the harbour's protective islands, Newcastle and Protection. The area has been rich in fossils, including such items as clams fossilized in coal.

As coal became depleted, mining for this resource was phased out and emphasis began to be placed more on forestry, including logging and sawmilling. The city of Nanaimo has supported a number of sawmills of various sizes since the turn of the century. One of the largest pulp mills in the province was brought into operation in 1950 at Harmac, about 6 km (4 mi.) southeast of Nanaimo City centre. The bulk of recent shipping from Nanaimo and Harmac has been in lumber and pulp.

Fishing has always been conducted both commercially and recreationally out of Nanaimo. At one time, when whaling was an important industry in British Columbia, there was even a whaling base in Hammond Bay, to the north of Departure Bay. Until World War II, Japanese-Canadian fishermen operated from Brandon Island in Departure Bay. At the northwest side of Newcastle Island, there was a reduction plant for pilchards when these were caught in large numbers during the 1930's. At the present time, a few salmon trollers and gill-netters are based in Nanaimo, and there is only a small custom canning establishment

and a large shrimp-peeling operation based on a West Coast fishery. Saltwater sport fishing is commonly pursued over a wide area in waters outside Departure Bay. Recreational boating is also popular, and the Nanaimo Yacht Club attracts a substantial number of local boaters, as well as pleasure craft from other Canadian and U.S. coastal points.

Nanaimo has been traditionally the transportation hub for Vancouver Island, with ferry service for passengers and freight provided for many years by the Canadian Pacific Railway into Nanaimo Harbour. After 1955, ferry service to Departure Bay was inaugurated by the Black Ball Line, which was later taken over by the B.C. Government ferry system. A regular service hourly in summer and about bi-hourly in winter, between Departure Bay and Horseshoe Bay, is now operated by the British Columbia Ferries, with less frequent service by the CPR's PRINCESS OF VANCOUVER (a passenger, auto and rail car ferry) between Nanaimo Harbour and Vancouver Harbour.

The Nanaimo River is one of many streams draining the east side of Vancouver Island into the Strait of Georgia and, besides having the largest estuary on Vancouver Island, it is the fifth largest on the whole coast of British Columbia, and considered by some to rank even higher in size of delta habitat. Like the other rivers, its potential for a domestic and industrial freshwater supply and for runs of salmon and trout has always been recognized. The pulp mill at Harmac found the Nanaimo River to be a valuable source of fresh water vitally needed for its pulp production. Steelhead fishermen have long known the Nanaimo River to be an excellent outlet for wintertime recreation. The Nanaimo River estuary, within the confines of Nanaimo Harbour, however, has served mainly as a booming ground for sawmills and the Harmac pulp mill. Until the late 1950's an outfall discharged raw sewage from southern Nanaimo onto the tidal flats. An assembly wharf for a sawmill operation has been in place since the early 1950's at the outer (northern) reaches of the western side

of the delta. The CPR wharf for passenger/automobile ferries, located at the northern extremity of the Nanaimo River delta in Nanaimo Harbour, was used until the early 1960's when most of the CPR ferries were phased out of service. The present CPR ferry service is from a relatively new railway/auto ferry slip just south of the old terminal. For the harbour ferry service and for the shipping of lumber, the main impact of the Nanaimo River has always been the silting in of the relatively shallow and narrow ship channels. This necessitates regular dredging.

For many years, the Nanaimo River estuary was not fully recognized as a vital ecosystem. Scientists from the Pacific Biological Station nearby occasionally examined certain specific fishery problems. It was evident, of course, that the log storage was having a detrimental effect on vegetaion and aquatic invertebrates of the delta. Sewage had long ago rendered the shellfish unsafe because of bacterial and viral contamination. The waters off Jack Point are popular for trapping edible crabs. Nanaimo River water is known to flow over these crab grounds on its way into the Strait of Georgia, and possibly nourishes them with organic materials washed down from the drainage basin. The Nanaimo River has modest runs of a number of species of Pacific salmon, but is generally better known to sportsmen for its winter-run steelhead. In the past, these fish stocks were considered to be adequately protected if the waters in the river and estuary were maintained free of pollution and the channels were kept unobstructed for the passage of adults upstream and juveniles downstream. Some attention has always been given to spawning grounds in the lower section of the river, so that they are not gouged by floating logs or covered by debris or silt. However, it was only recently that the importance of the estuary and delta as a nursery ground for juvenile salmonids of both local and other origins was adequately recognized.

The Nanaimo River estuary serves as a favorite year-round sanctuary for waterfowl and other aquatic birds, but is

particularly important as an overwintering area or migratory resting place. Thirty-eight species of waterfowl have been found here, as well as some 81 species of other aquatic birds. Migrating and wintering aquatic birds may feed and sometimes nest here, even though estuaries are usually poor nesting areas. The Nanaimo River estuary/delta, being a productive ecosystem, supplements the Fraser River estuary in supporting the largest wintering population of waterfowl in Canada. About 4 million aquatic birds fly along the B.C. coast to and from northern nesting and feeding grounds, and some of these stop over on the Nanaimo River estuary. The decline in species and numbers of shore-birds on the Nanaimo River estuary during the past three decades has been attributed to the adverse effects of log booming. Dependent on eelgrass for food, the black brant particularly have suffered from degradation of the delta and by the decline in food supply.

It was not until the Nanaimo Harbour Commission announced early in 1971 its proposal to develop the inner harbour into a larger deep-sea terminal that concerns were expressed about the ecological damage that might arise because of disturbance in the estuary by such development. As one citizen put it, "The Bath-Tub Capital of the World could end up with the largest bath-tub ring in the world". This concern led to a public hearing on January 25, 1973, at which a number of briefs by concerned individuals and groups were presented. Finally, a Nanaimo Environmental Assessment Task Force was set up under the Lands Directorate of Environment Canada which issued its important report in December, 1973, "An Environmental Assessment of Nanaimo Port Alternatives". The Task Force studied the four alternatives for port development in Nanaimo, considering environmental consequences in each case: (1) Inner Harbour; (2) Jack Point; (3) Duke Point; and (4) Harmac South. Its recommendations supported (4) as a first choice for development, followed by (3) without barge channel, and considered (1) and (2), as well as the inner part of Duke Point (with barge channel) as inviolate because of the serious environmental consequences expected as a result of their development.

Area coverage for the present report is somewhat broader than the Nanaimo River estuary *per se* to give it wider application. Its preparation has benefited greatly from the vast amount of information provided in the foregoing Task Force report. I wish to thank Dr. J.H. Ross, Chairman of the Task Force, for permitting full use of that report. The assistance provided in compilation of information by many people in Nanaimo, particularly staffs of the city of Nanaimo, the Greater Nanaimo Regional District, Harmac and Forestry Divisions of MacMillan Bloedel Ltd. and of the Pacific Biological Station, is gratefully acknowledged.

We hope that this report has fulfilled its major objective of providing a summary and sources of environmental information on the Nanaimo River estuary and its environs for users in government, educational institutions and for both professional workers and interested lay persons. The reports in this series would not have been possible without the generous financial support from regional directors-general and directors of Environment Canada.

M. Waldichuk

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The authors would like to thank the administrators of the City of Nanaimo, the Regional District of Nanaimo and the Nanaimo Harbour Commission for their assistance and co-operation during the preparation of this report.

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We are grateful to Dr. M. Waldichuk for writing the Oceanography Section, and for his guidance and continuing interest in this series of reports.

Finally, we wish to thank Mrs. Rose Dawson for typing the manuscripts.

SUMMARY

The Nanaimo River estuary, the largest estuary on Vancouver Island, encompasses approximately 820 ha (2,000 acres) of intertidal lands. Situated immediately south of Nanaimo Harbour and within the limits of the city of Nanaimo, the estuary is vulnerable to environmental disruption by future development.

The Nanaimo River, Millstone River, Chase River and Holden Creek are the main sources of freshwater discharge into the estuary. The Nanaimo River, with a mean annual discharge of 40 m^3/s (1430 cfs), rises on the slopes of Green Mountain, 48 km (30 mi.) west of the river mouth. With its main tributaries, including Haslam Creek and Jump Creek, it drains an area of approximately 84,149 ha (325 sq. mi.).

The climate of the Nanaimo estuary is characterized by long, cool and generally dry summers with short, mild and wet winters. Lying in the rain shadow of the mountains of the Vancouver Island Ranges, the region has a drier climate than that of most mainland estuaries. The average annual rainfall is only 1011 mm (40 in.) as compared to 2301 mm (91 in.) at Prince Rupert on the Skeena River. Mean daily temperatures range from 2.6°C in January to 17.8°C in July. Winds in the Nanaimo area, as elsewhere along the southeastern coast of Vancouver Island, are generally modifications of the winds in the open Strait of Georgia, owing to the protection afforded by the Gulf Islands. The prevailing wind direction is east to southeast during the autumn and winter months, with westerly and northwesterly winds predominating during the summer months.

The Nanaimo River and its estuary lie within the Nanaimo Lowland, a strip of low-lying country below 610 m (2,000 ft.) extending along the east coast of Vancouver Island. It is largely

underlain by sedimentary rocks of the Nanaimo Group of Upper Cretaceous age, comprised mainly of conglomerate, sandstones and shales. Within this group is the Extension-Protection formation, in which are located the coal seams that supported the Nanaimo coal mining industry for over one hundred years.

Prior to 1975 little was known about the extent and distribution of the sediments of the Nanaimo River delta. In February, 1976, the Pacific Biological Station initiated a project to sample the surficial sediments maintaining the subaqueous and intertidal zones of the delta. This work was carried out in conjunction with a program of on-going research of the meiofauna living in the sediments (Appendix 1.2).

Two main soil groups are evident in the vicinity of Nanaimo and the estuary, Brown Podzolic soils and Alluvial soils. The well-drained Chemainus soils (silty-loams) of the Alluvial group are the most desirable for agriculture. These soils are used for mixed and dairy farming and for cash crops such as potatoes, truck crops and vegetable seeds. The Haslam soils of the Brown Podzolic group cover 6,037 ha (14,725 acres) mainly in the Cedar District, south of Nanaimo. The majority of these soils, are generally not suitable for agriculture owing to droughtiness, low fertility and the frequency of rock outcrops.

The Nanaimo River estuary study area has a wide variety of oceanographic conditions related in part to a rather complex shoreline and topographic configuration. Oceanographic conditions range from vertically stratified and generally quiescent waters of Nanaimo Harbour to the turbulent, swift-flowing waters of Dodd Narrows. The Nanaimo River and small tributary streams introduce a considerable amount of fresh water into Nanaimo Harbour and Departure Bay during the period of high precipitation from November to March. However, when the Fraser River is in freshet during May and June, fresh water can move into the Nanaimo area from across the Strait of Georgia.

Within Nanaimo Harbour and Departure Bay, surface waters are strongly influenced by winds, while the deeper waters exhibit a more positive tidal component. Southeasterly winds move surface water from Nanaimo Harbour into Departure Bay through Newcastle Island Channel, whereas northwesterly winds tend to retain surface water in Nanaimo Harbour. Westerly winds in Departure Bay move surface water seaward. In Northumberland Channel, the currents are markedly tidal, but the surface flow tends to set to the southeast into Dodd Narrows on virtually all stages of the tide.

Wave action in the inner part of the study area is rather limited owing to the protection provided by Gabriola Island, Jack Point, Protection and Newcastle Islands. However, northwesterly winds can develop sufficiently vigorous seas at the entrance to Nanaimo Harbour to have an effect on the outer delta of the Nanaimo River. Northeasterly and easterly winds can also create choppiness in both Nanaimo Harbour and Departure Bay, with the attendant wave action on beaches and disturbance of intertidal forms.

In general, the rate of flushing is progressively better as one goes from Nanaimo Harbour to Departure Bay then to Northumberland Channel, and finally, the open Strait of Georgia. Because of the tendency for surface currents to set continuously to the southeast in the section of Northumberland Channel southeast of Harmac, any effluents released in this area are dispersed rather rapidly through Dodd and False Narrows. Prevailing winds tend to retain any substances introduced into Nanaimo Harbour. In Departure Bay, westerly (northwesterly in Strait of Georgia) winds aid the flushing process by moving surface water seaward.

The invertebrate fauna of the study area, particularly of rocky shorelines has been described in some detail owing to the proximity of the Pacific Biological Station. Investigations

into the benthic and pelagic invertebrate biology of the estuary, as it fits into an overall model of the estuary are in progress by scientists of the Pacific Biological Station. Preliminary results indicate that benthic copepods, *Harpacticus uniremis* in particular, are a key link in the salmon supporting, detritus based, food web of the Nanaimo River estuary. Shellfish and crabs are also found in abundance on the lower estuary. Dungeness crab populations support moderate commercial and substantial recreational fisheries. Shellfish resources within the present study area, though substantial, are presently closed owing to coliform pollution.

Five species of Pacific salmon (chum, coho, chinook, pink and sockeye) and two species of migratory trout (steelhead and cutthroat) occur in the rivers and streams draining into Nanaimo Harbour. All seven species occur in the Nanaimo River, whereas only steelhead and cutthroat are reported in the Millstone River, Hong Kong and Holden Creeks, and chinook, coho, chum, steelhead and cutthroat in Chase River. The estuarine and nearshore residency of juveniles and the importance of the estuary to local salmonid populations has been documented as a result of ongoing estuarine research.

These runs contribute not only to commercial and sport catches in the local area but also to catches in other parts of the Strait of Georgia and its approaches. Nanaimo River chum salmon are taken in the commercial gillnet and seine fisheries in the Strait of Georgia and Johnstone Strait. Coho and chinook salmon from Nanaimo Harbour streams may be caught in the troll fisheries off the west coast of Vancouver Island as well as in the Strait of Georgia troll and sport fisheries, and in the commercial net fisheries in Johnstone Strait, and the Straits of Georgia and Juan de Fuca. A local tidal sport fishery is based upon maturing chinook bound for the Nanaimo River, and an Indian food fishery depends largely on returning chums.

The Nanaimo area is extensively utilized by juvenile herring during their early life history; in fact, they were the most abundant fish species sampled on and around the estuary in 1973. Spawning occurred in Departure Bay and along the eastern foreshores of Newcastle and Protection Islands in 1975. Annual extensive spawning occurs north of Horswell Bluff into Nanoose Bay and these areas are the object of an intensive herring roe fishery. The landed value of the area 17 roe fishery has increased annually since 1970 and was worth over a million dollars in 1975.

Research into primary production on and around the estuary is on-going. The waters of the study area are generally more productive than the average in the Strait of Georgia and may become quite murky during phytoplankton blooms in early spring and late summer. Flora of the delta is categorized into upland, sedge or marsh and intertidal communities. The macrophytic algae biomass of the intertidal community is large owing to the lack of heavy spring freshet and the abundant suitable attachment substrate. Eelgrass grows on the lower portions of the estuary, in the Duke Point Lagoon, the False Narrows area and in places along the Departure Bay and eastern Newcastle and Protection Islands foreshores.

The estuary lies within the dry Douglas-fir biogeoclimatic subzone which borders the southeast coast of Vancouver Island. Most of the river watershed is classified as wet Douglas-fir, which merges into the western hemlock zone as elevation increases.

The Nanaimo River estuary, in conjunction with surrounding lakes, marshes and fields provides a habitat complex used by thousands of overwintering birds. The estuary is critical to waterfowl survival during periods of severe winter weather when freshwater feeding habitats freeze or are covered in snow. It is part of the larger complex of the Strait of Georgia estuaries that are vital feeding, resting, and marshalling areas for migrating birds of the Pacific flyway. Portions of the estuary

attractive to specific bird species are described. The river watershed supports sizeable populations of mule deer and wapiti, with stands of low-elevation, mature timber available for winter range. The waterfowl of the estuary and the ungulates and upland game birds of the watershed support considerable hunting activity. The wildlife of the study area is also enjoyed by bird watchers, nature photographers and other recreationalists. The continued existence and possible enhancement of area wildlife is dependent on the preservation of natural habitats.

The first people known to live in the Nanaimo area were the Indians of the Coast Salish tribe. In 1850 they occupied five villages on Nanaimo Harbour and the Nanaimo River. Nanaimo, established in 1852 by the Hudson's Bay Company to develop the Nanaimo coalfields, is one of British Columbia's oldest settlements. In 1874, when it was officially incorporated as the city of Nanaimo, it had a population of 1,500 people. This figure had increased to almost 15,000, when the last census was taken in 1971.

The early development of Nanaimo was controlled to a large extent by the primary industry of the time, namely coal mining. Between 1852 and 1953 over 50 million tons of coal were mined from the Nanaimo coalfields, making the industry the second largest mineral producer in British Columbia, next to the production of gold. In 1950, MacMillan Bloedel established a kraft pulp mill at Harmac, approximately 6 km (4 mi.) southeast of the city of Nanaimo. With the depletion of the coal resources in the 1950's,the economy of the area became dependent on the forest industry, forest products manufacturing and tertiary industries such as commercial business establishments, transportation and services. Nanaimo is now a major service centre for Vancouver Island.

The use of land for farming is limited by the availability of arable land. In 1971, there were 286 farms identified in

the Nanaimo census subdivision. The main farming activities are dairying and truck farming. Commercial fishing, although not a major industry of the area, has always provided a livelihood for a small percentage of the population of the Nanaimo region. However, herring and chum salmon fisheries can be substantial and have attracted fishermen from wide areas of the lower coast.

The Port of Nanaimo and the forest products industry are the principal users of the waterfront adjacent to the city of Nanaimo and the estuary. The intertidal zone of the estuary is used extensively for log booming and storage to supply area sawmills and the Harmac pulp mill. Log booming is held responsible by some for the alleged demise of eelgrass beds on the delta and is known to have deleterious environmental effects. The Nanaimo Harbour Commission controls the foreshore leases, which at present occupy almost one third of the estuary, 262 ha (640 acres). In 1973, a federal Department of Environment task force was established to investigate the environmental impact of the Nanaimo Harbour Commission proposals to construct additional lumber transshipment facilities. Four alternative sites were investigated including Duke Point, currently regarded as the most favourable for development from both an economic and environmental point of view.

Routine water quality data collected since 1968 are available for the Nanaimo River. Sewage discharge at the Duke Point and Newcastle Island outfalls has been curtailed with the start-up of the Five Finger Island outfall site and the Hammond Bay primary sewage treatment plant. Monitoring of the new effluent disposal site has not yet disclosed any significant environmental effects; however, the old discharge sites, particularly along the Newcastle Island foreshore, have shown marked improvements in water quality. The Harmac pulp mill has recently made operational a submarine effluent diffuser discharging into Northumberland Channel for the total combined mill wastes, including secondarily treated domestic sewage. The capacity of Northumberland

Channel to assimilate mill discharges has been estimated and the new deep-water discharge is calculated to adequately dilute, disperse and evacuate mill effluents. Biological monitoring of Harmac receiving waters has disclosed deleterious effects of mill effluents on local intertidal communities in the past, and will be continued in order to monitor any effects of the new discharge scheme.

Air emissions from the many primary and secondary industries of the Nanaimo area are not under permit with the Pollution Control Branch, and no local ambient air quality studies have been undertaken by government agencies. The Harmac pulp mill is the most obvious single source of air pollution. However, a recently completed assessment of environmental impact of sodium chloride from hog-fired power boilers, done under contract for MacMillan Bloedel Ltd., concluded that their emissions had no significant impact on the surrounding environment.

The use of estuaries for port development is, as previously discussed in reports in this series, usually detrimental to the natural renewable resources of the estuary. However, through the combined efforts of governments, industry, scientists and concerned citizens' groups, future development on and around the Nanaimo River estuary is being planned so as to minimize environmental disruption and maximize economic and social benefits.

1. INTRODUCTION

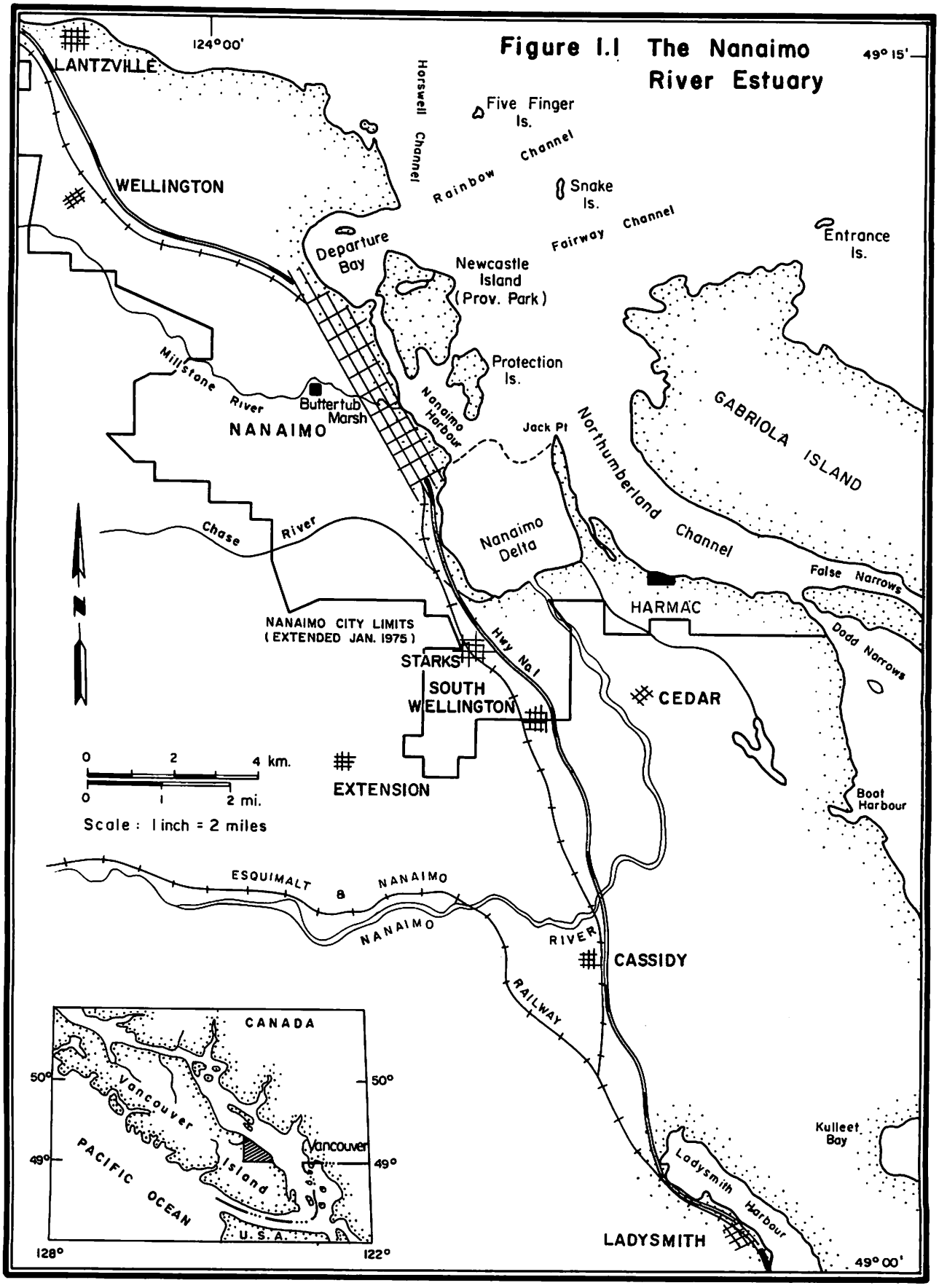
1 (i) GENERAL

The Nanaimo River estuary, encompassing approximately 820 hectares (2,000 acres) of intertidal lands, is the largest estuary on Vancouver Island and the fifth largest of approximately 170 estuaries on the entire coast of British Columbia (Trethewey, 1974). On the basis of morphology it can be classified as a coastal plain estuary (Pritchard, 1967), or from the physical oceanographers' viewpoint, as a tide-dominated estuary (Stommel, 1951).

For the purpose of this report the boundaries of the study area are defined as follows: On the landward side, the northern limit is marked by the town of Lantzville, latitude 49° 15' north and longitude 124° 02' west; the southern limit is defined by the town of Ladysmith, latitude 49° 00' north and longitude 123° 50' west (Figure 1.1). The seaward or eastern limit of the estuary includes Northumberland Channel (as far south as Dodd Narrows), Fairway Channel to Entrance Island, and Departure Bay, Horswell Channel and Rainbow Channel.

The Nanaimo River with an average annual discharge of 40 cms (1430 cfs), is the main source of freshwater inflow to the estuary. Additional, but lesser, quantities of fresh water are contributed by the Chase River, Holden Creek and an unnamed creek, known locally as Hong Kong Creek. North of the Nanaimo River delta, the estuarine system receives the discharge of the Millstone River (flowing into Nanaimo Harbour) and several small creeks flowing into Departure Bay.

The city of Nanaimo, the second largest on Vancouver Island, after the capital Victoria, extended its boundaries in 1975 as far north as Lantzville, and southwards to Harmac and


Figure 1.1 The Nanaimo River Estuary
124°00'
49° 15'
LANTZVILLE
WELLINGTON
Horswell Channel
Five Finger Is.
Rainbow Channel
Snake Is.
Fairway Channel
Entrance Is.
Departure Bay
Newcastle Island (Prov. Park)
Protection Is.
Millstone River
Buttertub Marsh
NANAIMO
Nanaimo Harbour
Jack Pt
Northumberland Channel
GABRIOLA ISLAND
Chase River
Nanaimo Delta
False Narrows
HARMAC
NANAIMO CITY LIMITS (EXTENDED JAN. 1975)
Hwy No.1
STARKS
SOUTH WELLINGTON
CEDAR
Dodd Narrows
0 2 4 km.
0 1 2 mi.
Scale : 1 inch = 2 miles
EXTENSION
Boat Harbour
ESQUIMALT & NANAIMO RAILWAY
NANAIMO RIVER
CASSIDY
CANADA
50°
49°
Vancouver Island
Vancouver
PACIFIC OCEAN
U.S.A.
128°
122°
Kulleet Bay
Ladysmith Harbour
LADYSMITH
49°00'

South Wellington. The redesignation of the boundaries increased the population of the city from 14,948 to 44,403, or 74 percent of the entire population of the Nanaimo Regional District. Once a major coal-mining centre (1852-1953), Nanaimo is now a main service centre for Vancouver Island with an economy largely dependent on the forest products industry and tertiary industries, such as business, transportation and services.

The forest products industry in the Nanaimo region is supported mainly by the MacMillan Bloedel Limited kraft pulp mill at Harmac, two chemical companies, and several sawmills and lumber companies. Some logging is still carried out in the hinterland in the vicinity of the Nanaimo Lakes. With available harbour facilities, and connecting railway and highway lines to nearby logging areas on Vancouver Island, Nanaimo has rapidly become a main port for lumber exports. In 1974, over one million tons of lumber, pulp and plywood were loaded at the Port of Nanaimo for destinations in foreign countries.

1 (ii) HISTORICAL PERSPECTIVE

Nanaimo, one of British Columbia's oldest settlements was established in 1852, when the Hudson's Bay Company commenced mining coal in the vicinity of Winthuysen Inlet, (the area now covered by Departure Bay, Nanaimo Harbour and Northumberland Channel).

A short history of Nanaimo and its environs has been compiled by Johnson (1974) and Johnson, Parker and Sedola (1966). The authors present an account of the history of the area based on a miscellany of historical journals of the late nineteenth and early twentieth centuries. It is upon these accounts, that the following historical perspective is largely based.

The first known people to live in the Nanaimo area were

the Indians of the Coast Salish. In 1850 they occupied five villages on Nanaimo Harbour and the Nanaimo River (Duff, 1964). When the bands met together as a group, they were referred to as "Snenymos", meaning the Great and Mighty People, from which word the city of Nanaimo derived its name.

The discovery of coal in 1851, by a local Indian, aroused the interest of the Hudson's Bay Company in Victoria. In 1852 an outcrop of coal, above the high-water mark on the beach in Nanaimo Harbour, was examined by James Douglas, the Governor of the Crown Colony of Vancouver Island, who instructed Joseph McKay, Hudson's Bay Company clerk in Fort Victoria "to proceed with all possible diligence to Winthuysen Inlet, commonly known as Nanymo, and formally take possession of the coal beds lately discovered".

The Hudson's Bay Company commenced mining operations immediately, under the direction of John Muir, and in September 1852, the first shipment of coal was taken by schooner to Victoria.

In 1853, The Bastion (a blockhouse) was built by the Hudson's Bay Company to protect the early settlers from the constant raids of the northern Indian tribes. This small group of settlers brought in to operate the coal mine, named their settlement Colvilletown in honour of the first Governor of the Hudson's Bay Company. With the advent of twenty-four families from England in 1854, the white population of Colvilletown was increased to seventy-five, and formed the nucleus of the new community, which in 1860, became officially known as Nanaimo. The Hudson's Bay Company, through its subsidiary, the Nanaimo Coal Company, continued to operate shaft mines in the Nanaimo area until 1861, when the mine areas (held as coal lands), townsite and business establishments belonging to the Company, were all sold to the Vancouver Coal Mining and Land Company.

In 1869, the Wellington coalfield was discovered by

Robert Dunsmuir, a former Hudson's Bay Company miner. By 1883, he had become the sole owner of Dunsmuir, Diggle and Company, and had renamed it R. Dunsmuir and Sons Limited. With the depletion of the coal reserves in the Wellington field, mining activity moved south. In 1895, the Extension coalfield was opened, resulting in the establishment of the town of Extension and the shipping port of Ladysmith.

The first official chart of Nanaimo Harbour and the surrounding area was prepared in 1862, by Captain Richards of H.M.S. Hecate. "Subsequent charts suggest little change in the position of the main delta front between 1862 and the present or in the foot of the delta front. The main changes since 1862 have involved fill to form much of the present area of downtown Nanaimo and alterations associated with construction of the present Assembly Wharf" (Pacific Biological Station, 1973).

On December 26, 1874, the settlement at Nanaimo (population 1,500) was officially incorporated as the city of Nanaimo. The first civic elections were held in January, 1875, when Mark Bate, manager of the Vancouver Coal Company, was elected mayor. Seven members were elected to the City Council, who met in the Court House, renowned as being the first stone building on Vancouver Island.

By 1882, the population of the city had reached 2,000, and while previously the majority of its inhabitants worked in the mines, many were now connected with the shipping of coal and the provision of services necessary to a growing city. There were 51 stores reported to be in business, and small industries were developing, such as the Nanaimo foundry, three breweries and a shipbuilding works. The Hudson's Bay Company operated a small sawmill on the Millstone River using water power, while logging was carried out in a small way, to provide lumber for homes and pit props for the mines.

In the same year (1882), a waterworks company was formed, and water, which had previously been carried in buckets from local springs, was piped from wells through wooden pipes. Later, the Chase River provided the water supply and gradually the wooden pipes were replaced by iron ones. In 1901, the waterworks were sold to the city, and in 1931 a dam was built on the south fork of the Nanaimo River, providing the city with its first adequate water supply system. In 1952, the Greater Nanaimo Water District was formed and the water supply system was expanded to supply 60,560 m^3 (16 million gal.) of water a day.

"The first light and power for the city was produced from local coal. In 1887, the Nanaimo Gas Works was opened and continued to operate until electric power became more feasible. The first electric power plant in Nanaimo was built in 1888, near Fraser Street, using steam from coal as a source of power, and electric lights were used in Nanaimo's streets by 1891" (Johnson, 1974). In 1907, a storage dam was constructed at Westwood Lake in East Wellington, for power generation, and the electrical system was taken over by the International Utilities Corporation. In 1945 the British Columbia Power Commission took over the generation and distribution of power on Vancouver Island.

Other public services such as telephone and telegraph systems, a fire department, hospital services and schools came into being in the late 1800's. A telegraph system connecting Nanaimo with Victoria was completed in 1879, and in 1887 a commercial telephone service was started, with eight telephones installed in a local store. The British Columbia Telephone Company took over the local system in 1905, and facilities were expanded to connect Nanaimo with country-wide lines.

The Nanaimo Fire Company was formed in 1878, at which time a hand-operated fire engine was purchased. Horse-drawn equipment was used until 1914 when La France fire trucks were purchased. Hospital service began in 1877, with the conversion

of a row of miners' cabins. In 1881, a larger hospital was built which served the area until 1928, when a new one was built. It was replaced in 1962 by the present Nanaimo Regional General Hospital.

In March, 1886, the first section of the E and N (Esquimalt-Nanaimo) Railway was opened between Nanaimo and Victoria, providing an alternate route to the well established "sea link". To the north, the line ran to Wellington where large railway shops were established, making Wellington an important railway centre. In 1905, the E and N Railway system was sold to the Canadian Pacific Railway.

The Vancouver Coal Mining and Land Company established in 1861, was sold to the Western Fuel Company of San Francisco in 1903. Reorganized as the Canadian Western Fuel Company in 1918, it was subsequently bought out by the Dunsmuir interests in 1928.

By 1931 the annual production of coal from Vancouver Island coalfields had dropped to 831,925 tons, well below the peak production of 1,754,656 tons achieved in 1922 (Muller and Atchison, 1971). The coal mining industry was now declining rapidly. In 1953, the Canadian Collieries' Bright Mine, south of the Nanaimo River, and the most southerly mine in the Douglas Seam, closed, thus ending an industrial era which, for more than one hundred years, had played a major role in the economic and cultural development of the city of Nanaimo.

2. GEOLOGY AND SOILS

2 (i) GENERAL GEOLOGIC SETTING

The Nanaimo River and its estuary lie within the Nanaimo lowland described by Holland (1964) as "a strip of low-lying country, below 2,000 feet [610 metres] elevation, which extends southeastward for 175 miles [282 kilometres] along the east coast of Vancouver Island, from Sayward on Johnstone Strait to Jordan River west of Victoria.....largely underlain by sedimentary rocks of the Nanaimo Group of Upper Cretaceous age (Appendix 2.1). It is flanked on its western side above the 2,000-foot [610-metre] contour line by the Vancouver Island Ranges..... The lowland consists of many low, wooded cuesta-like ridges separated by narrow valleys. The northwesterly elongation of the ridges and of the Gulf Islands is the result of differential erosion of the Upper Cretaceous sedimentary rocks. The ridges are underlain by hard sandstone and conglomerate beds, and the valleys are eroded in shales and softer rocks or along fault zones".

2 (ii) REGIONAL GEOLOGY

The Upper Cretaceous Nanaimo Group has been studied for more than one hundred years by geologists and paleontologists. The earliest geological reports pertaining to the Nanaimo area were made by Newberry (1857) and Hector (1861) after exploratory survey expeditions. Newberry established the Cretaceous age of the coal-bearing strata on the basis of its plant fossils.

Richardson (1872, 1873, 1878) investigated the Vancouver Island coalfields between 1871 and 1876 and divided them into three main areas of deposition; the Comox, Nanaimo and Cowichan Basins. Buckham (1947a) subsequently distinguished five basins

of deposition, adding the Alberni and Suquash (Port McNeill) basins.

In 1912, Clapp published a preliminary report on the geology of southern Vancouver Island, followed by a report on the geology of the Nanaimo map-area (Clapp, 1914). These works, in which he established and named the succession of formations in the Nanaimo area, have since become a standard reference on the Nanaimo Group. The most recent and definitive work on the geology of the study area is that of Muller and Jeletzky (1970), to which the reader is referred for detailed descriptions of the stratigraphy and biochronology of the area.

Nanaimo Group sediments comprised mainly of conglomerates, sandstones and shales are present along the east coast of Vancouver Island, and on the Gulf Islands. Muller and Jeletzky (1970), used the term Nanaimo basin or area to designate the Cretaceous rocks in the vicinity of Nanaimo and those of the Gulf Islands.

Buckham (1947a) described the basin as follows: "The Nanaimo basin is about eighty miles long [129 kilometres] from Nanoose Bay on Vancouver Island, to Orcas Island, off the state of Washington. Its greatest width is about twenty miles [32 kilometres], average width about nine miles [15 kilometres], and its area about 700 hundred square miles [181,300 hectares]".

Muller views the Nanaimo Group sedimentary succession as "a series of transgressive cycles, each exhibiting a progression from (a) fluvial to (b) deltaic and/or (c) lagoonal, to (d) nearshore marine and (e) offshore marine" (Muller and Jeltzky, 1970, p.6). His interpretation of the succeeding sedimentary cycles, their component formations and facies (rock type) is shown in Table 2.1. For a complete description of the distribution, lithology and age of these formations the reader is referred

Table 2.1. The Nanaimo Group Sedimentary Succession, formations and facies (after Muller and Jeletzky, 1970).

CYCLE	FORMATIONS	FACIES
Fifth - Deltaic	Gabriola	Sandstone, conglomerate, shale
Fourth - Marine	Spray	Shale
- Deltaic	Geoffrey	Sandstone, conglomerate
Third - Marine	Northumberland	Shale, siltstone, fine-grained sandstone
- Deltaic	DeCourcy	Conglomerate, sandstone
Second - Marine	Cedar District	Shale, siltstone, fine-grained sandstone
- Deltaic	Extension	Conglomerate, sandstone
- Lagoonal	Protection	Sandstone, shale, coal (Douglas seam at base)
- Lagoonal and littoral marine	Wellington Member	Sandstone, shale, coal (Wellington seam)
First - Marine	Haslam	Shale, siltstone, fine-grained sandstone
- Lagoonal	Comox	Sandstone, shale, coal
- Fluvial	Benson	Conglomerate, greywacke

to Muller and Jeletzky (1970).

One of the more important formations in the Nanaimo area is the Extension-Protection series, within which are located the coal seams that supported the Nanaimo coal mining industry for over one hundred years. It is best exposed in the area around Nanaimo and on Newcastle and Protection Islands, where its maximum thickness is estimated to be 570 m (1900 ft.) (Muller and Jeletzky, 1970).

"Outside the mining area the thickness decreases sharply and the formation is represented by conglomerate and pebbly sandstone without coal seams. North of Nanaimo some isolated areas of conglomerate and sandstone near Parksville and the coal-bearing beds of Lantzville are included in the formation (Muller and Jeletzky, 1970)."

2 (iii) ECONOMIC GEOLOGY

1. COAL:

The geology, history and potential of the Vancouver Island coal deposits, and in particular the Nanaimo area, have been described in detail by Muller and Atchison (1971) and James (1969), from whom the following description was taken.

"The Nanaimo coalfield occupies the northwestern end of the Nanaimo basin, extending roughly from Nanoose Bay to Cassidy. The furthest inland workings were six miles from the coast. The total area underlain by workable coal seams is approximately twenty-five square miles. The coal occurs in the lower part of the Nanaimo Group. The lowest seam, known as the Wellington seam, occurs in the East Wellington formation, about 213 m (700 ft.) above the base of the Nanaimo Group.

The Newcastle and Douglas seams occur in the Newcastle formation, about 305 m (1000 ft.) above the Wellington, being separated by 183 m (600 ft.) of conglomerate (Extension formation) and 122 m (400 ft.) of shaly sandstones and shales (Cranberry formation). The Newcastle seam is 8 to 30 m (25 to 100 ft.), average 18 m (60 ft.) below the Douglas seam. A few purely local and minor seams such as the three seams overlying the main Wellington seam in the extreme northwestern part of the coalfield have been worked to a limited extent, but nearly all the coal produced in the Nanaimo field has come from the three seams mentioned above."

For a review of the mining operations and mining methods employed by the major collieries operating in the Nanaimo area during the peak production years (early 1900's), the reader is referred to Strachan (1923, p. 73-95).

Coal mined from the Nanaimo coalfields was classified, according to the A.S.T.M. system of classification by rank, as High Volatile A Bituminous, with 11 percent to 15 percent ash and less than 1 percent sulphur (Dickson, 1948, Schwartzman and Tibbetts, 1953).

2. SAND AND GRAVEL:

The type, extent and location of sand and gravel deposits used commercially as a source of aggregate material, have been documented by Leaming (1968).

The main deposits occur along the Nanaimo River, from the mouth to a point about 16 km (10 mi.) upstream. Gravel deposits on both sides of the Island Highway north of Cassidy, underlie 1,886 ha (4,600 ac.) and are estimated to contain 122 million m^3 (160 million cu. yd.) (Leaming, 1968).

Fifteen pits in the vicinity of Cassidy supply aggregate for a variety of commercial uses, including a ready-mix concrete plant, an asphalt paving plant, road-bed material for the city of Nanaimo and the Department of Highways, and rail ballast for the Canadian Pacific Railway. During 1961, production of sand and gravel from pits in the Nanaimo River valley was valued at more than $197,000 (British Columbia Minister of Mines and Petroleum Resources, Annual Report, 1961).

3. OTHER MINERAL DEPOSITS:

Other mineral deposits on Vancouver Island have been described by Carson (1969). Known and probable tertiary mineral deposits in the Nanaimo area are the MacMillan copper-arsenic deposits near the Nanaimo Lakes, and some unidentified gold-quartz veins between Nanaimo and Nanoose Harbour.

2 (iv) SURFICIAL GEOLOGY

1. GENERAL:

The surficial geology of the Nanaimo area has been studied and mapped by Halstead (1963). The observations that follow have been extracted from the descriptive notes that accompany his map of the surficial deposits of the area (G.S.C. Preliminary Map 27-1963).

"The unconsolidated deposits throughout much of the area are related to the regimen and wasting of the last major ice-sheet that occupied Vancouver Island, the British Columbia mainland, and the Strait of Georgia." This last major period of glaciation was named the Fraser Glaciation by Armstrong, Crandell, Easterbrook and Noble (1965). During this period the ice sheet on Vancouver Island attained a thickness of about 1650 metres (5,500 feet) and upon retreat left a blanket of till.

Halstead in the descriptive notes for his preliminary map of the surficial geology of the Nanaimo area (map 27-1963) referring to the Fraser Glaciation states that "during retreat and wastage of this ice, sea-level was considerably higher than present. Heavily loaded streams issuing from valley glaciers in Nanaimo River and Haslam creek valleys, deposited sand and gravel as deltas into a sea that was about 150 metres (500 feet) higher than present sea-level. That sea-level reached these higher elevations is evidenced not only by the elevations of the top beds of the deltas but by erosion features such as wave-eroded caves on sandstone and conglomerate cliffs at elevations 116 to 128 m (380 to 420 ft.) near Extension, and also by gravel deposits that occur at a common elevation of about 150 m (500 ft.) along the west side of the lowland".

2. DELTAIC SEDIMENTS:

Prior to 1975 little was known about the extent and distribution of the sediments on the sub-aerial and sub-aqueous sectors of the Nanaimo River delta. Surficial sediment samples were taken at 7 stations in the intertidal zone, in December, 1975 and February, 1976, in conjunction with an on-going program of meiofauna research by the Pacific Biological Station (J. Sibert - pers. comm.).

In February, 1976, the Pacific Biological Station initiated a project to collect surficial sediment samples at 45 stations in the delta area. Stations were located at approximately 400 metre intervals and sampling was carried out on the delta front, the intertidal zone and the river mouth. Samples were collected at high-water by divers using a special coring device to obtain cores approximately 15 cm long and 6.25 cm diameter. The top 1 cm of the core was used for sediment identification to obtain a correlation between the sediment grain size and meiofauna data obtained by the biologists. The sediment sampling and analysis for grain size was carried out by scientists

from the Department of Geological Sciences of the University of British Columbia. The results of these analyses are expected to be published by mid-1976 (University of British Columbia - report in progress).

2 (v) SOILS

Soils of the southeastern sector of Vancouver Island, including the Nanaimo area, have been well documented by the Canada Department of Agriculture in co-operation with the University of British Columbia and the British Columbia Department of Agriculture (Day, Farstad and Laird, 1959), and more recently by the British Columbia Forest Service (Keser and St. Pierre, 1973).

Two main soil groups (Brown Podzolic soils and Alluvial soils), are evident in the vicinity of Nanaimo and the estuary area. Generally, Brown Podzolic soils are found in all areas except the deltas and flood plains of the Nanaimo, Chase and Millstone rivers, where Alluvial soils occur. Listed below are the principal soil types found in the area, based on the Duncan-Nanaimo map-sheet of the Vancouver Island soil map (Day, Farstad and Laird, 1959).

Brown Podzolic Group	-	Qualicum loamy sand
	-	Qualicum gravelly loamy sand
	-	Haslam shaly loam
	-	Bowser loamy sand
Alluvial Group	-	Chemainus silt loam
	-	Cassidy sandy loam

The following description of the soil characteristics for these series is based on Day, Farstad and Laird's soil survey (1959).

Qualicum loamy sand is found in and adjacent to the

city of Nanaimo. Qualicum gravelly loamy sand has been mapped in the Cassidy area and on both sides of the Nanaimo river west of Cassidy. The vegetation associated with these soils is composed principally of lodgepole pine with Douglas-fir, hemlock, red alder and occasionally arbutus. These soils are rapidly drained and have rapid permeability. They are submarginal for agriculture except where used for specialty crops. Cultivated areas are used mainly for the production of crops such as strawberries and vegetables for the early market. A limited acreage is used for pasture.

The Haslam Complex covers 6,037 ha (14,725 ac.) mainly in the Cedar District, south of Nanaimo. "Shaly loam is the dominant textural class but occasionally fine sandy loams or light clay loams may be encountered. The vegetation consists of Douglas-fir, hemlock, cedar, maple and shrubs somewhat less dense than on most other medium textured soils. Selected areas of this soil complex, where the solum is deep by reason of deposition of glacial material over the shale, are used for general farm crops, mainly hay and pasture. The majority of the soils, however, are not suitable for agriculture because of droughtiness, low fertility, and the frequency of rock outcrops."

The Bowser Series are well drained soils developed on coarse-textured marine materials underlaid by glacial till or marine clay. "They are characterized by 50 to 75 cm (20 to 30 in.) of reddish brown loamy sand containing many iron cemented clods. Loamy sand is the only textural class encountered. Gravel and stones are uncommon.

The vegetation consists of Douglas-fir, hemlock and red cedar with red alder dominant on logged-off areas. Only a small percentage of this soil is cultivated and it is used mainly for hay and pasture. Generally the Bowser is an inferior soil for agriculture."

17. Geology and Soils

Soils of the Chemainus Complex have developed on sandy and silty alluvium, and have textures ranging from fine sandy loam to clay loam, with the most common texture being loam.

"The vegetation is mixed. Some areas support valuable stands of hemlock and red cedar. Logged-off areas support a second growth of red alder and young conifers with a ground cover of sword fern, thistle, thimbleberries and huckleberries. In other areas, maple, red alder, willows and cottonwood are dominant with a ground cover consisting of grasses and shrubs."

"The well-drained Chemainus soils are very desirable for agriculture but the poorly drained phase is questionable unless adequately drained or diked. The soils are used for mixed and dairy farming and for cash crops such as potatoes, truck crops and vegetable seeds."

Soils of the Cassidy Complex have developed on a coarse-textured alluvium and have a texture ranging from sandy loam through coarse-textured classes to stony sand.

"The vegetation consists of maple, red alder and young conifers with a ground cover of shrubs. Stumps are present in the second growth but their frequency and the density of the second growth is lower than on Chemainus soils."

"No agricultural development has taken place on this soil except for the few areas used for timber grazing purposes. This soil has very low agricultural value and should largely remain in forests to aid in regulating stream flow and thus protect stream channels and cultivated soils nearer the sea."

3. CLIMATOLOGY

3 (i) GENERAL DESCRIPTION

The climate of the Nanaimo River estuary is characterized by long, cool and generally dry summers with short, mild and wet winters. It has been classified as transitional by Kerr (1951), lying between the wetter climates of both the mainland coast of British Columbia and the west coast of Vancouver Island, and the drier climates to the south.

It is often referred to as a cool-summer Mediterranean climate, based on the Koppen classification system (Trewartha, 1943, p. 311). For this classification the climatic type is based on three criteria as follows: (1) at least three times as much precipitation in the wettest month of winter as in the driest month of summer; driest month has less than 30.5 mm of rain, (2) the mean daily temperature of the warmest month is below 22^{o}C, and (3) the mean daily temperature of the coldest month is between 18^{o}C and 0^{o}C.

Lying in the rain shadow of the mountains of the Vancouver Island Ranges, the region has a drier climate than that of most mainland estuaries, as is evident from the following comparisons. The average annual rainfall of Nanaimo is 1011 mm compared to 1915 mm at Squamish and 2301 mm at Prince Rupert near the Skeena River.

Winds in the Nanaimo area, as elsewhere along the southeastern coast of Vancouver Island, are generally modifications of the winds in the open Strait of Georgia, due to the protection afforded by the Gulf Islands. The prevailing wind direction is east to southeast during the autumn and winter months, with westerly winds predominating during the summer months.

Mean daily temperatures range from 2.6°C in January to 17.8°C in July, with an extreme maximum of 40.5°C and an extreme minimum of - 17.2°C. The frost-free period extends over an average period of 181 days, from April 24 to October 23. The annual average of bright sunshine recorded at Nanaimo Airport from 1941 to 1971, was 1,846 hours.

3 (ii) CLIMATOLOGICAL STATIONS

Earliest records of temperature and precipitation at Nanaimo date back to January, 1892. The station operated more or less continuously at nearby sites until June, 1968, at which time it was closed. These records and those obtained at the Nanaimo Airport since 1947 provide the data base for the long-term climatic normals for the area (Can. Dept. Env., Atmos. Environ. Serv., 1971b).

Meteorological observations are currently being made at Nanaimo Airport, Departure Bay (Pacific Biological Station), Nanaimo CHUB and Entrance Island. The location of these and former weather stations are shown in Figure 3.1.

The weather data available from these stations, and a summary of the climate for the Nanaimo area, are contained in Table 3.1 and 3.2.

3 (iii) PRECIPITATION

The Nanaimo estuary shows the marked wet winter - dry summer regime of the British Columbia coast. It does, however, have a drier climate than most mainland estuaries owing to its geographical location.

The mean annual rainfall is 1011 mm, as measured at

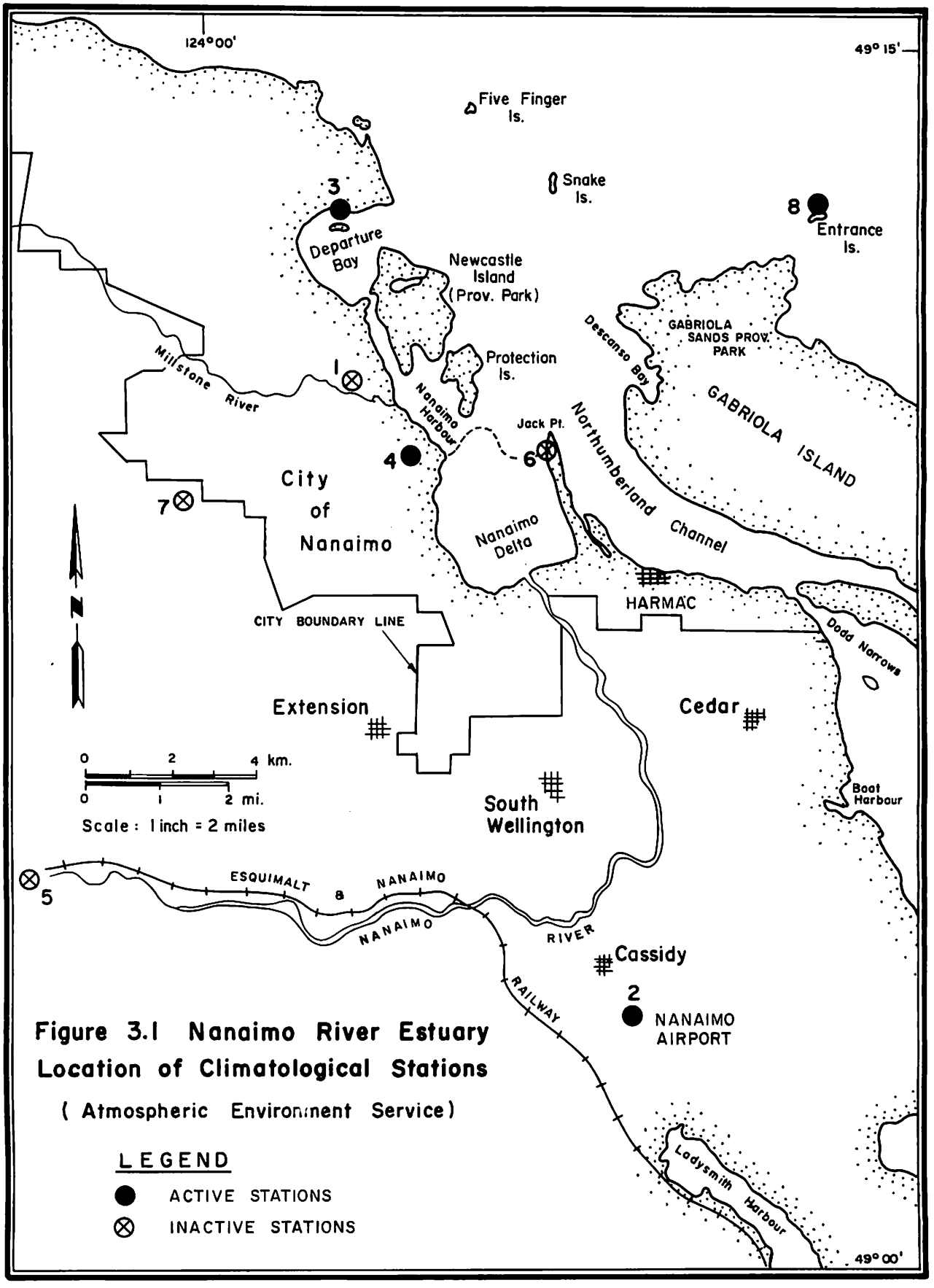

124°00'
49° 15'
Five Finger Is.
Snake Is.
3
Departure Bay
8
Entrance Is.
Newcastle Island (Prov. Park)
Protection Is.
GABRIOLA SANDS PROV. PARK
Descanso Bay
Millstone River
1
Nanaimo Harbour
Jack Pt.
6
4
GABRIOLA ISLAND
Northumberland Channel
City of Nanaimo
7
Nanaimo Delta
HARMAC
CITY BOUNDARY LINE
Dodd Narrows
Extension
Cedar
0 2 4 km.
0 1 2 mi.
Scale : 1 inch = 2 miles
South Wellington
Boat Harbour
5
ESQUIMALT & NANAIMO RAILWAY
NANAIMO RIVER
Cassidy
2
NANAIMO AIRPORT
Ladysmith Harbour
49° 00'
Figure 3.1 Nanaimo River Estuary
Location of Climatological Stations
(Atmospheric Environment Service)
LEGEND
ACTIVE STATIONS
INACTIVE STATIONS

Table 3.1. Nanaimo River estuary - available weather data (Can. Dept. Env., Atmospheric Environment Service, 1971a).

1. Nanaimo 49°11'N 123°58'W 230' ft. (70 m) asl.

1.1.	Temperature and Precipitation	January 1892 - July 1893 March 1901 - June 1968
1.2.	Sunshine	March 1901 - July 1936 April 1938 - November 1953

2. Nanaimo Airport 49°03'N 123°52'W 104' ft. (32 m) asl.

2.1.	Temperature and Precipitation	March 1947 - Continuing
2.2.	Wind Mileage	December 1950 - July 1960
2.3.	Sunshine	November 1953 - Continuing

3. Nanaimo Departure Bay 49°13'N 123°57'W 25' ft. (8 m) asl.

3.1.	Temperature and Precipitation	January 1913 - January 1926 August 1928 - Continuing
3.2.	Radiation	January 1959 - Continuing
3.3.	Rate of Rainfall	April 1971 - Continuing

4. Nanaimo CHUB 49°10'N 123°56'W 70' ft. (21 m) asl.

4.1.	Temperature and Precipitation	August 1969 - Continuing

5. Nanaimo River Camp 49°05'N 124°05'W 670 ft. (204 m) asl.

5.1.	Precipitation	August 1962 - December 1968.

6. Nanaimo 2 49°10'N 123°53'W 30' ft. (9 m) asl.

6.1.	Precipitation	March 1901 - April 1909

7. Nanaimo Water Reservoir 49°09'N 123°58'W 375' ft. (114 m) asl.

7.1.	Temperature and Precipitation	August 1962 - August 1967
7.2.	Rate of Rainfall	August 1962 - February 1967 June 1967 - August 1967
7.3.	Evaporation	June 1964 - February 1967 June 1967 - August 1967

8. Entrance Island 49°13'N 123°49'W 25' ft. (8 m) asl.

8.1.	Temperature and Precipitation	July 1914 - May 1918
8.2.	Wind Mileage	January 1922 - August 1939 October 1969 - Continuing

Table 3.2. Nanaimo River estuary - climate summary (Can. Dept. Env., Atmospheric Environment Service, 1971a).

1. Nanaimo	
1.1. Temperature	
Mean temperature - Annual	9.9°C
Mean temperature - January	2.6°C
Mean temperature - July	17.8°C
Extreme maximum temperature	40.5°C
Extreme minimum temperature	-17.2°C
1.2. Precipitation	
Mean annual total precipitation	1085 mm
Mean annual total rainfall	1011 mm
Mean annual total snowfall	70 cm
1.3. Annual Number of Days with:	
Frost	70 days
Measurable precipitation	161 days
1.4. Frost-Free Period	
April 24 - October 23	181 days
2. Nanaimo Airport	
2.1. Wind	
Prevailing wind direction by hours	West
Prevailing wind direction by miles	West
Mean annual wind speed	3.6 knots
2.2. Annual Number of Days with:	
Thunder	2.7 days
2.3. Average Annual Hours of Bright Sunshine	1,846 hours
2.4. Fog - Visibility Less than 1 kilometre	
Annual number of days with fog	21.8 days
Month with greatest average - January	5.2 days
Month with least average - April, June	0.1 days
3. Entrance Island	
3.1. Wind	
Prevailing wind direction by hours	East
Prevailing wind direction by miles	East
Mean annual wind speed	11.5 knots

the Nanaimo weather station for the period 1941 to 1970. An additional mean annual snowfall of 69.9 cm, increases the mean annual total precipitation to 1085 mm (Canada, Department of the Environment, 1971b).

Records for the 30 year average (1941 to 1970) show that the average number of days with measurable precipitation is 155, while snow falls on an average of 9 days a year. The heaviest snowfalls usually occur in December and January with lesser amounts falling during February, March and November.

In general, precipitation on the east coast of Vancouver Island increases northward, as is evident from the following comparison of figures from weather stations at Victoria, Nanaimo and Courtenay (Can. Dept. Env., 1971a).

Station	Height (asl)	Rainfall (mm)	Snowfall (cm)	Total Precip. (mm)
Victoria	68m	625	32.8	657
Nanaimo	70m	1011	69.9	1085
Courtenay	33m	1276	122.3	1398

3 (iv) TEMPERATURE

The long-term records of temperature for the Nanaimo area are based on readings obtained at the Nanaimo weather station from March, 1901 to June, 1968, at which time data records were terminated. Temperature readings are now obtained on a continuing basis from the following meteorological stations. The date readings commenced is shown in brackets. Nanaimo Departure Bay (August, 1928), Nanaimo Airport (March, 1947) and Nanaimo CHUB (August, 1969).

A comparison of the annual, winter and summer temperatures for these three stations is shown in the following table:

Table 3.3. Nanaimo - Mean Temperatures °C

Station	Annual (1941-1970 average)	Jan.	Jul.	Extremes max.	min.	No. years of record
Nanaimo	9.9	2.6	17.8	40.5	-17.2	66
Nanaimo A	9.1	1.5	17.1	36.7	-20.0	23
Nanaimo Dep. Bay	10.6	3.5	18.3	38.3	-13.9	52

Another indicator of the relative temperature differences between Departure Bay and the Nanaimo Airport is the annual number of days with frost. These are, based on the 1941-1970 normals, 43 days at Departure Bay and 112 days at Nanaimo Airport. These values reflect the strong gradients often encountered due to local exposure at coastal sites compared to slightly more inland locations.

3 (v) WIND

Hourly records of wind speed and direction are available from two stations in the vicinity of the Nanaimo estuary. A type 45B recording anemograph is located at the lightstation on Entrance Island, off the northeast point of Gabriola Island, and also on Brandon Island, adjacent to the Pacific Biological Station.

Wind mileage records are obtainable for the station on Entrance Island, from January, 1922 to August, 1939, and from October, 1969 to date (Table 3.1). The anemograph on Brandon Island was installed in June, 1974, where wind speed and direction is recorded hourly, on a continuous basis.

Prevailing winds in the vicinity of Entrance Island are from the east, with a mean annual wind speed of 11.5 knots (13.2 m.p.h.). A monthly summary of the hourly wind speeds recorded at Entrance Island during 1971 is shown in Table 3.4.

MONTH	FREQUENCY IN HOURS											PREVAILING DIRECTION	MEAN SPEED (mph)	MAXIMUM RECORDED HOURLY SPEED	
	Total # of Readings		N	NE	E	SE	S	SW	W	NW	CALM			MILES	DIRECTION
JANUARY	744	A*	1	13	242	220	75	42	102	44	5	E	12.7	43	E
		B*	2	93	3584	2770	714	346	1198	743					
FEBRUARY	672	A	9	10	131	181	39	22	136	142	2	SE	13.6	42	NW
		B	59	120	1692	2403	420	119	1564	2731					
MARCH	720	A	12	15	142	171	81	71	111	114	3	SE	15.0	42	SE
		B	58	48	3451	3078	761	644	1103	1683					
APRIL	720	A	15	13	218	153	70	38	168	37	8	E	11.8	34	SE
		B	64	115	2815	742	513	313	2432	481					
MAY	744	A	18	15	144	72	29	23	312	129	2	W	13.0	36	W
		B	78	61	1571	527	246	161	5263	1795					
JUNE	720	A	12	8	370	124	44	30	92	31	9	E	9.5	39	E
		B	48	41	4217	1051	245	204	728	270					
JULY	744	A	14	16	146	54	31	31	269	178	5	W	10.9	27	W
		B	42	55	1379	394	224	209	3320	2522					
AUGUST	742	A	14	12	238	126	27	25	197	95	8	E	10.0	30	SE
		B	41	43	2887	1067	175	113	1954	1118					
SEPTEMBER	720	A	15	17	157	120	30	27	264	88	2	W	9.9	30	W
		B	45	93	1773	1164	219	147	2875	825					
OCTOBER	744	A	6	10	256	129	36	40	179	86	2	E	13.0	45	E
		B	34	83	4050	1492	264	258	2488	1030					
NOVEMBER	720	A	2	6	264	169	52	31	153	43	0	E	15.1	44	E
		B	18	49	4923	2687	343	171	2247	455					
DECEMBER	744	A	6	20	186	135	66	49	215	67	0	W	16.0	40	E
		B	43	253	4130	1768	454	335	3772	1164					

Table 3.4. - Monthly Summary of Hourly Winds, 1971: Entrance Island (Giovando, 1973).

* A - Direction Frequency B - Mileage by Direction

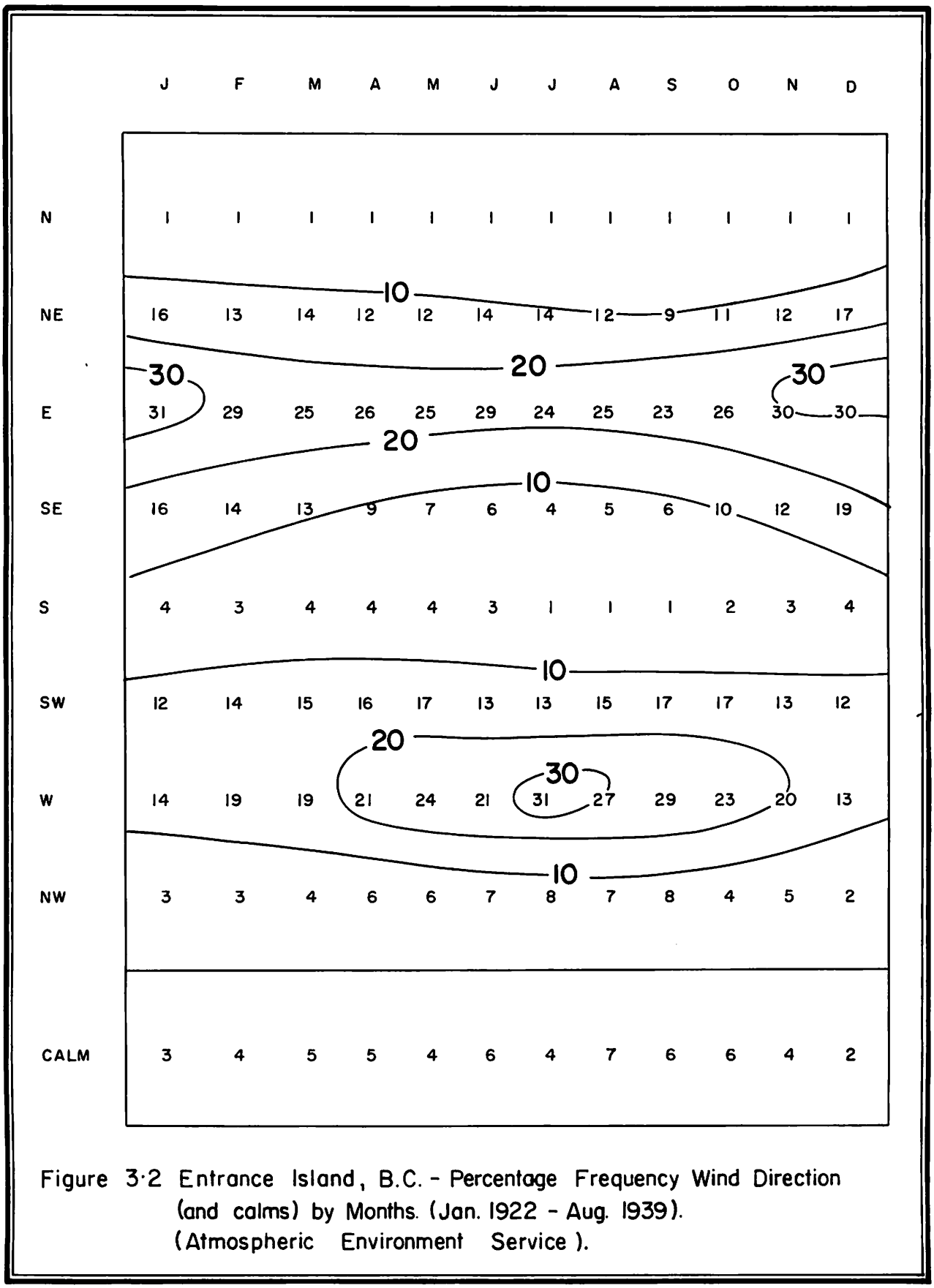


Figure 3·2 Entrance Island, B.C. - Percentage Frequency Wind Direction (and calms) by Months. (Jan. 1922 - Aug. 1939). (Atmospheric Environment Service).

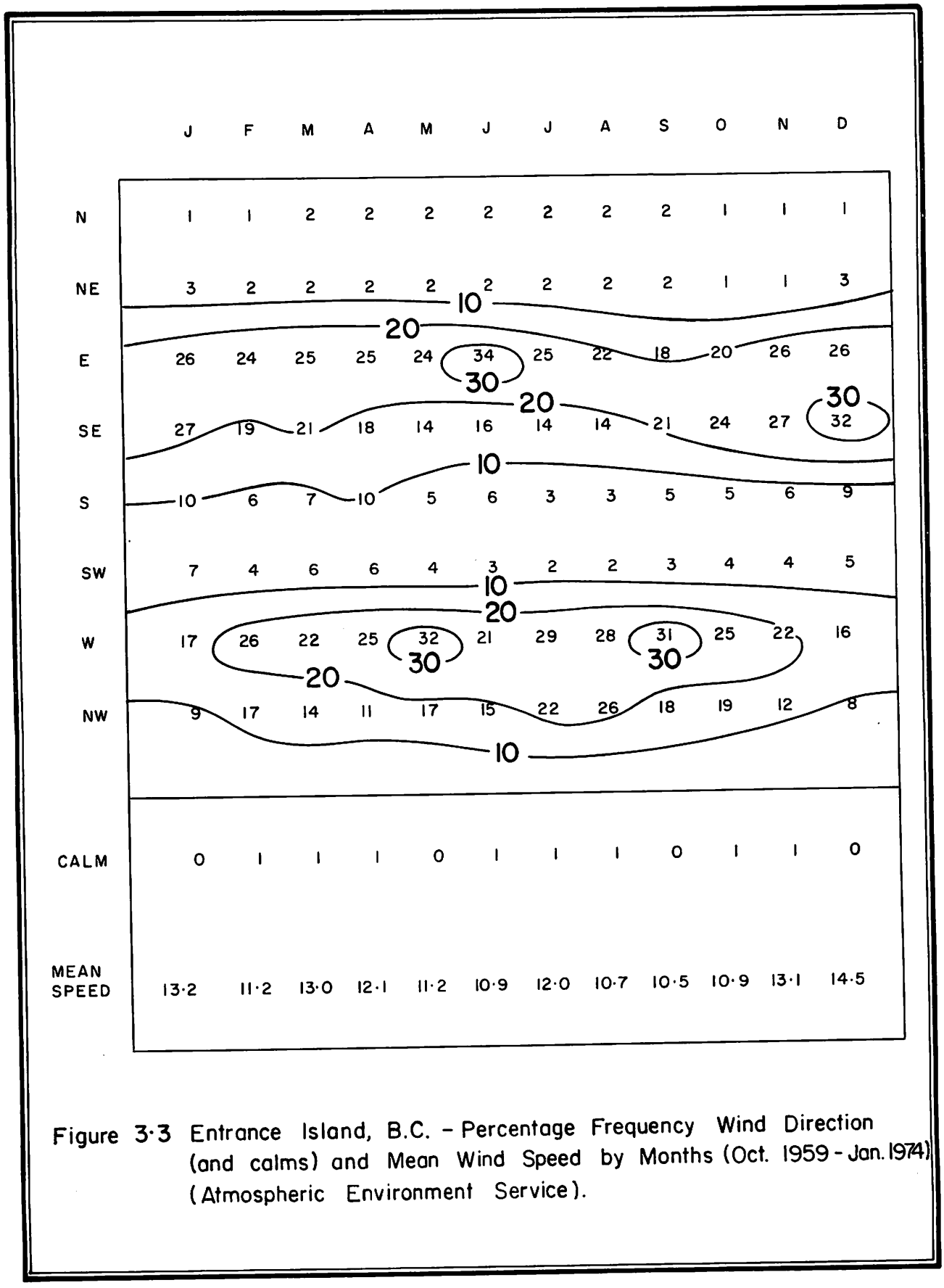


Figure 3·3 Entrance Island, B.C. - Percentage Frequency Wind Direction (and calms) and Mean Wind Speed by Months (Oct. 1959 - Jan. 1974) (Atmospheric Environment Service).

The percentage frequency wind direction and mean wind speed by months for the same station, for the periods January, 1922 to August, 1939, and October, 1969 to January, 1974, are shown in graphic form in Figures 3.2 and 3.3.

In Northumberland Channel, Nanaimo Harbour and the river estuary, winds may be of lower strength than those over the open Strait of Georgia due to the protection of the Gulf Islands and the modifying effect of the local topography.

3 (vi) OTHER PARAMETERS

Observations of other parameters, such as atmospheric pressure, vapour pressure, hours of bright sunshine, cloud cover and visibility are made at Nanaimo Airport. Summaries of these observations may be found in the "Monthly record of meteorological observations in Canada" (Canada Department of the Environment, Atmospheric Environment Service).

Bright sunshine averages 1,846 hours annually, while fog (visibility less than 1 kilometre), occurs on an average of 21.8 days a year. Of these the greatest number, an average of 5.2 days, occur in the month of January (Table 3.2).

3 (vii) CLIMATE CAPABILITY CLASSIFICATION FOR AGRICULTURE

Land use capabilities for agriculture are limited or enhanced by the climate. "In the CLI (Canada Land Inventory) system of classification, climate provides the basic limitations for agriculture to which all other limitations are tied" (British Columbia Land Inventory, Climatology Report Number 1, 1972). The climate class for a particular area is determined by the range of crops which can be grown. The wider the range of crops, the higher the class.

The east coast of Vancouver Island, including the Nanaimo area, has been designated as climatic class $1b_3$, under the climate capability classification for agriculture (British Columbia Land Inventory, 1972). The Saanich Peninsula and the Lower Fraser Valley are also identified by this class, which has the following characteristics and range of crops:

- The frost-free period is greater than 150 days.
- The range of growing degree days greater than 5.6°C is 3,000 to 3,500.
- Full capability can only be achieved if supplemental water is supplied.
- There are cool winter temperatures suitable for wintering cabbage and lettuce.
- A 762 mm maximum annual precipitation limit occurs for tree fruits.
- The probability of extreme winter temperatures exceeding -23.3°C is nil.
- Snow cover is discontinuous.

Range of Crops

(a) Key crops - Wide range of cool season crops such as: canning peas, cole crops, potatoes, raspberries, small fruits, sugar beet seed, lettuce and bulbs.

(b) A limited range of heat loving crops such as: beans, corn, cucurbits, narrow range of grapes, tomatoes, hardy tree fruits, onions and pumpkin.

(c) Cereal grains

3 (viii) AIR POLLUTION POTENTIAL

The meteorological factors important in determining the ability of the local atmosphere to disperse airborne pollutants

go through diurnal and annual cycles similar to those experienced at other coastal locations in British Columbia. The percentage frequency of calm winds is quite low and mean speeds are moderate. A well-marked land breeze/sea breeze circulation pattern occurs frequently in summer months.

Surface based inversions are frequent over night, year round. Occurrences during the day are also fairly frequent, being the result of overrunning warm air in fall and winter, and the cooling effect of Georgia Strait in spring and summer. Estimated seasonal percentages of ground-based inversions for early morning and late afternoon are as follows:

	Winter	Spring	Summer	Fall
A.M.	72	78	88	80
P.M.	32	28	30	43

Poorest conditions for the dispersal of air pollutants occur when light winds and inversions combine. Such is often the case during situations favouring the land breeze/sea breeze circulation in summer and early fall. In other seasons, inversions are often accompanied by stronger winds, favouring at least the horizontal dilution of pollutants.

4. HYDROLOGY

4 (i) GENERAL

The Nanaimo River rises on the north and west slopes of Green Mountain (1465 m), flows eastward for 42 km (26 mi.) to the Town of Cassidy, at which point it flows northwards for 6 km (4 mi.) before discharging into the southeastern end of Nanaimo Harbour.

The Nanaimo River system (Figure 4.1), with its main tributaries Haslam Creek and Jump Creek, drains an area of approximately 84,149 ha (325 sq. mi.). The main branch of the river (sometimes called the North Nanaimo River) connects a series of lakes known as First, Second, Third and Fourth Lakes, and is joined by the South Fork (South Nanaimo River) approximately 16 km (10 mi.) west of the Town of Cassidy. Storage dams are located on the river at the outlet of Fourth Lake, and 5 km (3 mi.) upstream of the South Fork junction. Their purpose, and effect on the river flow, is described later in this section.

North of the Nanaimo River estuary, the Millstone River originates on the northern slopes of Mt. Benson, drains Brannen, Long, Diver and Westwood Lakes, flows southeastward for approximately 11 km (7 mi.), and discharges into Nanaimo Harbour north of the present central business section of the city. The middle and upper river valley forms a good, though small agricultural district (Matheson, 1950).

Three other minor drainage systems are those of the Chase River, Holden Creek and an unnamed creek known locally as Hong Kong Creek (Figure 4.1). The Chase River originates on the southern slopes of Mount Benson, and discharges, along with the Hong Kong Creek into the main (westernmost) channel of the Nanaimo River. Holden Creek drains the Quennell Lake system and

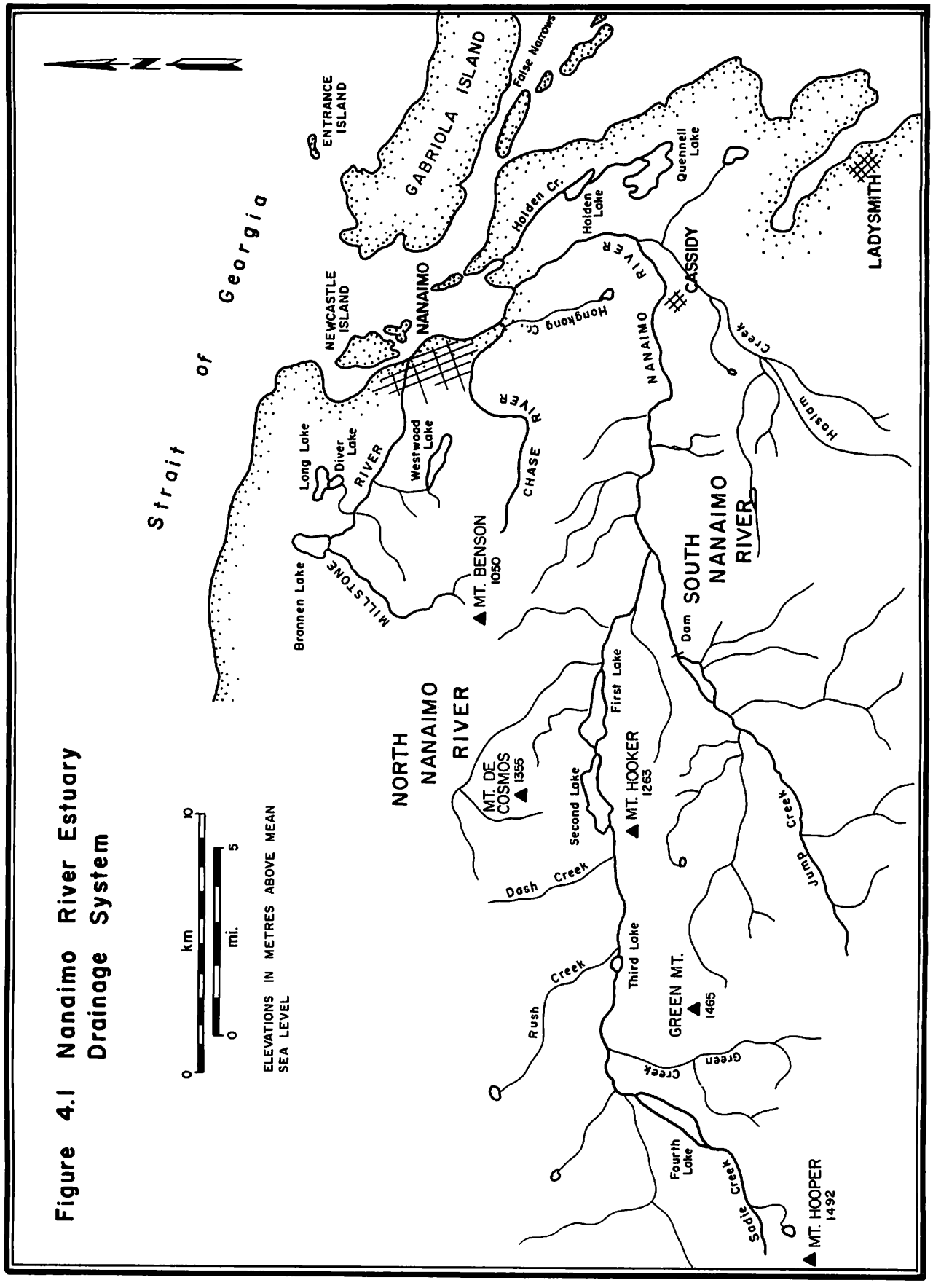


Figure 4.1 Nanaimo River Estuary Drainage System

discharges onto the southeastern area of tidal flats of the Nanaimo River delta.

4 (ii) STREAMFLOW GAUGING STATIONS

A list of streamflow gauging stations located on the Nanaimo Estuary river drainage system, showing their location and period of record, can be found in Appendix 4.1. Of the seven stations established in the area, there are, at present, only two recording flow data on a continuous basis. These are located on the Nanaimo River near Cassidy, and Jump Creek near the mouth.

The first continuous flow gauging station in the system was established on the Nanaimo River near Extension in 1913. Measurements at this station were discontinued in 1964, and a new station established at Cassidy, where the present river flows are obtained.

The long-term average (32 years - 1913 to 1964) for the mean annual discharge of the Nanaimo River near Extension, Station No. 08HB005, is 40 cms (1430 cfs). The short-term average (9 yrs. - 1965 to 1973) measured near Cassidy, Station No. 08HB034, is 41 cms (1460 cfs) (Can. Dept. Env., 1974). In 9 years of record (1965 to 1973) the lowest flows on the Nanaimo River occurred from June to September, while the maximum flows occurred in the period December to March. The minimum monthly flow during this period was 3 cms (115 cfs), recorded in September, 1973. The maximum monthly flow for the same period, occurred in December, 1966, and was 148 cms (5,230 cfs) (Can. Dept. Env., 1974). Other record-flow data measured at Station No. 08HB034 on the Nanaimo River near Cassidy, are listed in the following Table 4.1.

Table 4.1. Nanaimo River flow records (Can. Dept. Env., 1974).

	cms	cfs	date
maximum daily flow	626	22,100	Jan. 15, 1973
minimum daily flow	1	43.2	Sept. 14, 1973
largest mean annual flow	51	1,800	1968
smallest mean annual flow	28	995	1970
maximum mean monthly flow	148	5,230	Dec. 1966
minimum mean monthly flow	3	115	Sept. 1973

A hydrograph of the daily discharge for a typical year (1969) for the Nanaimo River, is shown in Figure 4.2. Records of the magnitude of floods in British Columbia have been compiled for selected rivers, including the Nanaimo River. Figure 4.3 shows a flood probability curve for the Nanaimo River, based on the maximum daily mean flows for the period 1914 to 1963, measured at Station 08HB005 near Extension (Can. Dept. Env., 1972c).

4 (iii) WATER SUPPLY SOURCES

The Nanaimo River, aquifers and artesian wells provide the main sources of water for industrial and domestic users. In 1931, the city of Nanaimo constructed a water reservoir on the South Fork of the Nanaimo River with a storage capacity of 2 million cubic metres (1,660 acre-feet). No provision was made for the release of water through the dam impounding the storage. As pointed out in an analysis of the water requirements for the fisheries resource of the Nanaimo River (Can. Dept. Env., 1973a), "during wet winter months, there will be spill over the crest but during the dry late summer and early fall months the reservoir level normally drops below the crest cutting off all flow into the river except the leakage flow". The Greater Nanaimo Water

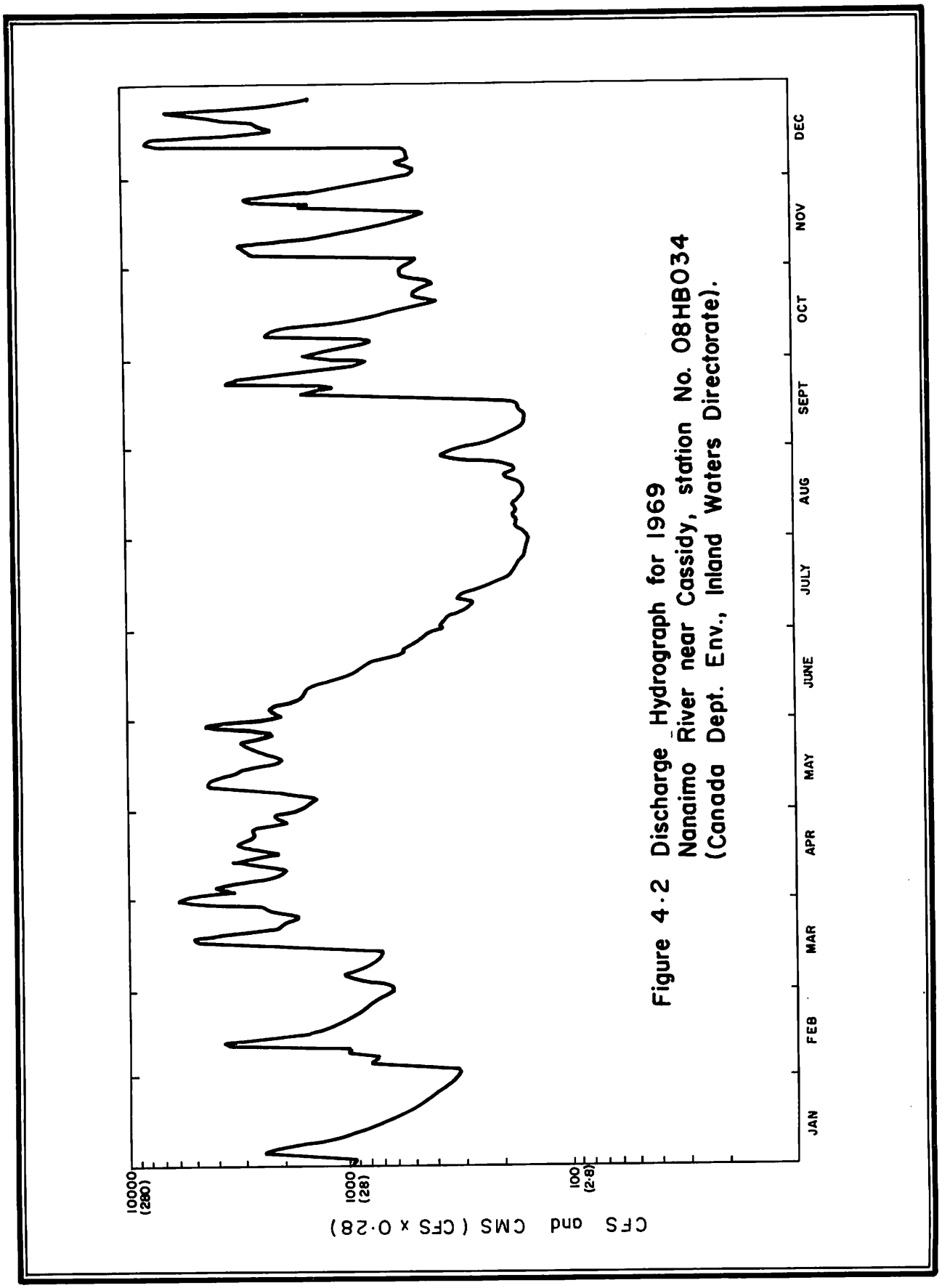


Figure 4.2 Discharge Hydrograph for 1969
Nanaimo River near Cassidy, station No. 08HB034
(Canada Dept. Env., Inland Waters Directorate).

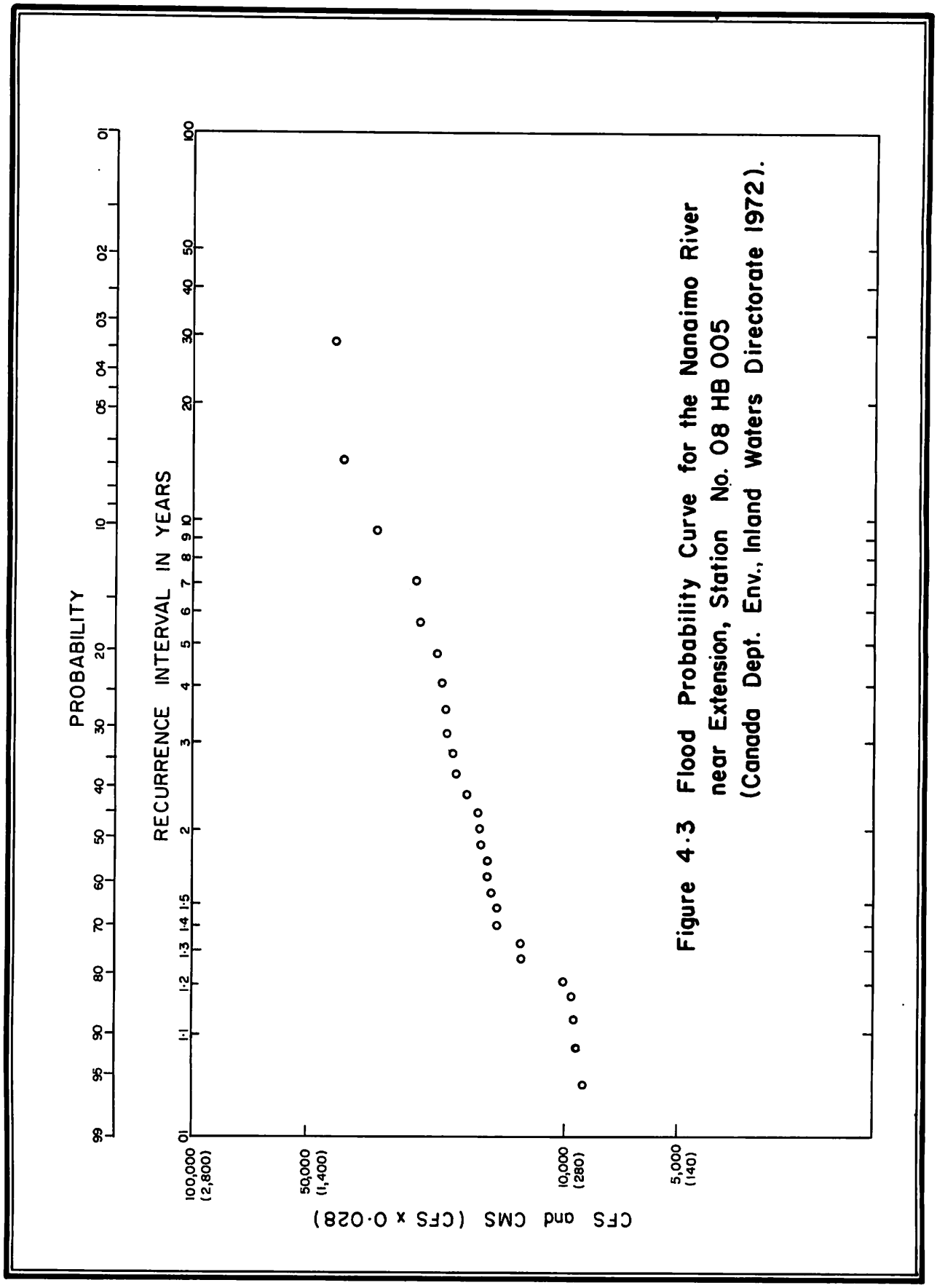


Figure 4.3 Flood Probability Curve for the Nanaimo River near Extension, Station No. 08 HB 005 (Canada Dept. Env., Inland Waters Directorate 1972).

District has initiated a program to increase primary storage capacity by the construction of a reservoir on Jump Creek. This program and its impact on the fisheries resources of the river are discussed later in this report under "Land and Water Use" (Section 10).

In 1954, MacMillan Bloedel Limited built a dam at Fourth Lake on the North Nanaimo River, to store water for the operation of the Harmac Mill. The following description of their water requirements and sources, was prepared by, and reproduced with the permission of the management of MacMillan Bloedel Limited, Harmac Division.

"The MacMillan Bloedel Harmac pulp mill, located on Northumberland Channel, uses 70 million U.S. gallons (265,000 cubic metres) of fresh water a day, all of which is obtained from the Nanaimo River system by two means.

The original source of water is ground water from the large aquifer in the Cassidy area. The main wells drawing on this source are three large capacity Ranney Wells, supplemented by two small bored wells.

After the original mill was established, and expansion of capacity commenced, the additional water demand was met through the construction of two pumphouses drawing directly from the river.

From these pumps, the water is delivered to the mill through two large diameter wood stave pipes, four miles in length.

To ensure a continuous supply during the usual dry summer season, a 30,000 acre-feet (37 million cubic metres) storage reservoir has been constructed in the watershed at Fourth Lake. During the summer the natural flow of the river is augmented as necessary by release from the lake directly into the river.

This release is adjusted as required to ensure that the demands of the pulp mill are met, and that a residual flow below the mill pumphouses is maintained in accordance with the rule curve formula set by the B.C. Water Rights Branch. During the dry season close liason is kept with the Federal Fisheries to ensure that their actual needs are met as best as possible at all times.

The water is not treated before being used in the pulp mill process system."

Groundwater sources of supply are confined mainly to aquifers along stream courses and drilled wells. Halstead (1967) described the surficial deposits of the areas surrounding the lower reaches of the Nanaimo River and their groundwater potential. The following is his description of the well supplying water for the Cedar community. "About 2 miles (3 km) upstream from the mouth of the Nanaimo River a well penetrates 29 feet (9 m) of gravel adjacent to the river bank. Water obtained from the well, which will produce in excess of 140 imperial gallons (636,400 m^3), supplies the Cedar community."

Sources of groundwater supply are discussed in a regional water study for the Regional District of Nanaimo (Associated Engineering Services Ltd., 1972). An outline of the potential groundwater sources in the vicinity of Cassidy, South Wellington and North Cedar is also contained in this report.

"Available data indicate the presence of a channel cut deeply into the bedrock, running northwest from Ladysmith Harbour, under the Nanaimo Airport, to the east of Cassidy and South Wellington to Nanaimo Harbour. Previous test wells drilled in 1949, into this channel, during the exploration for a water supply for the Harmac Pulp Mill, encountered sand and gravels with an extremely high transmissibility, which means that highly productive wells can be constructed."

5. OCEANOGRAPHY

5 (i) INTRODUCTION

For the purpose of the review of the oceanography of the Nanaimo River estuary, the boundaries have been considerably expanded beyond the true inner estuary, which might be considered as that southward of the line from Jack's Point to the old CPR ferry terminal. The expanded boundaries cover a much larger area within the lines from Neck Point on Vancouver Island to Five Finger Island, and thence through Snake Island to the northeast corner of Gabriola Island, with a cut-off at Dodd and False Narrows to the southeast. Therefore, the study area includes, in addition to the inner Nanaimo River estuary, Nanaimo Harbour, Northumberland Channel, Departure Bay, Hammond Bay and that part of the east-central Strait of Georgia (Rainbow and Fairway Channels) within the above line. It should be noted that much of the information reviewed here covers the peripheral areas rather than the core of the estuary, principally because published information is lacking for the latter.

Before 1970, little work was conducted on the inner Nanaimo River estuary. However, in the broader study area, various minor investigations, mainly biological/naturalist in scope, were conducted in the last three-quarters century because of the interests of scientists at the Pacific Biological Station, which had been officially established in Departure Bay in 1908. Many of the studies were associated with other major projects, or were conducted in Departure Bay mainly because of convenience to the Biological Station.

Oceanographic studies have never been conducted intensively to examine in detail the oceanographic characteristics of the study area. They have been somewhat fragmentary, conducted mainly to investigate specific problems. One of the earliest

interests in oceanographic phenomena centred on the relationship of physical characteristics of the seawater environment with distribution of certain groups of marine organisms. Consequently, as far back as the second decade in this century, salinity and temperature measurements were made in Departure Bay and the Strait of Georgia to provide data on the specific gravity and temperature variations in surface waters (Fraser and Cameron, 1916; Fraser, 1921b; Cameron and Mounce, 1922). This essentially initiated daily seawater observations by the Pacific Biological Station in Departure Bay, although there was a long lapse after the early series had been discontinued. During the mid-thirties, daily seawater observations were resumed in Departure Bay in conjunction with the programs of the Pacific Biological Station (Hollister, 1972). There is also a long series of daily seawater observations, started some time later, at the Entrance Island lighthouse near the northeast corner of Gabriola Island (Hollister, 1972), which provides a good index of salinity and temperature conditions in this part of the Strait of Georgia (Waldichuk, 1957b). The type of water and seasonal variations represented by Entrance Island and Departure Bay seawater observations have been analyzed statistically and compared with observations from other lighthouse stations along the B.C. coast by Pickard and McLeod (1953).

The first concerted study of oceanographic conditions in Nanaimo Harbour and Departure Bay was conducted in the spring of 1953, in connection with a proposal to improve the sewerage system and sewage disposal for Nanaimo. By 1950, a major part of Nanaimo city was equipped with sewers, but sewage was discharged raw through three outfalls into Nanaimo Harbour. This was regarded as undesirable from both aesthetic and health points of view, and by the early 1950's, it was decided that a plan was required to enlarge the sewerage network for Greater Nanaimo and for improving the system of sewage disposal. Through a remarkable community effort, utilizing available boat resources of the Nanaimo Yacht Club, as well as government vessels, a float survey was conducted

in Nanaimo Harbour and Departure Bay during two week-ends in late May and early June of 1953 (Anon, 1953). This was designed to determine the surface currents, and from them, infer the transport and dispersion of sewage that would occur in these waters (Tully and Waldichuk, 1953; Waldichuk and Tully, 1953; Waldichuk, 1954). A folio of 32 charts was prepared, showing current vectors for every two hours during the observational period, accompanied by the tide and wind information for that interval (Pacific Oceanographic Group, 1953). Current observations were made with an Ekman current meter from CNAV EHKOLI anchored in Nanaimo Harbour as a mother ship during the course of the observations (Pacific Oceanographic Group, unpublished data).

As a consequence of this study, it was recommended that sewage no longer be discharged raw into the Nanaimo Harbour, but that it be either fully treated (secondary treatment) and released through a suitable outfall, or that it be discharged following comminution into more exposed and better flushed waters of Northumberland Channel, and/or into the Strait of Georgia east of Newcastle Island. The latter recommendation was adopted by the Nanaimo City Council. The Greater Nanaimo Sewerage and Drainage District was established in 1958 to develop a sewerage plan with a goal of early implementation for Nanaimo City and for some of the suburban municipalities. Outfalls for comminuted sewage were installed through Canoe Pass off Duke Point for discharge into Northumberland Channel and off the northeast side of Newcastle Island into the Strait of Georgia.

The growth of the population of Nanaimo to the north, soon overloaded the Newcastle Island outfall and demanded a plan for a new sewage disposal system by the late 1960's (Dayton and Knight Limited, 1969). Once again, studies were undertaken by the Pacific Oceanographic Group during 1970 in cooperation with Dayton and Knight, Ltd., and Greater Nanaimo Sewerage and Drainage District, to predict the dispersal of sewage from an ocean outfall north of Departure Bay in the Five Finger Island area (Giovando,

1973). A monitoring program was conducted to obtain pre-operational data from March to September 1974 in the Five Finger Island area (Waters, 1975a).

The new primary sewage treatment plant, discharging through the Five Finger Island outfall, went into operation during the summer of 1975. The Newcastle Island outfall had ceased operation and the southern outfall into Northumberland Channel was reserved mainly for overflow. Monitoring studies were continued by the staff of Malaspina College in Nanaimo to obtain post-operational pre-treatment environmental information (Waters, 1975b).

Other oceanographic studies in waters adjoining Nanaimo have been conducted in relation to pollution from the Harmac full-bleached kraft pulp mill south of Nanaimo (Waldichuk, 1965; Waldichuk, *et al.*, 1968). Although these studies concentrated largely on Northumberland Channel, which receives the pulp mill effluent, oceanographic stations have been occupied also in Departure Bay, Newcastle Island Channel and in Nanaimo Harbour. Concern about effluent disposal from the Harmac pulp mill has been expressed by the B.C. Pollution Control Branch, and studies were undertaken by MacMillan Bloedel Limited to consider effluent disposal through a deep diffuser into Northumberland Channel with associated monitoring of water quality (T.W. Beak Consultants Ltd., 1970a, 1970b; H.A. Simons (International) Ltd., 1973; Associated Engineering Services Ltd., 1973; Melville, 1973, 1974; Ketcham, 1975).

A number of investigations conducted in waters in the study area have been related to larger projects, such as the basic productivity studies using a large volume plastic sphere in Departure Bay (Strickland, *et al.*, 1961; McAllister, *et al.*, 1961; Antia, *et al.*, 1963), the Strait of Georgia program during 1965-1970 (Bishop, *et al.*, 1966; Stephens, 1966; Stephens, *et al.*, 1967; Fulton, *et al.*, 1967, 1968, 1969; Seki, *et al.*,1969), and

investigations of diurnal characteristics of waters in Departure Bay for various purposes (Carter, unpublished data; Sibert, MS., 1975). Because sea water is taken from the bottom of Departure Bay to meet the needs of the Pacific Biological Station's seawater facilities, some information is available on salinity, temperature and dissolved oxygen content of this water from records maintained at this establishment. Coliform data were obtained by the Central Vancouver Island Health Unit (unpublished data) of the B.C. Health Branch at a number of points in Departure Bay during the 1953 float survey, and occasional samples have been taken on the public beaches, in shellfish beds, and near outfalls to monitor bacteriological conditions.

During the summer of 1968 a study was conducted in Departure Bay on effects of westerly-northwesterly winds in inducing local upwelling and in enhancing the flushing mechanism (Waldichuk, unpublished data). Part of the information acquired in this project was utilized in a study reported by Henry and Murty (1972) on a three-dimensional circulation in a stratified bay under variable wind-stress. During 1968 also, tidal measurements were made in Departure Bay (Can. Dept. Env., unpublished data (a)) to provide tidal data for a numerical/hydrodynamic study of tides and currents in the Strait of Georgia (Crean, 1969, 1972, in press). This study was supported by data from a series of 12 oceanographic cruises during 1968 in the Strait of Georgia-Juan de Fuca Strait system (Crean and Ages, 1971).

Partly as a result of the concern expressed about ecological effects of port development in Nanaimo Harbour on the Nanaimo River estuary, studies on the fisheries in the Nanaimo River were accelerated (see Fish Section). During the years 1973, 1974 and 1975, the primary and secondary productivity in the inner Nanaimo River estuary, and its relationship to the fisheries, have been intensively studied (Stephens, 1973; Sibert, unpublished data). Moreover, float studies have been conducted in waters outside of

Nanaimo Harbour and Departure Bay, in order to relate water movements to migration of juvenile salmonids and drift of plankton (Healey, unpublished data).

Parts of Nanaimo Harbour have been filled in since white settlers first arrived. What is now the lower part of Terminal Avenue was once a high-tide channel. Commercial Inlet, behind the old CPR Terminal, was partly filled in for a parking lot during the 1960's. South of the Millstone River estuary, filling for a shipyard and parking has taken place during the past three decades, and from time to time there is revival of plans for a marina on the north side of this estuary.

In line with continuous updating of hydrographic charts along the British Columbia coast, Departure Bay was resurveyed in 1968 by the Canadian Hydrographic Service at a scale of 1:8,000. The last survey in Nanaimo Harbour was carried out in 1937 at a scale of 1:6,000; it is planned to resurvey Nanaimo Harbour in 1976. The approaches to Nanaimo, including Northumberland Channel, were resurveyed during 1965-67 at a scale of 1:12,000. The Nanaimo River estuary/delta has been surveyed a number of times since 1860, but it is continuously changing in bathymetry with new channels being formed, as silting, erosion, dredging, filling, log booming and construction keep the bottom topography in a state of flux. Early and more recent charts showing changes in bottom topography are archived at the Canadian Hydrographic Service, Ocean and Aquatic Sciences of the Fisheries and Marine Service, Environment Canada, Victoria, B.C.

Hydrographic charts covering the study area are: No. 3581, NANAIMO HARBOUR, at a scale of 1:6,100; No. 3509, Plans in the Strait of Georgia - DEPARTURE BAY, at a scale of 1:18,300; No. 3558, APPROACHES TO NANAIMO HARBOUR at a scale of 1:18,200 (reproduced from former Admiralty chart No. 2512, but unfortunately no longer printed); No. 3456, APPROACHES TO NANAIMO HARBOUR at a

scale of 1:18,000 (surveyed by the Canadian Hydrographic Service 1938-1968), replaces chart No. 3558; No. 3577 SAND HEADS to BALLENAS ISLANDS at a scale of 1:77,300; and No. 3471, Plans in Stuart Channel - DODD AND FALSE NARROWS, at a scale of 1:18,000.

5 (ii) GENERAL OCEANOGRAPHIC CHARACTERISTICS

The study area has a rather irregular configuration of both its shoreline and bathymetry. This adds to its complexity as a coastal estuarine marine system. The inner Nanaimo River estuary is confined by the main coast of Vancouver Island on the west side and a rocky ridge of forested land on the east side terminating in Jack Point (Fig. 5.1). Nanaimo Harbour is a relatively shallow embayment, protected from the Strait of Georgia by two nearby islands (Newcastle and Protection), as well as Jack Point and Gabriola Island beyond, on the southeast and east sides. Departure Bay, located to the northwest of Nanaimo Harbour, is considerably deeper, being nearly a circular embayment with a number of small islands on the north side. Nanaimo Harbour and Departure Bay are connected by a shallow, somewhat narrow gut, known as Newcastle Island Passage. Whereas Departure Bay is quite deep for most ocean-going vessels, Nanaimo Harbour is somewhat restricted in depth and requires occasional dredging, in order to maintain a sufficiently deep shipping channel. In general, both Nanaimo Harbour and Departure Bay are protected quite well by Newcastle and Protection Islands, although parts of Departure Bay are somewhat exposed from the east.

In addition to receiving waters from the Nanaimo River, the general study area has a number of runoff sources which are mainly of significance during the heavy precipitation period of late autumn, winter and early spring. Chase River, Hong Kong Creek and Holden Creek discharge into the inner Nanaimo River estuary; Millstone River, drains directly into Nanaimo Harbour; Northbrook Creek, which is little more than a drainage ditch,

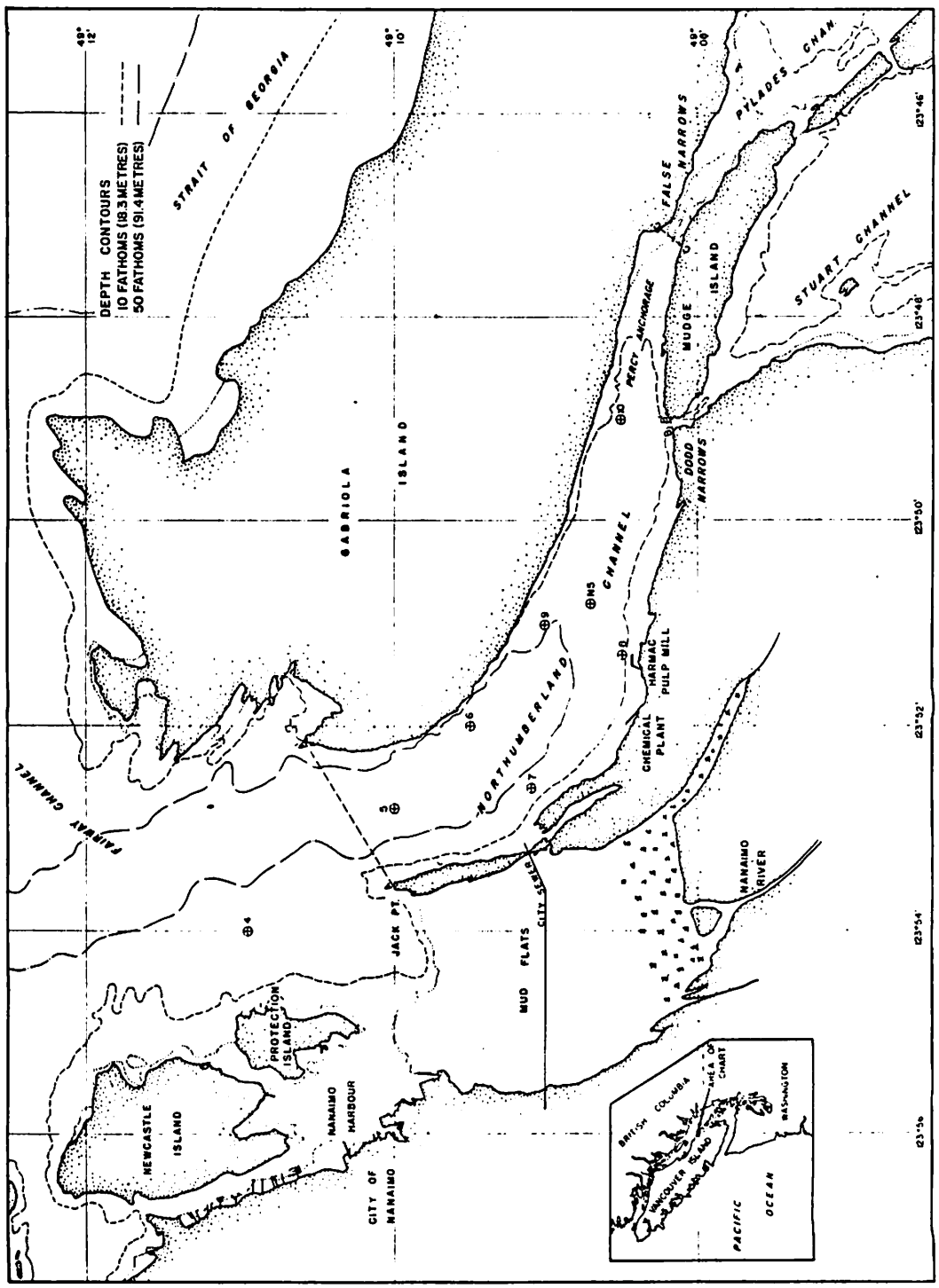


Figure 5·1 Chart of Northumberland Channel and adjacent waters, showing station locations occupied on surveys of July, 1957 and July, 1962. (From Waldichuk, 1965)

discharges into the southwest corner of Departure Bay near the B.C. Ferry Terminal, and Keighley Creek (sometimes known as Departure Bay Creek), drains into the northwest corner of Departure Bay. During heavy rain storms, these creeks and drainage ditches can contribute a considerable amount of fresh water, as well as mud scoured from their drainage basins, into the Nanaimo Harbour-Departure Bay area.

The Northumberland Channel-Strait of Georgia section of the study area is considerably different from the Nanaimo Harbour-Departure Bay system. It is deeper and more exposed to the wind and wave effects of the Strait of Georgia. Dispersive processes are much more vigorous and any substances introduced into these waters are rapidly diluted and transported elsewhere. Dodd Narrows and False Narrows at the southern boundary of the study area are extremely turbulent and swift, because of the vigorous tidal action through the narrow constricted channels.

In general, the whole study area can be considered as vertically stratified in salinity and density. Except for False and Dodd Narrows, where the fresh water is mixed thoroughly with the underlying sea water, there is a tendency for the fresh waters entering the system to lie on the surface. This is accentuated during the summer when surface waters increase in temperature as a result of solar heating.

The waters of the study area are generally quite productive arising both from the input of nutrients from the Strait of Georgia system through local upwelling by winds, as well as deriving benefit from nutrients and organic materials in runoff (Seki, *et al.*, 1969). They can be regarded at least as productive as the average in the Strait of Georgia (Parsons, *et al.*, 1970). During some periods of heavy blooms of phytoplankton, the waters become quite murky. Except during the heavy runoff periods, when mud may be introduced from the local streams, the

waters are normally quite clear allowing good light penetration. During freshet of the Fraser River, during May to July, the muddy waters from that river may impinge on the study area and enter Northumberland Channel. Most of the turbidity in the study area, however, can be attributed to the plankton present in the water, particularly during the bloom periods of early spring and late summer. Although toxic dinoflagellates have apparently contributed to shellfish toxicity in parts of the western shores of the Strait of Georgia (Anderson, 1960; Waldichuk, 1958), no major blooms of toxic *Gonyaulax* sp. have been reported in the present study area. The occasional outbreaks of red water, suggested by some as the "Red Tide" leading to shellfish toxicity, were identified by G.H. Wailes (1925) as merely blooms of the non-toxic ciliate *Mesodinium rubrum* (C. Berkeley, personal communication; Taylor, *et al.*, 1971).

5 (iii) TIDES

Tides in the Nanaimo River estuary study area are typical of the Pacific coast, being mixed and mainly diurnal, with two high and two low waters in a tidal day of about 25 hours, but with large differences in heights of succeeding low waters. Because both Nanaimo Harbour and Departure Bay have relatively open access for incoming waters from the Strait of Georgia, the tidal rise and fall in these two embayments coincide fairly closely with those in the Strait of Georgia. For this reason, the reference station at Point Atkinson, across the Strait of Georgia, where tidal observations were commenced in 1895, can be used quite reliably for prediction of tide heights in the study area. In order to provide harmonic constants for predicting tides in Nanaimo Harbour, thirty-day records of tidal observations were acquired as early as 1899 (Table 5.1).

Tidal measurements in Departure Bay were first carried out during a 2 - year period from October 1924 to September 1926.

Table 5.1 Tidal characteristics at the reference and secondary ports of the Nanaimo River estuary study area. (From Can. Dept. Env., 1976).

PORT	POSITION Lat.N.	POSITION Long.W.	Duration of Tidal Records	Mean Tidal Range m.	Mean Tidal Range ft.	Large Tidal Range m.	Large Tidal Range ft.
REFERENCE PORT							
Point Atkinson	49°20'	123°15'	1/II/1895 - Present	3.3	10.7	4.9	16.2
SECONDARY PORTS							
Nanaimo	49°10'	123°56'	25/III/1899-12/V/1899 19/IX/1924 -3/IV/1925 17/IV/1960 -17/V/1960 29/IX/1965 -15/X/1965	3.2	10.4	4.9	16.2
Harmac	49°08'	123°51'	28/III/1949-21/I/1950	3.3	10.9	5.0	16.3
Departure Bay*	49°13'	123°58'	1/X/1924 -13/IX/1926	3.2	10.4	4.9	16.2

Table 5.2 Differences in time and height for tides at secondary ports in the Nanaimo River estuary study area in relation to Point Atkinson. (From Can. Dept. Env., 1976).

SECONDARY PORT	DIFFERENCES										
	Higher High Water					Lower Low Water					
	Time h.	Time m.	Mean Tide m.	Mean Tide ft.	Large Tide m.	Large Tide ft.	Time h.	Time m.	Mean Tide m.	Mean Tide ft.	Large Tide m.	Large Tide ft.
Nanaimo	+0	11	-0.15	-0.5	-0.06	-0.2	+0	06	-0.06	-0.2	-0.06	-0.2
Departure Bay*	+0	11	-0.15	-0.5	-0.06	-0.2	+0	06	-0.06	-0.2	-0.06	-0.2
Harmac	+0	14	-0.03	-0.1	-0.06	-0.2	+0	07	-0.09	-0.3	-0.09	-0.3

*For all intents and purposes, the tidal characteristics of Departure Bay are considered to be the same as those for Nanaimo Harbour.

A year-long series of tidal observations was made at Departure Bay during 1968 to provide data for a numerical analysis of tides and currents in the Strait of Georgia (Crean, 1972).

Because of the need for tidal information in shipping from the Harmac wharf on Northumberland Channel, and because the tide here can be affected by water from Stuart Channel through Dodd and False Narrows, a 10 - month series of tidal observations was acquired at this point during March 1949 to January 1950 in order to calculate the essential harmonic constants for prediction of tide here. As shown in Table 5.1, there can be a small difference in time and elevation of tides at Harmac and Nanaimo, although for ordinary purposes, the tide at Point Atkinson would suffice to describe the tides at both these places.

5 (iv) WATER PROPERTIES

The salinity and temperature, and density derived therefrom, in the Strait of Georgia both spatially and seasonally have been described by Waldichuk (1957), while the nutrient distributions and their seasonal variations were reported by Tully and Dodimead (1957). The effects of the Fraser River and the stratification to which it gives rise in the Strait of Georgia can be noted as far westward as the approaches to Nanaimo Harbour and Departure Bay. The effect is particularly noticeable if the local runoff is small at the time of the freshet of the Fraser River, which usually occurs in the latter part of May to early July.

The salinity, temperature, density and dissolved oxygen profiles at a station (see N-5 in Fig. 5.1 for location) are shown in Fig. 5.2. It is clear from these profiles that there is a certain degree of vertical stratification even in this system which has a moderate rate of water exchange, at least in the surface layer to 20 m depth. The distribution of properties in vertical sections (see Fig. 5.1 for location of stations) through

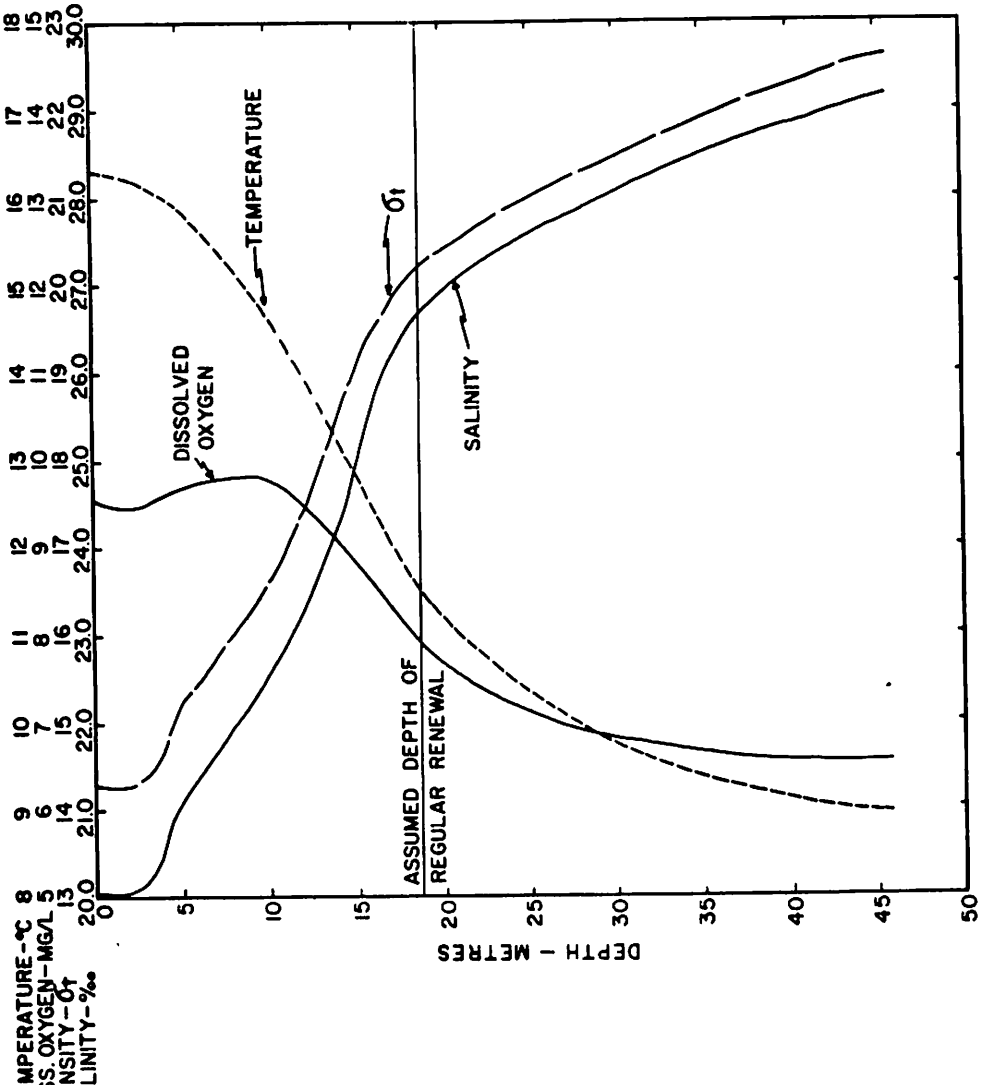


Figure 5·2 Salinity, temperature, σ_t and dissolved oxygen profiles at station N-5 in mid-Northumberland Channel, occupied on July 6, 1957. (From Waldichuk, 1965)

Northumberland Channel, during July 1962, is shown in Figure 5.3. Even at this time of year, the salinities in the surface layer drop to less than $24^{o}/_{oo}$ and exceed $30.5^{o}/_{oo}$ in the bottom layer at 100 m. The temperature showed a steady decrease with depth from more than 17^{o}C at the surface to less than 8.5^{o}C at 100 m. This temperature stratification, with a pronounced thermocline at about 15 m, accentuates the density stratification, as shown in the lower left-hand panel of Figure 5.3.

The non-conservative properties, as shown in the right-hand panels of Figure 5.3, again exhibit stratification that corresponds to that shown by the conservative properties. Although dissolved oxygen does not reach extremely low levels in the deep water, it does diminish to less than 6 mg/l below 50 m.

A series of 18 stations was occupied through Departure Bay - Newcastle Island Passage - Nanaimo Harbour - Northumberland Channel in May 1961 (Waldichuk, *et al.*, 1968) in order to gain a basis for comparison of water characteristics in these different components of the Nanaimo River estuary study area. Salinity stratification was quite pronounced with surface salinities ranging from 21^{o}/oo at the northeastern approach to Departure Bay to 22^{o}/oo in inner Departure Bay, 16^{o}/oo at the southeastern entrance to Nanaimo Harbour and 23^{o}/oo in mid-Northumberland Channel. Salinities at 10 m depth at the respective locations were 28.2, 28.5, 28.4 and 27.7^{o}/oo. Surface temperatures had already assumed a significant seasonal increase by this time and were 13.2, 14.9, 15.7 and 14.0^{o}C, whereas 10 - m temperatures were still 9.2, 8.8, 9.0 and 9.9^{o}C, respectively, at the foregoing four stations. While surface dissolved oxygen concentrations were all above 100% saturation at all stations, they were 8.4 mg/l (87% sat.), 8.2 (84%), 8.1 (83%) and 8.0 mg/l (84% sat.), respectively, at 10 m depth on the 4 stations selected above. In the deepest water sampled in Departure Bay (30 m), the dissolved oxygen concentration was 7.0 mg/l (72% sat.) and in Nanaimo Harbour (8 m)

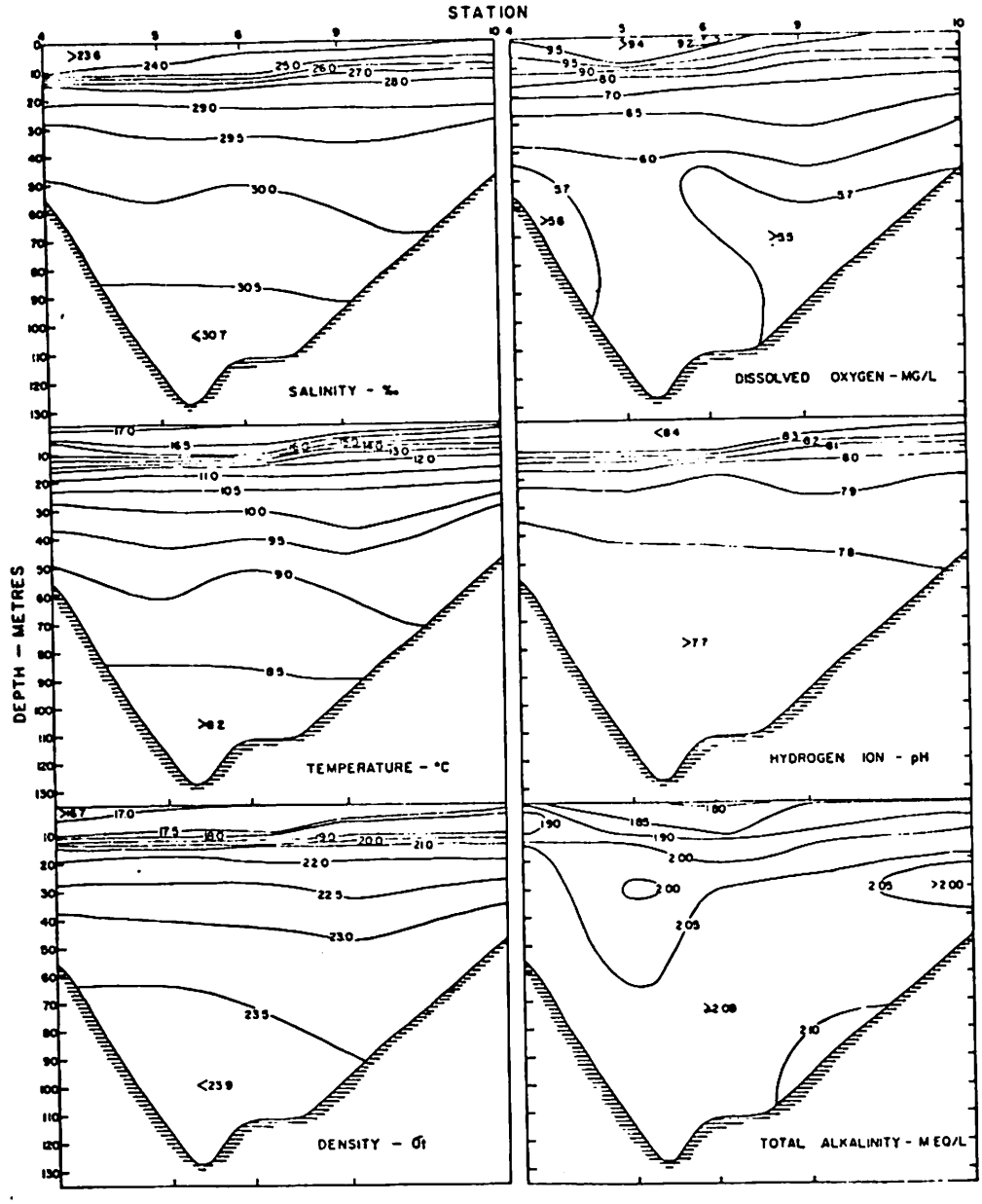


Figure 5·3 Distribution of properties on a vertical section through Northumberland Channel, during the survey of July 17, 1962. (From Waldichuk, 1965).

it was 9.1 mg/l (96%), obviously not yet seriously depleted at this time of year.

The seasonal variation in properties of the waters in Nanaimo Harbour - Departure Bay system will vary a great deal with runoff and insolation, and this can be followed through daily seawater observations of salinity and temperature (Hollister and Sandnes, 1972). The seasonal changes during 1973 in primary productivity of the inner Nanaimo River estuary, compared with Departure Bay, have been reported by Stephens (1973). More recent data are being analyzed (Sibert, unpublished data).

5 (v) CURRENTS AND CIRCULATION

It is difficult to ascribe a clear-cut predictable current system to the study area, because there are so many factors that contribute to currents and circulation, none of which is dominant at all times. In Nanaimo Harbour and Departure Bay, the factors of decreasing importance in surface water movement are: winds, tides, runoff, barometric pressure, and currents in the Strait of Georgia. Under some circumstances, the currents in the Strait of Georgia may dominate what goes on in Departure Bay and in Nanaimo Harbour. In general, currents in the Strait of Georgia outside of Nanaimo Harbour and Departure Bay are comparatively weak except on a large tidal range or when there has been a sustained period of strong winds from one direction. Based on tide heights at a number of key points in the Strait of Georgia, it has been possible to evaluate the current field for a particular tide using numerical computations (Crean, 1969, 1972, in press). Two sets of such computations for the Strait of Georgia-Juan de Fuca Strait system are shown in Figures 5.4 and 5.5. It is obvious from the computed vectors that while currents may be strong in some of the channels south of the Strait of Georgia and in Juan de Fuca Strait, they are certainly not prominent in the vicinity of Nanaimo.

Surface currents in the study area are affected by both tides and wind. In some parts, the tidal effect may be masked quite strongly by the wind-driven current, especially during periods of strong winds. In other parts, the tidal effect will predominate. Except during large local run-off, the Nanaimo River and the six creeks tributary to the system, contribute little to the water movements. In general, the net flow along the east coast of Vancouver Island in the Strait of Georgia is considered to be southward; this has not been fully substantiated by measurements, but general observations indicate a southward residual current in this part of the Strait (Waldichuk and Tabata, 1955; Waldichuk, 1958a). Certainly, in Northumberland Channel, the net movement is southward, as shown by driftpole observations near Harmac. In fact, the current reverses to a northward set for only a relatively short period on the tidal cycle, and this is mainly in the northwestern part of Northumberland Channel. In Nanaimo Harbour and Departure Bay, although there is clearly a tidal current in the deeper water, the surface flow is largely dominated by winds. Newcastle Island Passage acts as an equilibrating system for the two embayments, so that currents will vary here according to whether winds or tides have affected the water levels in Departure Bay relative to Nanaimo Harbour.

Float observations conducted in Nanaimo Harbour and Departure Bay during two weekends in the spring of 1953 basically showed that wind effects are dominant in surface waters (Tully and Waldichuk, 1953; Waldichuk and Tully, 1953; Waldichuk, 1954). Although some of the wind effect has to be attributed to the drag on the exposed part of the float, there was sufficient evidence from well submerged floats with very little exposure, indicating that surface waters responded to winds rather strongly in both Nanaimo Harbour and Departure Bay. The effects of northwest and southeast winds are shown in Figure 5.6. These are the predominant

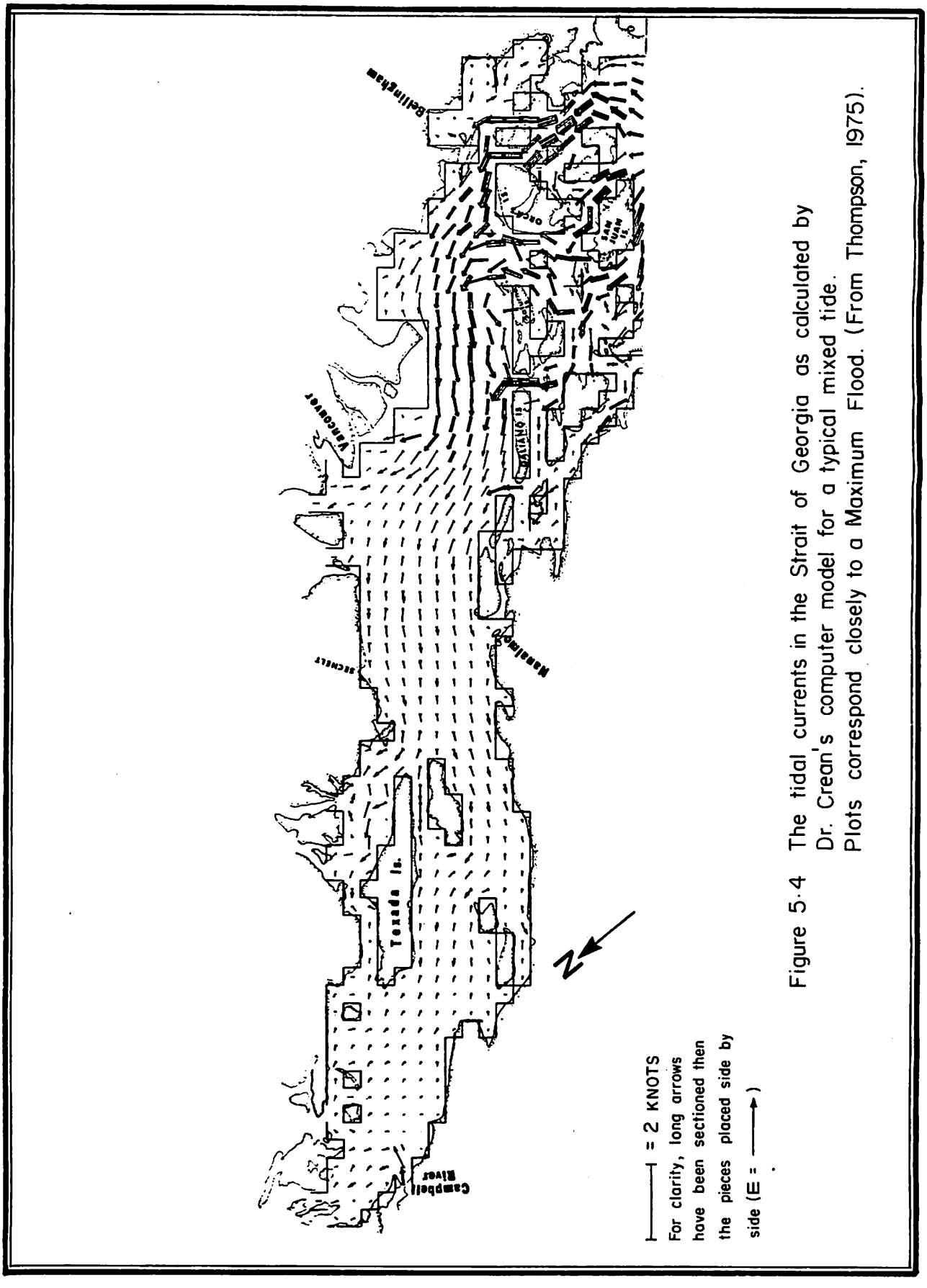


Figure 5.4 The tidal currents in the Strait of Georgia as calculated by Dr. Crean's computer model for a typical mixed tide. Plots correspond closely to a Maximum Flood. (From Thompson, 1975).

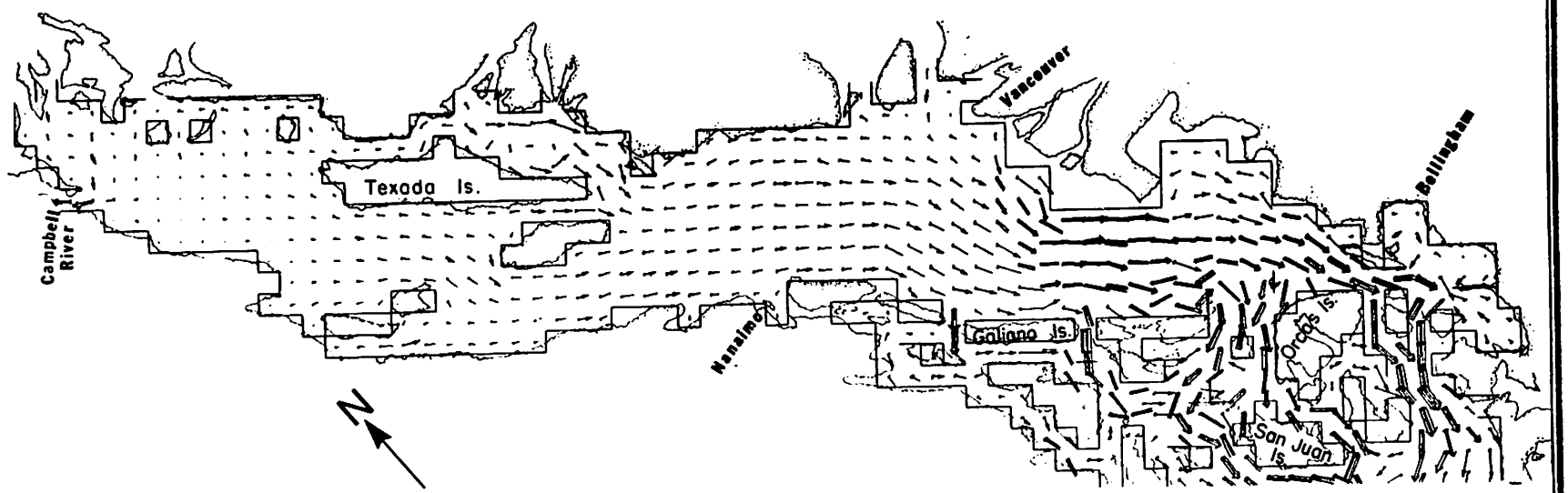


Figure 5·5 The tidal currents in the Strait of Georgia as calculated by Dr. Crean's computer model for a typical mixed tide. Plots correspond closely to a Maximum Ebb. (From Thompson, 1975).

wind directions in the Nanaimo area. Periods of calm without strong tidal currents exhibited currents converging on southern Departure Bay from north and south or a somewhat confused current pattern with eddies and weak currents (Figure 5.7).

Current measurements made in Nanaimo Harbour during the course of the 1953 survey clearly showed a tidal effect at depths greater than 2 m where the current tended to follow the predicted tidal cycle in strength and direction (Pacific Oceanographic Group, unpublished data). A flood tide sets into Nanaimo Harbour during the rising tide, and an ebb sets out of the Harbour during the falling stage of the tidal cycle. Generally, this was also found to be true for Departure Bay when continuous current measurements were made by the Canadian Hydrographic Service (Can. Dept. Env., unpublished data (b)) during the summer of 1968.

With the proposed inner harbour construction, as envisaged in the original plan of the Nanaimo Harbour Commission (1971) for inner harbour development, it was clear that the current at the eastward edge of the Nanaimo River delta would increase owing to the constriction of the channel. A simple numerical model evaluation by A. Ages (Can. Dept. Env., 1974, Appendix 4) of the currents in this area showed that they would increase from about 1 knot (50 cm/sec) to 2 knots (100 cm/sec) at peak flood and a similar doubling of current with a slightly higher speed at peak ebb.

Currents in Dodd and False Narrows are strong and highly predictable. They follow the tidal cycle closely, as illustrated in Figure 5.8. These data were taken with drift poles and current meters suspended from a boom into the narrows to avoid the effects of a boat (Can. Dept. Env., unpublished data (a); Waldichuk, 1965). Because this narrows is navigable, but with extreme care necessary in order to choose the right stages of the tidal current for passage, current tables have been prepared for

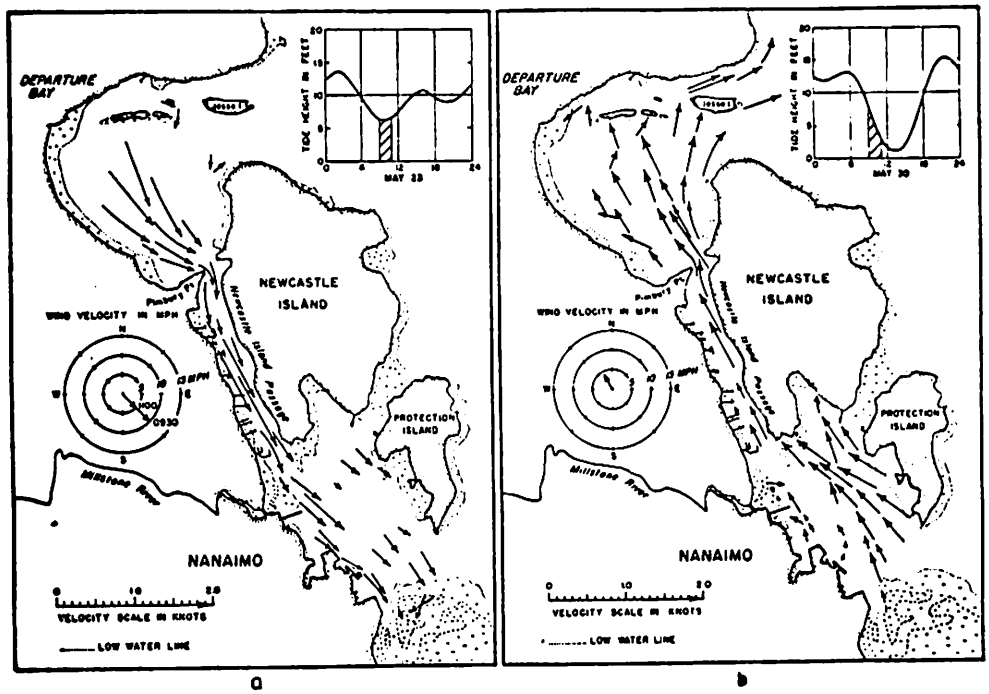


Figure 5·6 Typical surface current pictures (a), a northwest wind and (b) a southeast wind. (From Waldichuk and Tully, 1953).

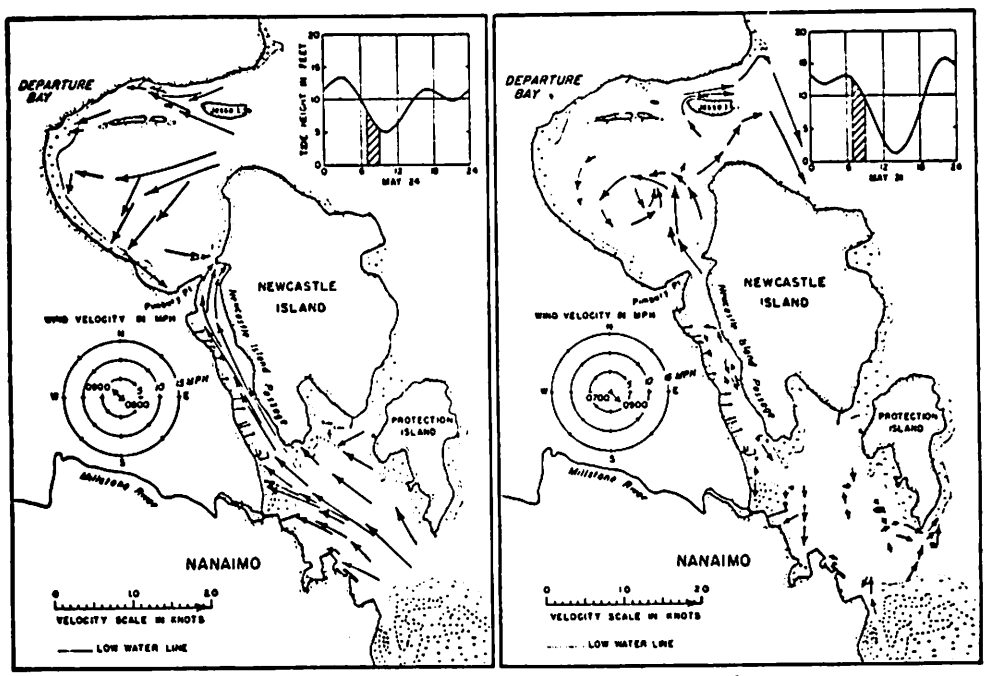


Figure 5·7 Variable and confused surface current patterns during calm to small local winds. (From Waldichuk and Tully, 1953).

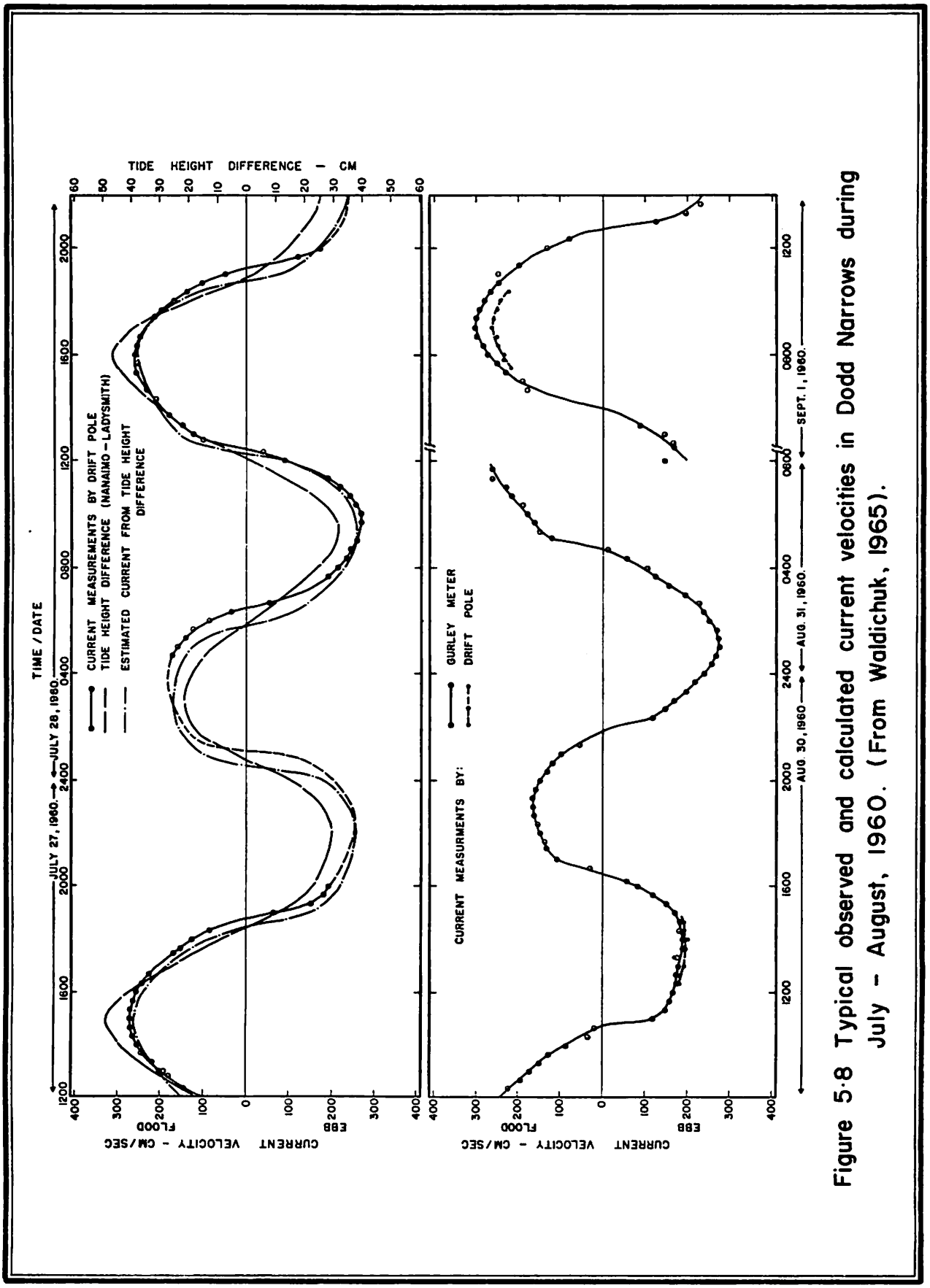


Figure 5·8 Typical observed and calculated current velocities in Dodd Narrows during July - August, 1960. (From Waldichuk, 1965).

the time and speed of current during maximum flow, as well as the time when the tide turns (Can. Dept. Env., 1976).

False Narrows, lying between Gabriola Island and Mudge Island (see Fig. 5.1) is considerably shallower than Dodd Narrows and only passable to smaller boat traffic. However, it is also quite swift, and the speed and direction of the currents can be predicted on the basis of the current in Dodd Narrows. The characteristics for tidal currents in both Dodd and False Narrows are given in Table 5.3.

Table 5.3. Characteristics of Tidal Currents in Dodd and False Narrows. (From Can. Dept. Env., 1976.)

STATION	POSITION		MAXIMUM RATE					
	Lat.N.	Long.W.	Turn to -Dir. Ebb	Turn to +Dir. Flood	+Dir. Flood		-Dir. Ebb	
			h.m.	h.m.	cm/sec	knots	cm/sec	knots
Reference Station								
DODD NARROWS	49°08'	123°49'	-	-	464	9.0	412	8.0
Secondary Station								
FALSE NARROWS	49°08'	123°47'	+0 25	+0 10	232	4.5	232	4.5

Currents in Northumberland Channel were observed by drift pole in the vicinity of the Harmac pulp mill during 1949 for the purposes of deep-sea shipping from the new wharf (La Croix and Dando, 1949). These observations clearly showed that the currents set to the south almost on all stages of the tide. This condition provides a favourable flow for any discharge of waste into Northumberland Channel, in that it becomes well mixed in both False and Dodd Narrows before being carried further afield into Stuart Channel. The profile of residual currents in Northumberland Channel (Fig. 5.9) exhibits a rather interesting phenomenon, with a net flow to the southeast in the surface layer, a flow to the northwest in the intermediate layer from 2 to 10 m

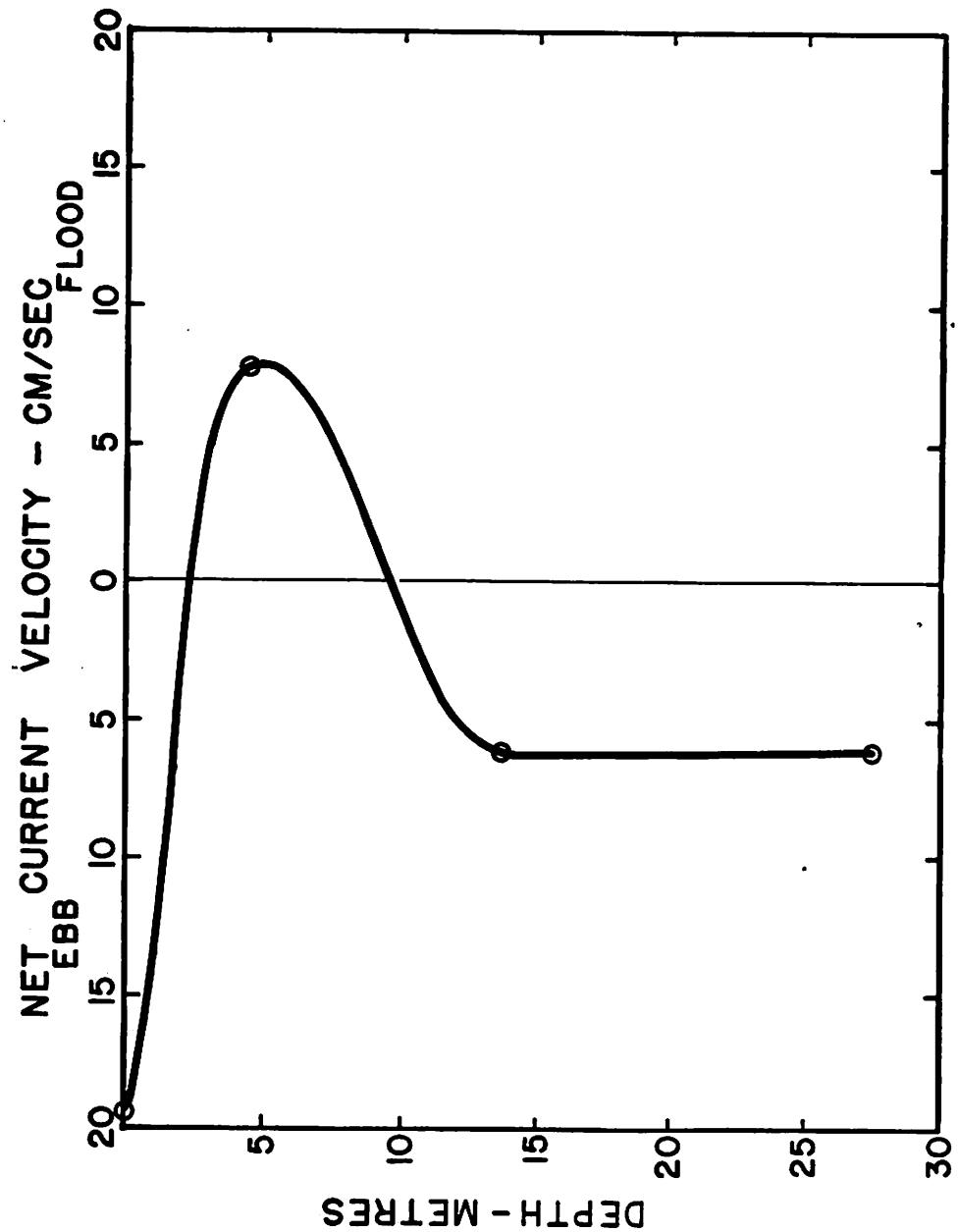


Figure 5·9 Net currents at Station N-5 for a 25 hour period, July 8 - 9, 1957. (From Waldichuk, 1965)

deep, and a flow southeastward again in the water below 10 m depth. It is believed that this curious three-layered residual flow may be related to the mixing action in Dodd Narrows which provides an intermediate water for Northumberland Channel during the northwestward (flood) flow water through Dodd Narrows (Waldichuk, 1965). It is obvious from the net flow to the southeast into the narrows that the release of wastes into the surface waters of Northumberland Channel would be better dispersed and dissipated than similar introductions into Nanaimo Harbour, for example (Waldichuk, 1973).

Although currents in Northumberland Channel are strongly associated with the tide, the configuration of the shoreline and the position of Gabriola Island with respect to the Strait of Georgia and the Gulf Islands is important. Currents here are also affected by wind and to some extent by runoff. There is a great deal of regional variability in the currents of Northumberland Channel from Dodd Narrows to the entrance of Nanaimo Harbour. Therefore, local knowledge is quite important for one to be able to judge the current speed and direction in any part of this channel.

Current drogue studies were conducted during the summer of 1970 north of Departure Bay near a proposed new location for an outfall from an expanded sewerage system for the Greater Nanaimo area. The objective was to select a point for sewage disposal where mixing and currents were such as to provide rapid dilution and dispersion away from shore. Current observations were made by the consultants (Dayton and Knight, 1970) under supervision of the Pacific Oceanographic Group (Giovando, 1973). The main study concentrated on the Five Finger Island location northeast of Departure Bay. In general, while it was found that the current did not necessarily move always to the southeast and offshore as it had been hoped, there was a sufficiently strong current in the seaward direction to warrant use of this site for an

outfall. Certainly with the proposed depth of outfall (about 75 m or 250 ft.), it was not anticipated that the effluent from the sewage treatment plant would ever rise all the way to the surface.

5 (vi) WAVE ACTION

Although both Nanaimo Harbour and Departure Bay are fairly well protected from the open Strait of Georgia by Newcastle and Protection Islands, as well as by Jack Point, winds from the northeast and east can create considerable choppiness within these two embayments. Departure Bay is particularly exposed to easterly winds, and winter storms can be devastating for vessels tied up at wharves in this bay. In Nanaimo Harbour, northwesterly winds might be of more concern than those from the southeast. It has been suggested that the shape of the Nanaimo River estuary delta has been influenced considerably by wave action, in that the delta front appears to be concave in the eastern part of the delta toward Jack Point and convex adjacent to the city of Nanaimo. This asymmetry in the delta front has possibly been caused by wave action in the more exposed area adjoining Jack Point and deposition of sediments in the western part of the harbour.

No wave measurements have been made over any length of time in Nanaimo Harbour or Departure Bay. However, it is believed that waves seldom exceed a height of 1 m (3.3 ft.) in these inside waters. A curious phenomenon occurs in Departure Bay during strong northwest winds in the Strait of Georgia. Under these circumstances, the winds in the bay blow from west to east, with considerable atmospheric turbulence, presumably because of the topographic effect in the path of the wind. They do not build up waves of any significant height locally because of the short fetch involved. Generally, a banded pattern of ruffled water at the surface moves from west to east within the bay, and these

bands appear to correspond to the turbulence of the atmosphere above the water. The importance of this wind action is not so much in creating waves as it is in flushing the surface waters out of the bay (see Section 5 (vii) FLUSHING ACTION).

Until a seawall was constructed along the western shore of Departure Bay around 1970, heavy erosion of the bordering land occurred through wave action on the bathing beach in this area. The wake from ferries entering the bay accelerated the process. One of the earlier roads along the Departure Bay seashore had been partly washed away. The instability of the beach materials in this area, along with the wave action, rendered it a poor place for intertidal organisms to become established. Most of Nanaimo Harbour, especially the Nanaimo River delta, does not suffer from this condition.

5 (vii) FLUSHING ACTION

No quantitative assessment has been made of the flushing rates in either Nanaimo Harbour or Departure Bay. However, an attempt was made to determine the rate of flushing in Northumberland Channel using a technique of tide height and current data (Waldichuk, 1965). It was estimated that in a layer of about 19 m depth (approximately depth of the sill in Dodd Narrows) about 35% of the water is flushed out every five tidal cycles, or 2½ days. The rate of flushing in waters below 19 m would be considerably slower. It is estimated that a film of oil would require a little over 9 hours, on the average, to be transported from the northwest end of Northumberland Channel to Dodd Narrows, a distance of 6.5 km (3.5 n.mi.). The big advantage for disposal of effluents into Northumberland Channel is that currents for at least part of the channel tend to be unidirectional, i.e. to the southeast into Dodd and False Narrows. Rapid dispersion takes place after the effluent is mixed into the narrows and carried on into Stuart Channel.

The flushing of Nanaimo Harbour is partly dependent on the flow from the Nanaimo River. Effluents released at the surface into Nanaimo Harbour are carried seaward with the freshwater layer from the river and eventually reach the Strait of Georgia through Fairway Channel. Southeast winds transport any surface water and water-borne effluents into Newcastle Island Passage, and then on into Departure Bay, as observed in float studies during the spring of 1953. At the present time, the extent of such transport can only be qualitatively stated. Northwest winds tend to retain surface water in Nanaimo Harbour, and perhaps mix it into the water column.

In Departure Bay, there is a much more vigorous exchange of water with the Strait of Georgia. Part of this is due to the fact that there is relatively little constriction through Rainbow Channel between Departure Bay and the Strait of Georgia. No sill restricts water movement, and only Newcastle and Jesse Islands tend to reduce the complete exposure of Departure Bay to the Strait of Georgia.

Wind effects have a rather interesting influence on water exchange in Departure Bay. It has long been known that during periods of strong northwest winds in the Strait of Georgia (westerly winds in Departure Bay) water on the bathing beach tends to be colder than during periods of calm or light southeast winds. This is so in spite of the usually sunny weather that accompanies nothwest winds during the summer months. Studies conducted on this phenomenon in the summer of 1968, covering periods of westerly winds in Departure Bay, allowed an examination of the local upwelling induced by the wind action and recognizable through salinity and temperature distribution (Waldichuk, unpublished data; Henry and Murty, 1972).

The anticipated effect of local upwelling due to winds was clearly demonstrated by a series of temperature profiles made

through the bay following sustained westerly winds blowing from the shore toward the Strait of Georgia. There was a definite tilt in the isothermals with the colder water obviously being carried to the surface as the warm water was blown off shore by the westerly winds. This effect was further investigated by Henry and Murty (1972), when they developed three-dimensional models for the circulation in Departure Bay under stratified conditions with variable wind stress. In one model they treated the steady-state, homogeneous situation taking bottom topography into account, while in the second model they included the thermal effects but no topography. It is evident from these studies that winds can be extremely important in transport of surface water seaward, and along with it the contained pollutant, thus effecting a degree of flushing that might not be possible otherwise.

Although Departure Bay and Nanaimo Harbour are comparatively open for exchange of water with the Strait of Georgia, they are not systems actively and continuously flushed by tidal action. This means that pollutants introduced into these two embayments can be retained for some time before wind-driven and tidal currents carry them seaward. This has been demonstrated particularly in Nanaimo Harbour where there have been a number of small oil spills from vessels recently. During periods of east and southeast winds, surface waters can be moved rather steadily and quite strongly onto shore. Consequently, such substances as oil could be blown on shore and held there for extended periods.

6. INVERTEBRATE BIOLOGY

6 (i) TERRESTRIAL INVERTEBRATES

Records of insects and arachnids in the Nanaimo area are few and there are no publications describing the insect fauna of the southeast coast of Vancouver Island. The collections of the B.C. Provincial Museum are centered largely on the Coleoptera (beetles) and Lepidoptera (butterflies and moths) at present and were collected for the most part, on southern Vancouver Island (R.H. Carcasson, Curator, Entomology Division, pers. comm.).

6 (ii) FRESHWATER INVERTEBRATES

Distribution and abundance of the invertebrate (largely insect) fauna of the Nanaimo River system has not been documented. For an introductory guide to the stream insects of southern Vancouver Island the reader is referred to Mounce (1973).

In his study of some possible effects of logging on stream biota, Narver (1972) reported few and inconsistent differences in the quantity and types of invertebrates in the stream drift between logged and timbered sections of Jump Creek. Immature and adult mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera) and true flies (Diptera) (in order of importance) comprised the bulk of the diet of trout (*Salmo gairdneri*). Terrestrial insects were a more important trout food source in logged sections of the creek.

6 (iii) MARINE INVERTEBRATES

A program to identify parasite fauna and load on commercially important fishes in Georgia Strait is ongoing at the Pacific Biological Station. Chum and some chinook salmon fry

were collected during their downstream migration in the Nanaimo River and on the estuary in 1975. Preliminary results showed the fry to be almost completely free of parasite infections (Pacific Biological Station, 1976).

1. BENTHOS:

An ongoing sampling program is being conducted on the Nanaimo River estuary to determine the abundance and productivity of benthic food resources of young salmon and other species. Salmon fry in the estuary utilize harpacticoid copepods extensively as a food source and over 20 species have been identified from the mud flat. *Harpacticus uniremis* is the most important species, though other species such as *Tisbe furcata* (epibenthic) and *Huntemania jadensis* (interstitial) are also consumed. Partial and preliminary analysis of meiofauna data from March to July, 1975 at one station showed a mean number of 364 copepods/10 cm^2 or 8.3 g/m^2 in terms of biomass. Between March and May, 1975, harpacticoid numbers dropped from 503 to 93/10 cm^2, the low count coinciding with the disappearance of young chum salmon from the mud flat (Pacific Biological Station, 1976).

Laboratory determinations of harpacticoid feeding rates and population dynamics, coupled with field studies including determinations of autotrophic and heterotrophic production, salmonid migrations and feeding activity are being conducted in order to complete an overall model of how the estuary functions to generate renewable resources. The bulk of this work is not published, but is being processed by scientists in the Strait of Georgia program at the Pacific Biological Station. Preliminary results indicate that benthic copepods are a key link in the salmonid supporting, detritus based, estuarine food web.

The Dungeness crab (*Cancer magister*) forms the basis of a small but steady crab fishery on the delta. The distribution, size and sex composition and density of *Cancer magister* was studied from June to October, 1973 (Can. Dept. of Env., 1974).

This study revealed that the upper estuarine flats, particularly the east (Holden Creek) and west (Nanaimo River) channels are utilized by yearling crabs as moulting sites during June and early July. Adults utilize the lower delta, particularly the eelgrass beds to moult and breed in May and June. Legal males are generally most abundant on grounds adjacent to the present Assembly Wharf while breeding females prefer the area immediately west of Jack Point. Smaller individuals of both sexes congregate off the Assembly Wharf area.

The lower portion of the estuary is populated by cockles (*Clinocardium nuttalli*), horse clams (*Tresus capax, T. nuttalli*), polychaetes and burrowing crustaceans (i.e. mud shrimp, *Callianassa californiensis*). The slightly elevated ridge of coarse gravel supports a large population of Pacific oysters (*Crassostrea gigas*). A few butter clams (*Saxidomus giganteus*) and large numbers of horse clams, Japanese little-neck (*Venerupis japonica*), mya (*Cryptomya californica*) and soft-shelled (*Mya arenaria*) clams are found in this area. The encrusting sponge *Haliachondria* sp. and shore crabs (*Hemigrapsus oregonensis*) are also abundant (Can. Dept. Env., 1974). The list of species recorded on the estuary in August of 1973 is presented as Appendix 6.1.

Oysters are found in commercial abundance along the northwest shore of Newcastle and Protection Islands, as well as in the Duke Point lagoon (D. Smith, Marine Resources Branch, pers. comm.). These areas are presently closed to the taking of shellfish owing to possible bacterial or viral contamination. The Marine Resources Branch of the B.C. Department of Recreation and Conservation has used these oyster populations to stock recreational oyster reserves located along southeast Vancouver Island (measures are taken to ensure that the oysters are depurated and therefore safe for human consumption).

The intertidal life of the Nanaimo area has been studied in some detail by biologists working out of the Pacific

Biological Station. Stephenson and Stephenson (1961a) gave an account of the flora and fauna on rocky substrata on Brandon Island in Departure Bay and discussed the zonation of this life with respect to environmental conditions. The shore community of this sheltered island was of the cold temperate type and was zoned distinctly. Echinoderms, particularly the large starfish *Pisaster ochraceus* formed an important part of the community of Departure Bay. In 1947 the Japanese oyster *Crassostrea gigas* was not a dominant animal, whereas it was by 1960. The spread of the Japanese oyster and other species introduced along with the oyster, an example being the Japanese little-necked clam (*Venerupis japonica*), was discussed by Quayle (1964). Notes on comparable coasts in the vicinity were included by Stephenson and Stephenson and they noted that the zonation described for Brandon Island was widespread. In another paper by the same authors (Stephenson and Stephenson, 1961b), the shore community of Horswell Bluff and a reef in False Narrows was described and compared with communities found elsewhere along the southeastern coast of Vancouver Island. Lewis and Quayle (1972) discussed some aspects of the littoral ecology of British Columbia giving a general account of principal biological features of different types of habitats.

Recent surveys of intertidal life in the present study area have been made to assess environmental impacts of pollution sources. Waters (1975a,b,c) surveyed intertidal transects at Lagoon Head, Newcastle Island and Gabriola Island in conjunction with the Five Finger Island sewage outfall. The intertidal biota of Northumberland Channel has been assayed using artificial substrates as part of receiving water quality monitoring by the Harmac pulp mill (Beak, 1970; Melville, 1973, 1974; Ketcham, 1975). Mill effects on intertidal biota are discussed in the Pollution Section.

Many of the early investigations of Pacific marine life were conducted within the present study region and these references are included in the bibliography where applicable. A survey

of Duke Point lagoon biota, done in 1973 as part of the Nanaimo Port alternatives study (Can. Dept. Env., 1974) yielded a species list which is included as Appendix 6.2. This list may not be complete but gives a representative picture of the predominant species of the area. A more complete species list representative of the present study area may be found in the Cowichan-Chemainus report (Bell and Kallman, 1976).

2. ZOOPLANKTON:

Many early investigations of Pacific marine fauna were conducted in the vicinity of the Pacific Biological Station and these descriptive references are listed in the Invertebrates bibliography.

Microzooplankton observations have been made in the Nanaimo area from January, 1973 to January 1976 as part of the Strait of Georgia program (R.J. LeBrasseur, PBS, pers. comm.). Analysis of these data (ongoing) will elucidate annual trends and the availability and significance of these plankton to larval and juvenile fishes. Further zooplankton observations were made from March to July, 1975 in support of fisheries studies; however, data from this study are also presently being analyzed.

6 (iv) INVERTEBRATE FISHERIES RESOURCE

Other than the estuarine crab fishery little commercial fishing occurs within the present study area. There are no commercial foreshore shellfish lots presently leased within the study area and many of the suitable shellfish growing areas are presently closed owing to bacterial contamination (see Figure 11.1). Annual reported landed values for statistical area 17, which extends from Nanoose Bay to Crofton and includes the west half of the Strait of Georgia between those points, are presented in Table 6.1.

Table 6.1. Annual reported landed values of the Invertebrate Fisheries in Statistical Area 17 in $000's from 1967 to 1975 (compiled from Area Worksheets, Economics Branch, Fisheries Operations, Fisheries and Marine Service, Pacific Region, Vancouver, B.C.).

	Prawns	Shrimp	Clams	Crab	Abalone	Oyster
1975	5.7	29	33	40	*	*
1974	9	41	36	28	*	*
1973	6	34	47	5	3	157
1972	3	38	33	1	*	117
1971	2	18	65	4	*	91
1970	4	12	46	3	*	71
1969	*	44	26	3		97
1968	*	96	26	2		115
1967	*	91	32	3		126

* nil value

The estuary area, particularly the waters immediately southwest of Jack Point, is extensively fished by crab fishermen during low tides, particularly in late spring and early summer. Thirty to fifty people may be seen crabbing on weekdays on the estuary and this number may increase to 100 on weekends. The annual catch is estimated to have ranged from 1,800 to 6,000 crabs between 1969 and 1973 (Can. Dept. Env., 1974). The landed values quoted in Table 6.1 for the Area 17 crab fishery are almost exclusively derived from the local Nanaimo estuary fishery (E.E. Epps, Area 17 Fisheries Officer, pers. comm.). The increased value of the fishery in 1974 and 1975 is a result of greatly increased reported landed weights and a 10% annual increase in price per unit weight.

Oysters are plentiful on the central gravel bar of the estuary, on the northeast shores of Newcastle and Protection Islands, and in the Duke Point Lagoon. These stocks may be commercially

havested as "wild" oysters and either relaid on registered commercial oyster leases for two weeks or treated in the oyster depuration plant located in Ladysmith. These "wild" oysters are generally soup grade oysters (14-22 oysters/litre or 65-100 oysters/gal.) as opposed to the smaller table grade (22-33 oysters/litre or 100-150 oysters/gal.) which make up 95% of the market demand for oysters. Wild oysters make up only 25 to 35% of annual landed values because of the small market demand for soup grade oysters (D. Smith, Marine Resources Branch, pers. comm.). These oyster stocks have been used to stock provincial oyster reserves for recreational picking. Commercial oystering was previously reviewed in the Cowichan-Chemainus report (Bell and Kallman, 1976) but for a more complete discussion the reader is referred to Quayle (1969, 1971).

Clams are abundant on suitable grounds in the Nanaimo area, the lower Nanaimo estuary not withstanding. Though harvesting of shellfish on the estuary and area shoreline is presently illegal owing to high coliform counts, what recreational harvesting that does occur is expected to increase with the improved water quality resulting from the sewer outfall relocation to Five Finger Island (see Pollution Section). Butter (*Saxidomus giganteus*), Japanese littleneck (*Venerupis japonica*), and native littleneck (*Protothaca staminea*) clams are those generally sought after by commercial and recreational pickers, although horse (*Tresus capax, T. nuttalli*) and soft shelled (*Mya arenaria*) clams and cockles (*Clinocardium nuttalli*) are also valuable and make good table fare.

Commercial shrimp trawling and prawn trapping in the area is limited to grounds in the Hudson Rocks and Five Finger Island areas (E.E. Epps, pers. comm.).

7. FISH

7 (i) GENERAL DISCUSSION

The Nanaimo River is a popular steelhead stream for local as well as lower mainland anglers and is also an important producer of salmon. All five salmon species (chum, coho, chinook, pink and sockeye) were at one time represented; however, pink and sockeye numbers have declined in recent years to the point where they are only occasionally reported. The river may be considered intermediate in terms of salmon production (as estimated by escapements) between the Cowichan and Chemainus Rivers which were previously reviewed in this series (Bell and Kallman, 1976). Steelhead and cutthroat trout are reported in the Millstone River (which has an impassable falls about 1.2 km (.75 miles) upstream from the mouth), Hong Kong and Holden Creeks, and chinook, coho, chum, steelhead and cutthroat in the Chase River.

Mining and extensive logging within the watershed, the construction of dams and reservoirs for domestic and industrial water supply and log booming on the delta are all likely to have had effects on fish production in the Nanaimo River system; however, any alleged effects have not been documented.

Much of the available fisheries information was summarized in the Nanaimo port alternatives report (Can. Dept. Env., 1974) which marks the beginning of a considerable research effort investigating the estuarine residency (timing, distribution, growth and mortality as well as related physical parameters, invertebrate studies and primary production) of juvenile salmonids from the Nanaimo and other river systems. Available information from this program is discussed under the appropriate species headings.

A summary of Nanaimo River salmon escapements, a list

of fish species sampled by various means on and around the estuary, annual reported landed values for statistical Area 17, salmon sport catch for Area 17, and steelhead catch data for the Nanaimo and Chase Rivers is presented as appendices 7.1 to 7.6, respectively. The reader is also referred to the bibliography for references not cited in the text.

1. SALMON:

(a) Coho salmon (*Oncorhynchus kisutch*). Annual estimated escapements have varied from a low of 800 in 1968 to between 50,000 and 100,000 in 1938 and have averaged approximately 4,300 between 1964 and 1975. Earlier running coho spawn in the Nanaimo River and its tributaries upstream as far as Second Lake. Later running coho spawn in the lower part of the river in the same areas as do chum salmon. Some coho also spawn in Chase River and in Hong Kong and Holden Creeks. Coho begin to arrive in the river in late August and September. Spawning takes place from late September to late December or early January, peaking in late October to early November (Aro, 1973).

Coho tend to remain in fresh water for up to a year after their April emergence. However, many fry are displaced from fresh water and rear in the estuary, particularly near shore. Second year coho (smolts) enter the estuary in spring and move rapidly to the outer estuary (over the eelgrass beds and off the delta front) where they feed primarily on larval and juvenile fishes though marine zooplankton were also represented (Can. Dept. Env., 1974).

(b) Chum Salmon (*Oncorhynchus keta*). Annual escapements of chum salmon have varied from a high, in excess of 100,000 in 1950 to a low, between 2,000 and 5,000 in 1963. In the 11-year period from 1964 to 1975, the average escapement was about 35,000 chum annually. Chum salmon spawn in the Nanaimo River from its confluence with the Chase River upstream as far as Haslam Creek. Most of the spawning takes place in the main channel up to and adjacent

to Indian Reserve No. 3 and above the Cedar Road Bridge in Polkinghorne's Slough and Side Channel and in Maffeo's Side Channel. Some chum also spawn in the lower reaches of Haslam Creek. Returning chum salmon begin arriving in the rivers from late August to late September. Spawning commences shortly after arrival in the stream, reaches a peak in mid to late October, and ends by late November or early December (Aro, 1973).

An estimated 51.6 million chum fry entered the estuary in 1975 shortly after their springtime emergence (mean length - 41 mm; mean weight - 0.5g), though some degree of freshwater rearing may have occurred. They were found over the flats from March to May and in other nearshore environments from March to June after which numbers declined rapidly. Nanaimo chum stocks were supplemented by others after May. Early running fish spent approximately 15 days on the flats and later running ones as little as 1.5 days. Juvenile chum residence in the nearshore environment was in the order of 24 to 28 days. Benthic harpacticoid copepods were the dominant food article and an estimated 4,000 to 5,000 kg of food organisms were consumed by the growing salmon on the mudflats between March and May, 1975 (Pacific Biological Station, 1975).

(c) Chinook salmon (*Oncorhynchus tshawytscha*). Annual escapements have varied from a low of 525 in 1975 to between 10 and 20,000 in 1939 and have averaged 2,125 annually from 1964 to 1975. The Nanaimo River chinook run has spring and fall components. Spring chinook enter the river from early April to late June and spawn in the mainstem below First Lake. The fall chinook enter the river in late August and September and spawn in the mainstem below the Trans-Canada Highway Bridge downstream as far as Cedar. Spawning generally commences in September, reaches a peak in October and ends in November or December (Aro, 1973).

Chinook salmon normally display two peaks of seaward

migration though they may enter the ocean throughout the year. The first of these peaks includes the majority of fish and occurs approximately three months after emergence, hence the name "90 day fry". The second peak occurs after one year of freshwater rearing. The numbers of chinook smolts in the 40-70 mm and 70 to +150 mm size ranges sampled on the estuary during the summer of 1973 confirmed this dual migration pattern (Can. Dept. Env., 1974).

The diet of chinook "90 day fry" caught in early spring was comprised mainly of estuarine benthos while the diet of large juveniles (smolts) was primarily larval and juvenile fishes from spring until mid-summer. These predominances were not apparent when the fishes were sampled from over the intertidal mud flats. The diet of these fishes was diverse regardless of the season, as estuarine, freshwater and terrestrial invertebrates were all well represented. Surface insects were also heavily preyed upon during their summer emergence (Can. Dept. Env., 1974).

Eggs of chinook salmon returning in the fall of 1973 were collected from the Nanaimo River and reared to smolt stage in the Big Qualicum hatchery. Approximately 11,000 tagged smolts (clipped adipose fin and magnetic wire nose tag) were then released on June 24, 1974 into the Nanaimo River at the Cedar Bridge, approximately one mile upstream of the mouth. Fishing commenced on June 25 at stations in the estuarine area using a small hand operated purse seine in order to determine local residency of juvenile salmon. The following conclusions were drawn as a result of this work (Sibert, 1975):

1. Juvenile chinook salmon (of unidentified origin) were found in the Nanaimo River estuary for a period of at least 4 months, Nanaimo River populations were found in the estuary for a period of at least 2½ months and individual Nanaimo River fish may have used the estuary for 2 weeks.

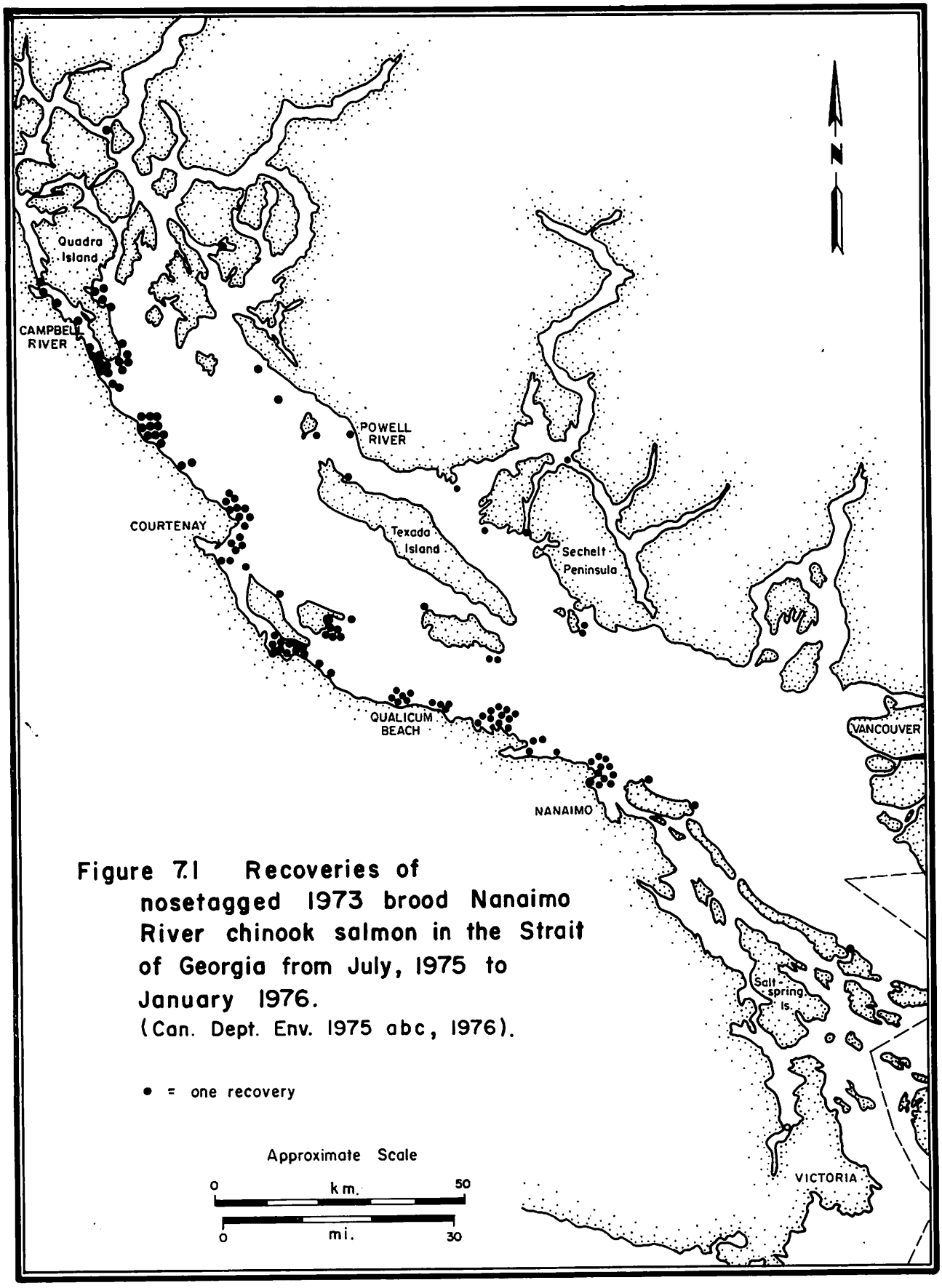


Figure 7.1 Recoveries of nosetagged 1973 brood Nanaimo River chinook salmon in the Strait of Georgia from July, 1975 to January 1976.
(Can. Dept. Env. 1975 abc, 1976).

• = one recovery

2. The total population of juvenile chinooks using the Nanaimo estuary was approximately 70,000 fish and the maximum number using the estuary at any one time was approximately 40,000 fish.

3. The instantaneous growth rate of juvenile chinooks in the estuary was approximately 0.0084 DA^{-1} (increase in fork length per day).

The marked Nanaimo fishes entered the Strait of Georgia salmon fisheries in the summer of 1975 and returns are being reported in bulletins of the Fisheries and Marine Service (Can. Dept. Env., 1975 a,b,c, 1976). Figure 7.1 illustrates the recapture locations up until January, 1976 for Nanaimo River chinooks.

Chinook salmon from the Nanaimo River contribute to the commercial troll fishery operating off the west coast of Vancouver Island, the troll and net fisheries of the Strait of Georgia and its approaches, the Strait of Georgia sport fishery (which exploits both grilse and mature homing salmon, particularly in Nanaimo Harbour waters around Jack Point), and the Indian food fishery, operating in the lower reaches of the Nanaimo River.

(d) Pink salmon (*Oncorhynchus gorbuscha*). In the fifties, small numbers of pink salmon were reported in the Nanaimo River in both even and odd numbered years. None has been reported since 1960. The pinks spawned in the lower three miles of the Nanaimo River and lower quarter mile of Haslam Creek. According to long-time residents of the area, substantial numbers of pinks spawned in Haslam Creek (Aro, 1973).

(e) Sockeye salmon (*Oncorhynchus nerka*). Sockeye salmon have been reported in the Nanaimo River in 1951, 1957, 1958 and 1972. These sockeye either were strays from other river systems, or were the descendants of sockeye which may have resulted from the

introduction of eyed sockeye eggs and fry into the Nanaimo River system in 1886, 1887, 1889, 1902, 1903, 1904 and 1933, or resulted from kokanee which may have migrated to the sea as juveniles. The kokanee present in the Nanaimo Lakes are known to have been there prior to the introduction of sockeye eggs to the system in 1933. It is not known if kokanee were present in the system before the earlier introductions (Aro, 1973).

2. ANADROMOUS TROUT:

No estimates are available of the number of steelhead and migratory cutthroat spawners in the Nanaimo River. From studies of the ratio of catch to escapement of steelhead in other systems it is likely that annual catches represent less than one-third of the total steelhead run. The steelhead catch in the Nanaimo River has been estimated to be between 664 and 2,573 steelhead annually in the years 1966 to 1971. The Nanaimo River steelhead run consists of a winter run, a spring run, and a fall run of "jacks". Steelhead spawn in the Nanaimo River to a point slightly upstream from its confluence with Sadie Creek, and in many of its tributaries, including Haslam Creek, Elkhorn Creek, South Nanaimo River, North Nanaimo River, Rush Creek, Green Creek and Sadie Creek. Spawning occurs between February and May. Migratory cutthroat also occur in the Nanaimo River and its tributaries as far upstream as Sadie Creek. As mentioned earlier, steelhead also occur in the Chase and Millstone rivers, and migratory cutthroat in the Chase River and in Hong Kong and Holden Creeks (Aro, 1973).

Emergence likely begins in May and peaks in late June or mid-July (Withler, 1966). Most steelhead fry spend their first summer in their natal stream or adjacent to their birthplace in the mainstem. In late fall, sub-yearlings generally migrate from the colder headwaters to the warmer lower reaches. They return to the headwaters in the summer months, and then retreat again to the lower river as second-year fingerlings. Most

juveniles undergo smolt transformation in the spring of their third year, and their seaward migration occurs approximately from mid-April to mid-May. Some may remain in brackish water of the estuary for a time before leaving the river system entirely.

A survey of angler caught steelhead in the Nanaimo River (Narver and Withler, 1974) gave the following catch distribution: 2% in December, 16% in January, 40% in February, 31% in March and 11% in April. The number of repeat spawners was low (6%) and mean smolt length (13.5 cm or 5.3 in.) was less than average for other winter steelhead streams. Fish in their fourth year of life (2.1 years) were most common (41%) and fish in their fifth year (3.1 years) less so (26%).

3. RESIDENT FRESHWATER SPECIES:

The presence and distribution of fishes in the Nanaimo River system has not been documented to any great extent. However, no introductions other than sockeye salmon have been made to the system.

Cutthroat trout (*Salmo clarki clarki*) are found throughout the Nanaimo River system and in the Chase and Millstone rivers and Hong Kong and Holden creeks. Spawning occurs between February and May in tributary streams when the fish are three or four years old (Carl, Clemens and Lindsey, 1959). Cooper (1970) investigated the growth of cutthroat trout in Chef Creek, an eastern Vancouver Island stream located 80 km (128 miles) north of Nanaimo.

The non-migratory or resident form of the rainbow trout (*Salmo gairdneri*) is also distributed throughout the rivers and creeks of the study area and at all times of the year. The life history of resident rainbow trout is similar to steelhead, except that lakes are sometimes substituted for the ocean environment (some fish may remain within a stream for their entire lives). Spawning occurs in the spring in tributary streams when the fish are three or four years of age (Carl, Clemens and Lindsey, 1959).

Dolly Varden char (*Salvelinus malma*) are also reported from the Nanaimo River (R.S. Hooton, Fish and Wildlife Branch, pers. comm.). Spawning takes place in the fall but no specific information is available.

Peamouth chub (*Mylocheilus caurinus*) are found in Holden and Quennell lakes which drain into the Nanaimo estuary via Holden Creek. These fish were either introduced to the area by man of which there is no record or by having been passively carried across the Strait of Georgia during the Fraser River freshet. Clark and McInerney (1974) investigated the latter possibilty. Their simulated crossing experiment concluded that the crossing represents a low-probability or "sweepstakes" emigration route owing to the chub's limited tolerance of dilute seawater.

Threespine sticklebacks (*Gasterosteus aculeatus*) are present in marine, brackish and freshwater habitat in the Nanaimo area. They form an important part of the diet of predatory fishes including trout and other game fishes, as well as the American merganser and other fish eating birds (Hart, 1973; Scott and Crossman, 1973).

The prickly and Aleutian sculpins (*Cottus asper, C. aleuticus*) are found in the streams of the Nanaimo area and are able to live in the brackish water of the estuary. They may at times be destructive of eggs and fry of food and game fishes as well as compete for common food sources; however, they are in turn eaten by trout and fish-eating birds, particularly mergansers (Mason and Machidori, 1976).

4. MARINE SPECIES:

Systematic fish sampling was conducted by Environment Canada personnel on and around the Nanaimo estuary during the months of May through August and November of 1972 and from January through September of 1973. Purse seining, beach seining, tow

netting and pole netting capture techniques were used on a bi-weekly basis to sample stations representing a variety of habitats within the estuary (Can. Dept. Env., 1974). Besides juvenile salmonids, many other species, listed in Appendix 7.2, utilize the food resources generated by the estuary.

Herring (*Clupea harengus pallasi*) were the most abundant species sampled in the Nanaimo area waters during this program. The majority of these fish (mostly juvenile) were sampled in Northumberland Channel and across the delta front (Can. Dept. Env., 1974). Fraser (1921) reported herring, particularly young herring, as being plentiful in the Nanaimo area. McHugh (1940) recorded the growth of first year herring in Departure Bay from two spawnings that occurred there in 1939. Herring spawn in late winter particularly during March. Spawn is deposited on kelps, eelgrasses, rockweed, other seaweeds, or sometimes rocks, pilings, or trash between high tide and 11 m (36 feet) depth. After hatching (10 days) and absorbing their yolk sac (2 weeks) they begin feeding on invertebrate eggs, copepods and diatoms. The larval herring become prey for many different invertebrates and fishes. As the herring grow larger their diet broadens to include barnacle, mollusc and decapod larvae, bryozoans, rotifers, amphipods, and euphausids, but copepods remain the dominant food item (Hart, 1973; Parker and Kask, 1974).

Some amount of spawning occurs within the study area annually. Spawning in 1975 was the heaviest recorded in recent years, owing to the increasing size of Gulf Islands herring stocks. Spawning occurred in Departure Bay and along the seaward (eastern) shores of Newcastle and Protection Islands (see Figure 7.2). Heavy spawning occurred (as in previous years) from Horswell Bluff northward along the shoreline into Nanoose Bay (Can. Dept. Env., unpublished data). No spawning has occurred within Nanaimo Harbour proper or along the delta front in the past 15 years (E. E. Epps, Area 17 Fisheries Officer, pers. comm.). Herring spawning is not only essential for the continued existance of herring

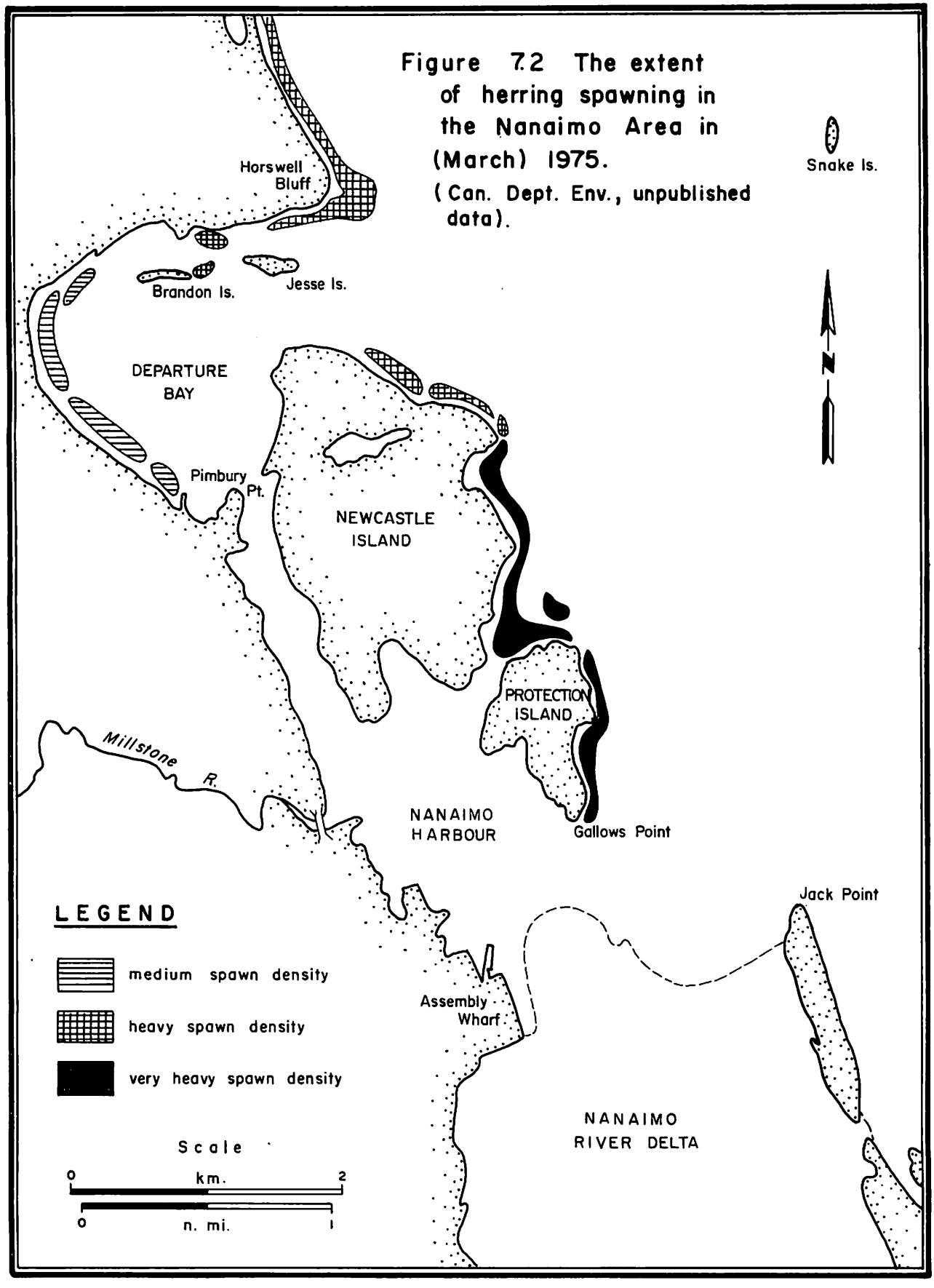


Figure 7.2 The extent of herring spawning in the Nanaimo Area in (March) 1975. (Can. Dept. Env., unpublished data).

populations but also makes substantial contributions to estuarine and nearshore salmon-supporting food chains.

7 (ii) THE FISHERIES RESOURCE

1. COMMERCIAL FISHING:

The Nanaimo area salmonid runs contribute to commercial catches in the local area and to catches in other parts of the Strait of Georgia and its approaches. Chinook and coho stocks contribute to the west coast of Vancouver Island, and Strait of Georgia troll fisheries, as well as commercial net fisheries in Johnstone Strait and the Straits of Georgia and Juan de Fuca. Chum salmon are taken in the gillnet and purse seine fisheries in the Strait of Georgia and Johnstone Strait.

Commercial fishing statistics for area 17 which includes the western half of the Strait of Georgia extending about 32 kilometers (20 miles) to the north and south of Nanaimo, is presented as Appendix 7.3. In 1975, approximately 267,000 kg (588,400 lbs.) of salmon with a landed value of $401,000 and 5,366,000 kg (11,820,000 lbs.) of other fish (mainly herring) with a landed value of $1,365,000 were fished from Area 17.

The high density herring spawning that generally occurs from Horswell Bluff northward into Nanoose Bay is the object of an intensive herring roe fishery. Gillnets and seines are used to capture mature herring during February, March and April, just before spawning. This kind of fishery, which commenced in 1971 and replaced a more wasteful, less valuable herring reduction fishery draws primarily from the large migratory lower east coast and middle east coast spawning populations. The dramatic increase in value of the Area 17 herring fishery (from $10,000 in 1970 to $1,129,000 in 1975; see Appendix 7.3) is a result of the much greater value of roe herring over reduction herring as well as the result of years of close management of these fish stocks.

Commercial fishing of invertebrate species, including crabs, shrimps, prawns and shellfish is discussed in the Invertebrates Fisheries Resource subsection.

2. SPORT FISHING:

(a) Freshwater sport fishing. Public access records for the Nanaimo Lakes watershed have been kept by Crown Zellerbach Canada Ltd. Reports compiling information on angler harvests and recreational use have been prepared by Burns (1970) and Shepherd (1975) and form the basis of the following discussion.

The Nanaimo Lakes watershed (that portion of the Nanaimo River drainage above the outlet of First Nanaimo Lake) has been a highly popular recreation area since public access has been allowed. Fishing in the various lakes and streams has been a major activity of people using the area. Rainbow (*Salmo gairdneri*) and cutthroat (*S. clarki clarki*) trout are present in about equal numbers in most lakes with natural populations (First, Second Fourth, Nanaimo Lakes and Panther and Echo Lakes) and introduced rainbows are present in Heart and Williams Lakes. Though chinook and coho salmon and steelhead may be present, they are generally angled for in the first 16 km (10 miles) of the river. As more people have been using the watershed area (4.9% increase annually) the total catch and catch per angler have decreased over the years (see Table 7.1).

Table 7.1. Total Catches and Catch/Angler for the Nanaimo Lakes Watershed (Shepherd, 1975).

Year	No. Fish	Fish/Angler	Year	No. Fish	Fish/Angler
1972	3873	0.78	1968	6171	1.16
1971	4213	1.02	1967	7873	2.19
1970	3508	1.09	1966	5707	2.15
1969	4069	1.01	1965	3565	1.69

First, Second and Fourth Nanaimo Lakes sustain the greatest amount of angling effort (generally by boat). Second Lake is aesthetically most pleasing, as much of First Lake is used for log booming and Fourth Lake (a reservoir on Sadie Creek) is subject to drawdown. Heart and Williams Lakes are subalpine and generally fished on foot.

Table 7.2. Catch and Effort Distributions for the Nanaimo Lakes Watershed, 1964-1968 (Burns, 1970).

Lake	% Anglers	% Fish
Fourth	40.0	44.8
First	17.7	14.7
Second	15.2	13.7
Panther	7.6	11.9
Echo	5.3	5.9
Other *	14.2	9.0

* Other includes Heart and Williams Lakes, Nanaimo and Green Rivers and unclassified streams.

The South Nanaimo River is closed to the public as it is the primary water supply source for the City of Nanaimo. However, anonymous sources claim that the fishing is excellent.

The lower Nanaimo River is a popular steelhead stream for both local and lower mainland fishermen. Fishing effort is concentrated in the first 8 to 25 km (5 to 15 miles) of the river and a few coho and chinook salmon are also taken. Steelhead questionnaire results for the Nanaimo and Chase Rivers are appended (Appendix 7.5 and 7.6). The Nanaimo River has consistently ranked between fifth and fourteenth in size of anglers' catches among the over 300 streams fished by steelhead anglers in British Columbia. The biology of the Nanaimo River steelhead has been investigated using angler caught samples supplied by members of

the Nanaimo Fish and Game Club (Narver and Withler, 1971, 1974).

(b) Tidal Sport Fishing. Mos and Harrison (1973) surveyed resident recreational boating activity in the Strait of Georgia. Results show that almost 30% of the Nanaimo and Gabriola Island area residents own boats and that 85% of boat use is for fishing. The appended results (Appendix 10.1) illustrate the extensive interest and participation of local residents in the tidal sport fishery.

The local sport fishery in tidal waters takes place mainly within the confines of the Nanaimo Harbour Limits, but can be expected to contain fish of mixed origin. However, during late July and early August, a sport fishery develops in Northumberland Channel near Jack Point for maturing chinook bound for the Nanaimo River. The fish caught in this fishery average less than 25 pounds but have been taken up to 55 pounds. Up to 40 or 50 boats, containing visiting as well as local fishermen, may fish in this area at any one time. The average seasonal catch has been about 50 fish. In addition, coho and a few chinook are taken by anglers in non-tidal portions of the Nanaimo River (Can. Dept. Env., 1974). Tidal sport fishing statistics for statistical area 17 are presented in Appendix 7.4. An estimated 90% of this fishing activity is located within the Nanaimo Harbour limits (see Figure 11.1) (E.E. Epps, Area 17 Fisheries Officer, pers. comm.).

3. INDIAN FOOD FISHERY:

Prior to, and in the early days of settling by white immigrants, the Nanaimo area probably supported on the order of 2,000 Indians, wholly dependent upon local and largely marine resources. Approximately 500 Indians now live on reserves in the Nanaimo area (Statistics Canada, 1972) and the annual salmon food fishery conducted close to the mouth of the Nanaimo River remains a link to their cultural past as much as a supplementary food

source. Thirty permits are issued annually for this fishery and the numbers of salmon caught are presented in Table 7.3. Steelhead are are also taken, but no estimates of numbers are available for all years. The fish are taken mainly with gillnets operated in the Nanaimo River from its confluence with the Chase River up to the Cedar Road bridge. A few salmon are taken with spears. The reduced number of salmon taken in 1975 correlates with the reduced escapements observed in the Nanaimo River and is also partially attributable to higher than normal water levels.

Table 7.3. Native food fishery statistics from 1968 to 1975 (Can. Dept. Env., 1974; E.E. Epps, pers. comm.).

	Number of fish caught				Number of		
Year	Chum	Coho	Chinook	Steelhead	Permits	Families	People
1968	680	300	255	30	17	17	85
1969	760	65	10	-	25	26	130
1970	2,450	750	150	-	34	40	200
1971	1,800	545	175	-	32	37	165
1972	2,975	60	50	-	30	28	175
1973	3,150	145	90	-	30	32	175
1974	2,750	95	75	-	30	32	175
1975	1,750	50	60	-	30	32	175

- no value reported

8. FLORA

8 (i) AQUATIC VEGETATION

Documented information pertaining specifically to the freshwater aquatic vegetation, both pelagic and benthic, of the Nanaimo River system is not available.

Notes on early collections of macrophyte marine algae in the Departure Bay area, out of the Pacific Biological Station are presented by Collins (1913), Bailey and MacKay (1916) and Connell (1928). South (1968) reports on extensive collecting conducted on Gabriola Island. Widdowson (1964) and Druehl (1965) studied variations in the algal genus *Alaria* and the taxonomy, distribution and ecology of the genus *Laminaria*, respectively, using sampling stations in the Nanaimo vicinity. Intertidal flora of Brandon Island is discussed with respect to zonation by Stephenson and Stephenson (1961a,b). Waters (1975a,c) completed several intertidal transect surveys describing macrophyte distribution on Neck Point (Hammond Bay), Newcastle Island and Gabriola Island. Biological surveys of the Harmac receiving waters (Northumberland Channel) include descriptions of intertidal flora (Beak, 1970; Melville, 1973, 1974; Ketcham, 1975).

Information on the lignicolous or wood inhabiting marine fungi of Canadian Pacific waters is limited. Meyers and Reynolds (1959, 1960) noted a number of genera from submerged basswood and yellow pine panels at the Pacific Biological Station, Departure Bay. Hughes (1969) identified the Fungi Imperfecti *Alternaria maritima, Cirrenalia macrocephala, Humicola alopallonella, Monodictys pelagica, Zalerion maritimum* and the Ascomycetes species, *Lulworthia medusa* from test panels also submerged at the Biological Station.

Investigations into the phytoplankton and primary

production of the Nanaimo estuary and contiguous waters have been conducted as part of larger programs such as basic productivity studies using a large volume plastic sphere in Departure Bay (Strickland, *et al.*, 1961; McAllister, *et al.*, 1961; Antia, *et al.*, 1963) and the Strait of Georgia program of the Pacific Biological Station (Bishop, *et al.*, 1966; Stephens, 1966; Stephens, *et al.*, 1967; Fulton, *et al.*, 1967, 1968, 1969; Seki, *et al.*, 1969). The Strait of Georgia program and investigations conducted on the Nanaimo River estuary are ongoing (Pacific Biological Station, 1976; see Appendix 1.2). Nutrient concentrations, physical parameters and the presence and degree of autotrophy and heterotrophy were determined at stations on the delta, in Departure Bay, and in Horswell, Rainbow, Fairway and Northumberland Channels for one year (1974-75) and the data are presently being analyzed. Changes in primary production in the water column over a 24-hour period have also been monitored. Some production information is available as a data record (Stephens, 1973) and in a series of Five Finger Island sewage outfall monitoring reports (Waters, 1975 a,b,c).

Three years of microplankton data were collected from Departure Bay as part of an investigation of diurnal changes in water characteristics and are presently being analyzed (Pacific Biological Station, 1976). There was an order of magnitude increase in the number of phytoplankton cells over this period, attributable to an increase in abundance of *Chaetoceros* sp. over the past two summers. *Skeletonema* sp. has declined in abundance but may indicate by the size and duration of its spring bloom the size and duration of the bloom of *Chaetoceros convoluta*, which has been responsible for fish mortality at the Biological Station on occasion. The spring phytoplankton bloom in the Nanaimo area occurred in mid-February in 1973, end-March in 1974 and early May in 1975. Explanation is being sought in the physical data collected over these periods (Pacific Biological Station, 1976).

The waters of the study area are generally quite productive, at least as productive as the average in the Strait of Georgia (Parsons, *et al.*, 1970). This may be attributed to the input of nutrients from the Strait of Georgia system through local upwelling by winds and to input of nutrients and organic materials from runoff (Seki, *et al.*, 1969). Local waters can become quite turbid during periods of heavy phytoplankton bloom, particularly during early spring and late summer. The occasional outbreaks of red water are attributed to of the non-toxic ciliate *Mesodinium rubrum* rather than the toxic dinoflagellate *Gonyaulax* sp. (the "red tide" organism) responsible for paralytic shellfish poisoning (Taylor, *et al.*, 1971).

Primary and heterotrophic production results in the water column and sediments of the delta flats have suggested that approximately ten times the annual primary production of carbon is recycled by heterotrophic activity. This suggests an unknown allochthonous source of primary production, possibly from the rivers draining into the estuary or from the eelgrass beds (Pacific Biological Station, 1976).

A short term diatom survey was conducted during and after a two week shutdown of the Harmac pulp mill during the fall of 1973 (Melville, 1974). Diatoms were sampled by using intertidally placed artificial substrates and analysed for species composition and dominance. A decrease in overall speciation and changes in dominance occurred after resumption of mill activity. Some information describing seasonal diatom abundance, as related to local salinities is presented by Mounce (1922).

8 (ii) DELTAIC VEGETATION

The vegetation of the Nanaimo River estuary has been described by Foreman (1975) with respect to macrophytic algae and by Forbes (1972, 1973) as a general description done under

contract to the Canadian Wildlife Service. The reader should keep in mind that these surveys were conducted over short-time periods and that the following summary serves only as a basic description of the estuarine flora. Figure 8.1 shows the distribution of the plant communities on the estuary and Appendix 8.1 consists of the species observed from these communities.

The upland areas surrounding the estuary are generally very rocky and were therefore never cleared for agricultural purposes. Those areas cleared, specifically the seaward portion of Indian Reserve No. 3 on the east bank of the Nanaimo River, are used primarily for grazing livestock. Woodlands are typical of climax communities of the dry Douglas-fir subzone described in the terrestrial flora subsection. The interfluvial ridges are dominated by Douglas-fir, with arbutus (*Arbutus menziesii*) and garry oak (*Quercus garryana*) appearing in the more open areas. Alluvial areas with a shallow water table are vegetated by red alder (*Alnus rubra*), broadleaf maple (*Acer macrophyllum*), grand fir (*Abies grandis*), and western red cedar (*Thuja heterophylla*) Understory shrub vegetation consist largely of sapling or immature individuals of species described in the overstory (Forbes, 1972).

The sedge (marsh) community is found in areas subject to innundation by brackish water and is comprised mostly of black grass (*Juncus gerardii*) with lesser amounts of other sedge-like growth. Lyngbye's sedge (*Carex lyngbyei*) and black grass are dominant landward of the dykes on the southeast portion of the estuary. Portions of these dyked lands are used for hay production and are lightly grazed upon by domestic animals. However, because of the low aspect of the land and periodic inundation by brackish water (standing water may remain on the fields for some time) no cultivation is attempted and halotrophic plant species predominate.

The intertidal community can be divided into three

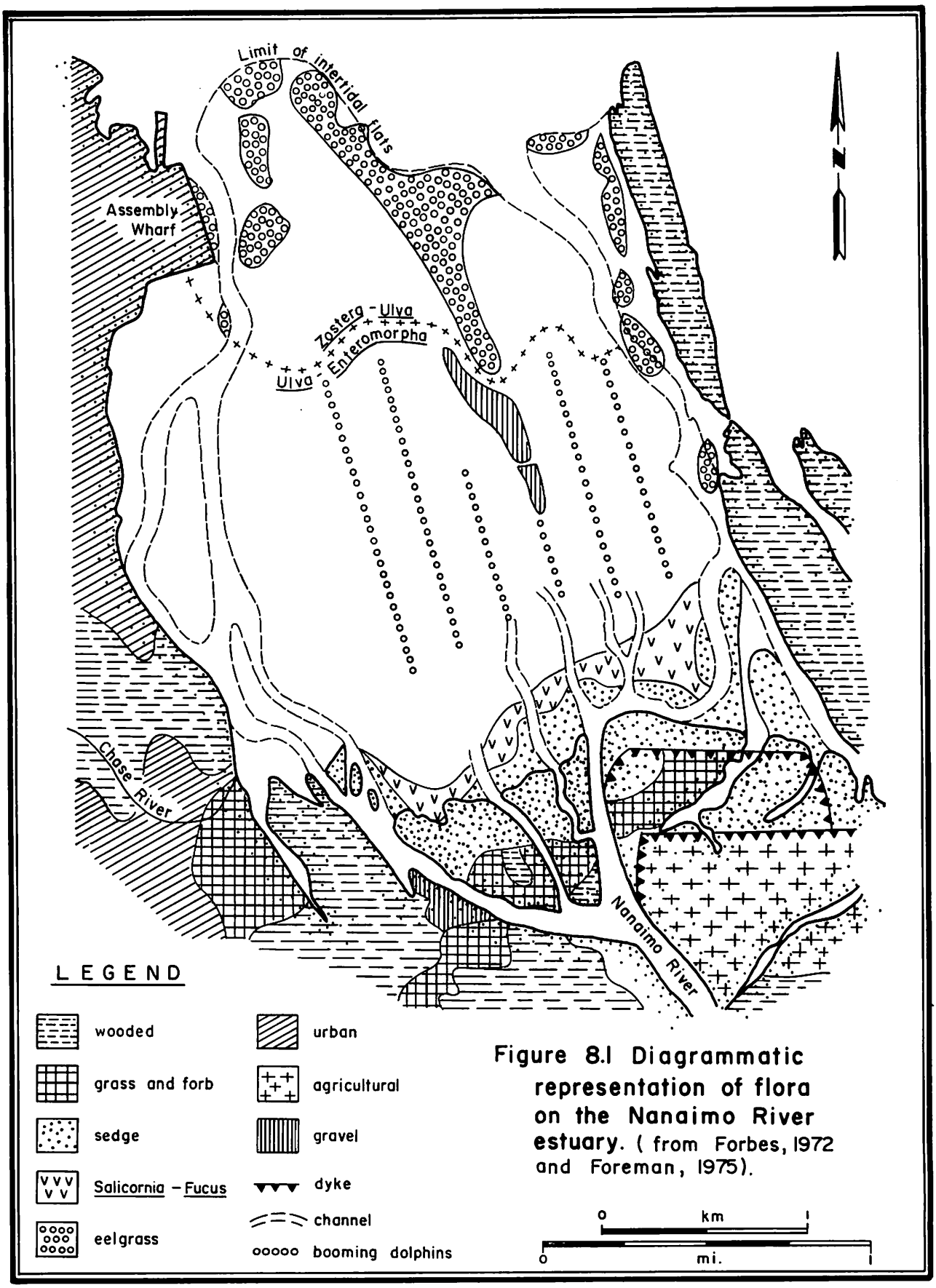


Figure 8.1 Diagrammatic representation of flora on the Nanaimo River estuary. (from Forbes, 1972 and Foreman, 1975).

zones based on the distributions, associations and importance of macrophytic algae (Foreman, 1975) and these zones are marked in Figure 8.1. The *Fucus-Salicornia* association occurs along the southeastern portion of the delta merging with the sedge community to landward and the mudflats to seaward. The middle portion of the estuary is dominated by an *Ulva-Enteromorpha* association which merges with the *Zostera-Ulva* association to seaward.

Forbes (1973) noted that much of the macrophyte community is not sessile but drift material deposited by wind and tidal action. However, Foreman (1975) reported a relatively high macrophyte biomass, approximately five times as great as that reported for the Squamish River estuary (Pomeroy, 1974; Pomeroy and Stockner, 1973) and seven times that reported from the Fraser River estuary (Lindstrom and Foreman, 1974). The higher biomass of macrophytes was attributed by Foreman to the lack of a heavy spring freshet in the Nanaimo River and to abundant suitable attachment substrate on shells, cobbles, log booms and log boom debris.

Production rates were measured for primary producers on the mud flat during the summer of 1975 by PBS investigators. Both macroalgal and microalgal production were low, on the order of 1 and 80 mg C/m^2/day (milligrams carbon fixed per square metre per day) respectively. Heterotrophic production was high, about 88% of total production, which was 1,021 mg C/m^2/day. These figures are consistent with estimates of bacterial standing crop of 31.4 mg C/m^2 and 8.9 mg C/m^2 of microalgae (Pacific Biological Station, 1976).

Eelgrass is an important form of intertidal vegetation as it supplies food for waterfowl, spawning substrate for herring, and habitat for crabs, other invertebrates, and fishes. It contributes large amounts of detritus to the food web (Harrison and Mann, 1975b) and its roots stabilize and prevent erosion of sediments. McRoy *et al.* (1972) have demonstrated the importance

of eelgrass in recycling phosphorus from the sediments into the water column.

Apparently, eelgrass was once much more widespread on the estuary than at present. Prior to 1948, when the estuary was essentially undisturbed, eelgrass is reported to have been growing over two-thirds of the 80 ha (2000 acre) estuary (Narver, 1972). The major environmental change which was considered by Narver to have eliminated the eelgrass community from the middle portion of the delta has been the intensive log booming that began in 1948 and continues to the present. Eelgrass beds presently extend north of the booming grounds where average tidal action prevents the grounding of floating material. The alleged retreat of the eelgrass beds has also been attributed to the deposition of coal washings from the now abandoned coal workings in the area and to changes in sedimentation rates and patterns as a result of clearcut logging of most of the watershed (Can. Dept. Env., 1974). Trethewey (1974) has suggested that increased accretion of sediments on the delta has raised the substrate level above that suitable for eelgrass.

Eelgrass beds were reported to have been declining in abundance during the spring of 1950, particularly in the Cowichan and Nanaimo-Ladysmith areas (Stevenson, 1950). It was considered at the time that the abnormally cold winter and late spring had retarded growth and in some areas actually frozen higher intertidal plants on their leafy portions. However, by May growth again appeared to be normal, and no plants appeared diseased.

Existing beds may be arbitrarily divided into three units which have been surveyed in a preliminary manner (see Table 8.1). The eelgrass beds extend to approximately 10.5 m (32 ft.) depth along the delta front (D. Goodman, Fisheries Operations, pers. comm.). Eelgrass within the present study area generally appears to have been increasing in abundance in the past few years (E.E. Epps, pers. comm.). This improvement is a general

observation by the Area 17 federal Fisheries Officer (E.E. Epps) but has not been quantified or documented.

Table 8.1 Location, area and abundance of three main units of eelgrass in the Nanaimo River estuary (Trethewey, 1974).

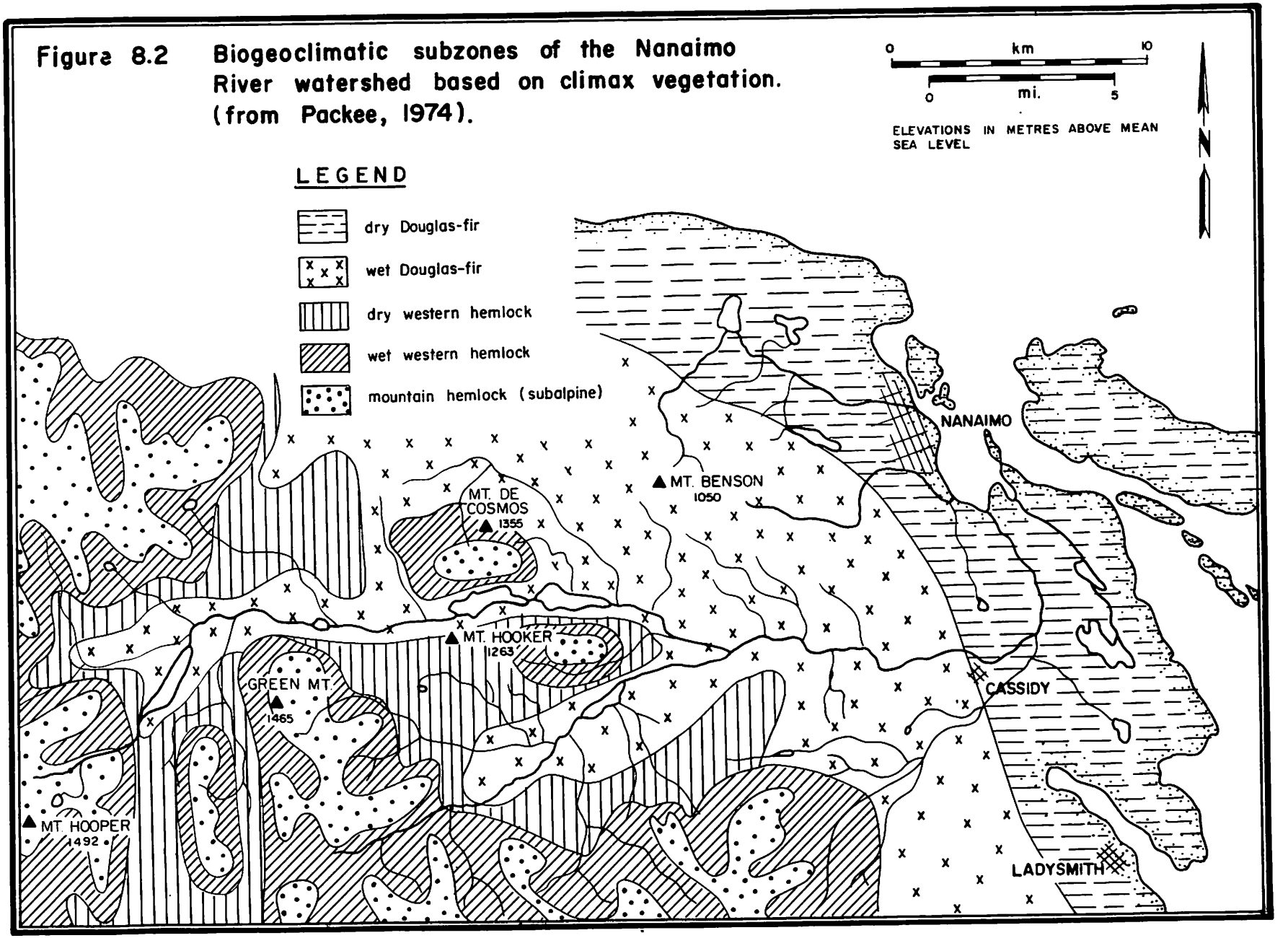
Location	Approximate Area hectares (acres)	Abundance, (blades/m^2)
Western estuary	1.4 (34)	15
Central estuary	2.8 (71)	38
Eastern estuary	1.1 (28)	18

Extensive eelgrass beds are known to occur in the False Narrows area southeast of Northumberland Channel. The central portion of the Duke Point lagoon is also vegetated by an extensive, permanently submerged eelgrass bed (Can. Dept. Env., 1974).

8 (iii) TERRESTRIAL VEGETATION

The biogeoclimatic subzones, as characterized by climax communities, of the Nanaimo River watershed are depicted in Figure 8.2. A brief description based on Packee (1974) of the characteristics of each subzone follows. Forest associations found on the east coast of Vancouver Island (Krajina and Spilsbury, 1953) were summarized in the Cowichan-Chemainus report (Bell and Kallman, 1976).

The Douglas-fir dry subzone, bordering the Strait of Georgia is the warmest and driest within the map area. The forests of the subzone range from dry, open oak woodlands to closed-canopy forests of Douglas-fir and, in seepage areas, of western red cedar (*Thuja plicata*) and grand fir (*Abies grandis*). Typical indicator species include garry oak (*Quercus garryana*), Rocky Mountain juniper (*Juniperus scopulorum*), manzanita (*Arctostaphylos columbiana*), poison oak (*Rhus diversiloba*), and prickly pear


Figure 8.2 Biogeoclimatic subzones of the Nanaimo River watershed based on climax vegetation. (from Packee, 1974).
0 km 10
0 mi. 5
ELEVATIONS IN METRES ABOVE MEAN SEA LEVEL
N
LEGEND
dry Douglas-fir
wet Douglas-fir
dry western hemlock
wet western hemlock
mountain hemlock (subalpine)
NANAIMO
MT. BENSON 1050
MT. DE COSMOS 1355
MT. HOOKER 1263
GREEN MT. 1465
CASSIDY
MT. HOOPER 1492
LADYSMITH

cactus (*Opuntia fragilis*).

The Douglas-fir wet subzone encompasses most of the Nanaimo River watershed. There are no known species endemic to this subzone; however, Douglas-fir is the characteristic dominant. Arbutus (*Arbutus menziesii*) and grand fir are common, particularly below 305 m (1000 ft.) asl. Western hemlock (*Tsuga heterophylla*) may occur as a climax species in well watered areas; however, it is generally found in the understory owing to its intolerance of drought conditions.

McMinn (1960) described the influence of water relations of forest distribution in the Douglas-fir zone found in the Nanaimo River valley. Since there is little rainfall during the growing season in this region, soil moisture regimes were found to be highly dependent on moisture-storage capacity of soil profiles and the extent of influence of seepage. Species representation and the abundance and vigor of plants on valley hillsides seemed to reflect the sequence of soil-moisture regimes controlled by these factors.

The western hemlock dry subzone, found in upper watershed areas, is an intermediate between the wet Douglas-fir subzone and the wet western hemlock or mountain hemlock subzones. Climax vegetation is dominated by western hemlock, but varies according to elevation and wetness. In the drier, lower elevation portion of the subzone, species indicative of the Douglas-fir biogeoclimatic zone, such as arbutus, grand fir, oceanspray (*Holodiscus discolor*) and red-flowering currant (*Ribes sanguineum*), frequently occur. In the wetter portions or at higher elevations species indicative of the wet hemlock subzone or mountain hemlock zone are present.

The wet western hemlock subzone forest climax consists of amabilis fir (*Abies amabilis*), western hemlock and western red cedar. Western red cedar is particularly dominant in drier

areas where a thin soil mantle overlies bedrock. The mountain hemlock (subalpine) biogeoclimatic zone, found on the peaks surrounding the watershed, is characterized by amabilis fir and mountain hemlock (*Tsuga mentensiana*). Yellow cypress (*Chamaecyparis nootkatensis*) is found in increasing amounts as elevation exceeds 1000 m (3300 feet) asl and alpine fir (*Abies lasciocorpa*) also occurs on some of the higher peaks. Productivity is low and decreasing with increasing altitude.

For an annotated list of plant species found on Saanich Peninsula, which is considered representative of the Douglas-fir zone of the present study area, the reader is referred to a B.C. Provincial Museum publication by Szczawinski and Harrison (1972). Forest cover maps (B.C. Dept. of Lands, Forests and Water Resources, 1947-48, 1970) detailing forest types, timber volume, land compartments and other miscellaneous information are available for the Nanaimo River watershed. Only those lands for which the Forest Service retains cutting rights are annotated; however, both the 1947-48 and 1970 versions are available. Most of the Nanaimo watershed is owned by logging firms (MacMillan Bloedel, Crown Zellerbach) who retain tree farm licences.

9. WILDLIFE

The Nanaimo River estuary, the largest on Vancouver Island, is an extremely important waterbird overwintering and staging area. It is an important component of the Fraser River and east coast Vancouver Island estuary complex, the vital feeding and marshalling area of the millions of migrant birds of the Pacific flyway. On a more local scale, the estuary, in conjunction with surrounding lakes, marshes and fields, provides an adequate habitat complex for thousands of overwintering birds and lesser mammalian, amphibian and reptilian populations.

A Canadian Wildlife Service survey (Vaudry and Land, 1973) of bird distribution and abundance on the estuary from October, 1972 to December, 1973 forms the basis of the following discussion. This survey was conducted as part of the investigation into the Nanaimo port alternatives and was previously summarized by Trethewey (1974).

9 (i) WATERFOWL

The British Columbia Land Inventory rates the Nanaimo harbour, estuary and river area as being important migration and/or wintering areas for waterfowl, but not important for waterfowl production (Class 3M) (B.C. Waterfowl Capability Manuscript Map 92G/4). Many thousands of waterfowl winter or stop in the Nanaimo area, but most species migrate to nesting grounds further north for the spring and summer. Waterfowl production on the estuary is therefore minimal and this may in part be attributed to higher and fluctuating water levels during the nesting season.

Dabbling ducks, geese and swans were most often observed on the marsh and adjacent mudflats on the southern end of the estuary (see Figure 9.1). The southwestern portion, which receives

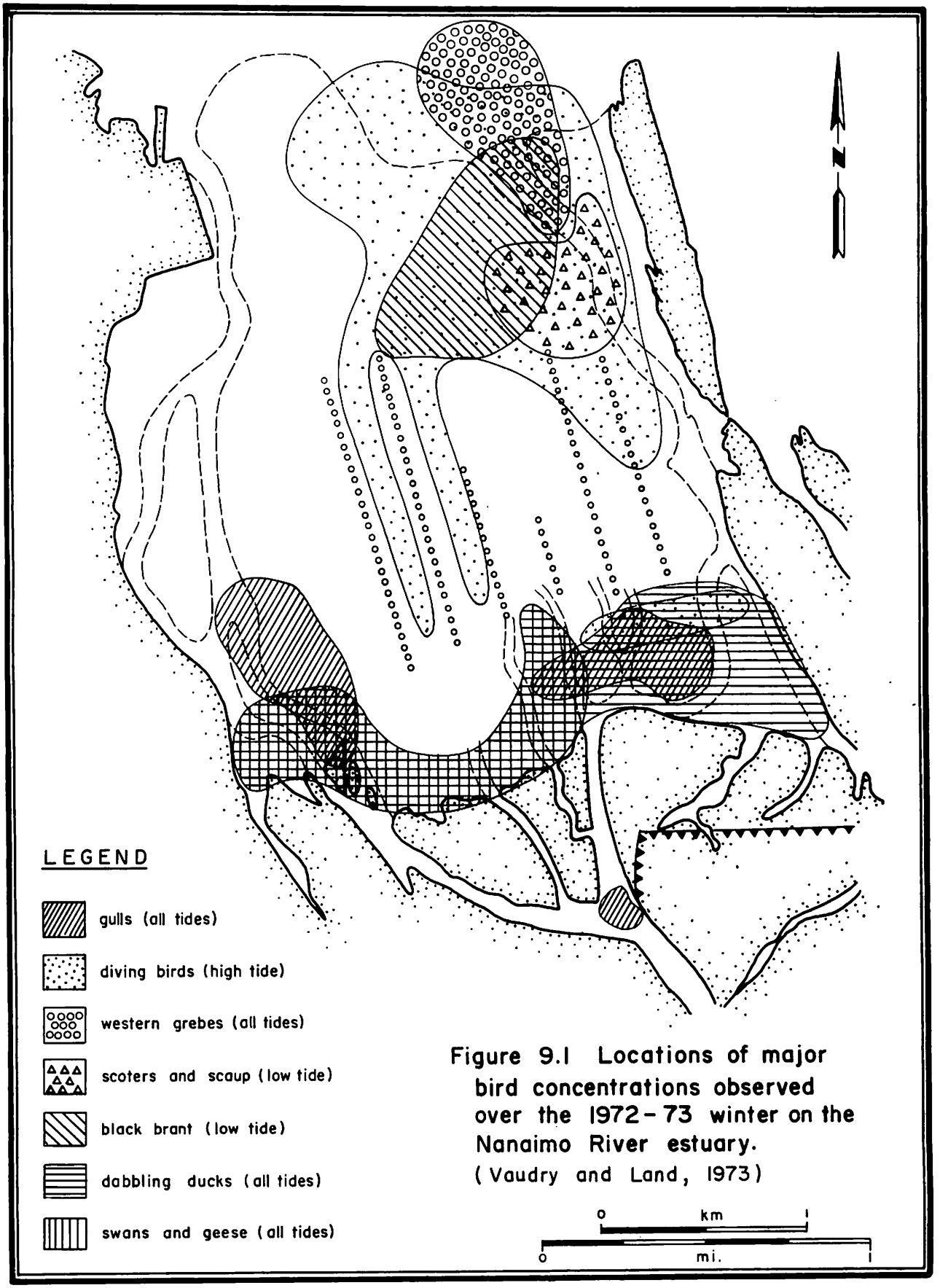


Figure 9.1 Locations of major bird concentrations observed over the 1972-73 winter on the Nanaimo River estuary. (Vaudry and Land, 1973)

freshwater input from the Nanaimo and Chase Rivers and Hong Kong Creek, is most extensively utilized by these birds. Here they feed near the tideline in pools left by the receding tide. American widgeon (*Anas americana*) were most common, comprising nearly half of the dabbling duck observations during the winter of 1972-73 (Vaudry and Land, 1973). This may largely be due to food preference, as sea lettuce (*Ulva* spp.) which is abundant on the estuary (Foreman, 1975), is a preferred food of this species (Munro, 1949). Pintail (*A. acuta*), mallard (*A. platyrhynchos*), and green-winged teal (*A crecca*) were also numerous and frequently observed. Gadwall (*A. strepera*), European widgeon (*A. penelope*) and northern shoveler (*A. clypeata*) were less common and infrequently observed.

Dabbling ducks (Anatinae) generally prefer freshwater feeding habitat (Godfrey, 1966) and the major factor affecting species composition and numbers on the estuary is the condition of surrounding lakes and fields. Prior to heavy winter rains, which flood low-lying agricultural fields, large numbers of dabblers are observed on the estuary. Numbers decline as preferred habitat becomes available. However, when winter cold spells freeze or cover freshwater habitats with snow, the food resources of the estuary are critical for survival. Vaudry and Land (1973) noted large influxes of birds during two such spells in the winter of 1972-73. Narver (1972) reported similar observations for the 1968-69 and 1971-72 winters when most ducks in the surrounding area congregated on the estuary.

Canada geese (*Branta canadensis*), trumpeter swans (*Olor buccinator*) and whistling swans (*O. columbianus*) utilize habitat similar to dabblers, and are equally dependent upon estuaries during cold weather, as is evidenced by the fact that the greatest number of swans observed on the estuary during the 1972-73 winter (26 on December 5) coincided with a cold spell. An average of 14 swans per day were observed on the estuary from December through February and they kept largely to the western portion of the marsh

(see Figure 9.1). Smith and Blood (1972) reported that all major swan overwintering areas on Vancouver Island, with one exception, centered on estuaries and that Nanaimo may be considered a major overwintering area. Their evaluation was based on the fact that 51 swans were seen on the estuary during the winter of 1970-71. Efforts to establish a local stock of Canada geese have met with success, as a small flock circulates around feeding areas in the Nanaimo area (S. Devereaux, Fish and Wildlife Branch, pers. comm.). Vaudry and Land (1973) reported 9 geese per day over January and February and 4 per day in March of 1973. Narver (1972) reported that 12 flocks (about 300 birds) of migrating Canada geese and 4 flocks (about 200 birds) of migrating snow geese (*Chen caerulescens*) were observed on the estuary in October, 1966.

Black brant (*Branta bernicla nigricans*) rely on eelgrass (*Zostera* sp.) and to a lesser extent sea lettuce (*Ulva* spp.) for a major portion of their diet (Einarsen, 1965). Brant were observed on the estuary in April and May during their northward spring migration when an average of 137 and 32 brant, respectively, were observed daily. The maximum number observed on one day was 311 which occurred on April 17 (Vaudry and Land, 1973). They occurred only on the outer one third of the estuary and only during tides low enough to expose portions of the eelgrass beds (see Figure 9.1). Historically, brant occurred in greater numbers on the estuary (Narver, 1972). Their numbers were apparently correlated with the amount of eelgrass present (see Flora Section).

The northern or outermost portion of the estuary provides habitat extensively utilized by diving ducks (see Figure 9.1). Diver concentrations depended largely on the state of the tide and the birds were readily displaced to other parts of the estuary or to islets in Stuart and Northumberland channels by boating or booming activity. The diet of these birds consists of small fish, molluscs and crustaceans which abound in the outer estuary. Concentrations of approximately 800 (April-May) scaup

(*Aythya marila, A. affinis*) 560 (February) scoters (*Melanitta* spp.), 280 (December) goldeneye (*Bucephala clangula, B. islandica*) and 180 (January) bufflehead (*B. albeola*) were seen during the winter of 1972-73 (Vaudry and Land, 1973). Smaller numbers of oldsquaw (*Clangula hyemalis*), harlequin (*Histrionicus histrionicus*) and canvasback (*Aythya valisineria*) were noted in addition.

9 (ii) MARSHBIRDS AND SHOREBIRDS

Marshbirds and shorebirds are abundant on the estuary in the winter months. Vaudry and Land (1973) reported nineteen species (see Appendix 9.1) during their survey from October, 1972 to May, 1973 and these species accounted for one percent of all bird sightings. No data exist at present for mid-to-late summer when most of the southern migrants are passing through the area.

The great blue heron (*Ardea herodias*) hunts in the tide pools and shallows of the estuary when tidal conditions permit. They loafed in groups as large as thirty on log booms on the southeast corner of the estuary when the flats were completely inundated and were most numerous in February when forty-eight were observed at one time (average 34 per day). A number of heronries are located inland in the Cassidy and Extension areas and the subdivision of a parcel of crown land near Extension was halted owing to the proximity of an active nesting site (G.W. Smith, Fish and Wildlife Branch, pers. comm.).

The smaller shorebirds were present yet not observed regularly on the estuary. The largest numbers occurred during prolonged cold weather when freshwater habitats were frozen and/or snow covered. Common snipe (*Capella gallinago*), long-billed dowitcher (*Limnodromus scolopaceus*), killdeer (*Charadrius vociferus*), spotted sandpiper (*Actitus macularia*) and black oystercatcher (*Haematopus bachmani*) were observed on the estuary by Vaudry and

Land (1973).

9 (iii) GULLS

Gulls were the most numerous birds observed over the 1972-73 winter on the estuary, as they accounted for over 40 percent of the total bird sightings (Vaudry and Land, 1973). Numbers of overwintering gulls increased monthly and peaked in January and February when an average of 2,400 birds were observed per day. Over 4,000 gulls were observed on the estuary on one day in February. Numbers declined thereafter until May when most gulls had departed.

Though gulls were observed throughout the estuary area, they concentrated on and around the log booms in the southwest portion of the estuary, near the Duke Point sewage outfall, at the municipal garbage dump just south of the estuary and at a gravel bar in the Nanaimo River midway between the estuary and garbage dump (see Figure 9.1). Feeding activity centered in the southwestern portion of the estuarine marsh, on the tidal flats at water's edge and at the garbage dump (Vaudry and Land, 1973).

Glaucous-winged gulls (*Larus glaucescens*), California gulls (*L. californicus*) and mew gulls (*L. canus*) were identified during this survey. Glaucous-winged gulls are known to nest on Five Finger Island, Hudson Rocks, Snake Island (Drent and Guiguet, 1961) and along the Gabriola Island sea cliffs (B.C. Provincial Museum, unpublished data).

9 (iv) OTHER WATERBIRDS

Groups of diving birds other than the diving ducks (scaup, scoter, bufflehead, etc.) also utilize the estuary extensively, particularly the outer estuary. The alcid species identified were pigeon guillemot (*Cepphus columba*), marbled murrelet

(*Brachyramphus marmoratus*) and Cassin's auklet (*Ptychoramphus aleuticus*) (Vaudry and Land, 1973). Tatum (1972) describes the pigeon guillemot and marbled murrelet as being common residents and Cassin's auklet as a rare migrant. Pigeon guillemot nesting colonies are found on Five Finger Island, (15 pairs), Snake Island (10 pairs) and the Gabriola Island seacliffs (2 pair) (Drent and Guiguet, 1961, B.C. Provincial Museum, unpublished data). Larger colonies of pelagic cormorants (*Phalacrocorax pelagicus*), 91, 22 and 367 pairs respectively, also nest at these sites. Cormorants are often observed on the water covered portions of the estuary.

Loons and grebes, which nest in freshwater areas move to marine areas to overwinter. Grebes were the second most abundant bird group (after gulls) observed on the estuary during the winter of 1972-73 (Vaudry and Land, 1973). Western grebes (*Aechmophorus occidentalis*) were most abundant, being observed in flocks of up to 900 birds on the northeast portion of the estuary (see Figure 9.1). Horned (*Podiceps auritus*) and red-necked (*P. grisegena*) grebes also overwintered on the northern portion of the estuary. A small number of eared grebes (*P. nigricollis*) and pied-billed grebes (*Podilymbus podiceps*) overwintered on the lower Nanaimo River. Four species of loons (listed in Appendix 9.1) were observed on the estuary over the winter of 1972-73 (Vaudry and Land, 1973)

Though the hooded merganser (*Lophodytes cucullatus*) generally prefers fresh water, both it and the more marine oriented red-breasted merganser (*Mergus serrator*) were seen overwintering on the estuary (Vaudry and Land, 1973). The common merganser (*Mergus merganser*) which also prefers freshwater habitats (Godfrey, 1966) can be seen on the estuary during both their spring and fall migration. These birds feed on small fishes in the estuary.

9 (v) RAPTORIAL BIRDS

Bald eagles (*Haliaeetus leucocephalus*), turkey vultures (*Catharates aura*), osprey (*Pandion haliaetus*), red-tailed hawks (*Buteo jamaicensis*), and short-eared owls (*Asio flammeus*) were all observed on the estuary during the winter of 1972-73 (Vaudry and Land, 1973). Thirteen other species are reported to occur in the Nanaimo vicinity and at least six species bald eagle, Cooper's hawk (*Accipiter cooperii*), goshawk (*A. gentilis*), osprey, peregrine falcon (*Falco peregrinus*) and merlin (*F. columbarius*) nest in the vicinity of the estuary and Northumberland Channel (Trethewey, 1974).

The marshes and fields at the head of the estuary are noted as being most attractive to the birds of prey. However, the bald eagle, the most common raptorial species, is frequently observed hunting over the exposed intertidal flats.

9 (vi) OTHER BIRD SPECIES

Five species of upland game birds are reported to occur in the Nanaimo vicinity. They include the ring-necked pheasant (*Phasianus colchicus*), ruffed grouse (*Bonasa umbellus*), blue grouse (*Dendragapus obscurus*), band-tailed pigeon (*Columba fasciata*) and mourning dove (*Zenaida macroura*) (Trethewey, 1974). These birds occur and support considerable hunter activity throughout the Nanaimo River watershed including the woodlands and farmlands adjacent to the estuary.

Starlings (*Sturnus vulgaris*) and northwestern crows (*Corvus caurinus*) were observed in large numbers, overwintering on the estuary in 1972-73 (Vaudry and Land, 1973). They were observed feeding on the tidal flats particularly around the Nanaimo River.

Many other species of songbird (see Appendix 9.1) are reported from the Nanaimo area. Their abundance and distribution is not well documented and individual species have many diverse requirements. The Nanaimo District Naturalists Club have completed the 1975 Christmas bird count for the Nanaimo area and it is soon to be published in Audubon Field Notes (B. Wilkes, Nanaimo District Naturalists Club, pers. comm.). Over 14,000 individual birds of 101 species were recorded, more than recorded in previous years. Nesting bird counts have also been made in the Nanaimo area for the past three years (P. Van Kerkoerle, Nanaimo District Naturalists Club, pers. comm.).

9 (vii) MAMMALS

There are few data available describing the distribution and abundance of mammals in the study area. A list of mammals, as well as of amphibians and reptiles, occurring or strongly suspected to occur in the study area is included in Appendix 9.1.

Censusing of marine mammals by scientists of the Pacific Biological Station (M. Bigg, PBS, pers comm.) has shown a permanent resident population of approximately thirty harbour seals (*Phoca vitulina*) to occur within a 5-10 miles radius of the estuary. Groups of 20-30 seals may be observed hauling out on the log booms within the estuary. Killer whales (*Orcinus orca*) pass through the study area, moving through Dodd Narrows and past Entrance and Five Finger Islands. Up to 65 whales have been spotted in one day and groups of 15 are not uncommon. Approximately 10 Northern sea lions (*Eumetopias jubata*) frequent the Dodd Narrows area.

River otters (*Lontra canadensis*) and muskrats (*Ondatra zibethicus*) are found along the lower river courses and on the estuary. Townsend voles (*Microtus townsendii*) inhabit the moist fields and sedge meadows of alluvial areas. Other small mammals

known to occur in the area include the deer mouse (*Peromyscus maniculatus*), shrews (*Sorex obscurans, S. vagrans*). American red squirrels (*Tamiasciurus hudsonicus*), raccoons (*Procyon lotor*), and American mink (*Mustela vison*). The house mouse (*Mus musculus*), Norway rat (*Rattus norvegicus*) and roof rat (*R. rattus*) were introduced to the region with the coming of the white man.

Mule deer (*Odocoileus hemionus columbianus*) are known to be present in the Duke Point area and probably occur in the wooded upland areas from Jack Point to Dodd Narrows (Trethewey, 1974). The Nanaimo River watershed supports sizeable populations of mule deer and wapiti or American elk (*Cervus elaphus roosevelti*) as it contains the most extensive low-elevation stands of mature forest of any east coast Vancouver Island watershed (W. Harling, PBS, pers. comm.). Annual winter range surveys are conducted in the south fork of the Nanaimo River by the Nanaimo and District Fish and Game Protective Association (1973 , 1974) to determine critical winter range areas and timbered access corridors. Hunting pressure keeps the animals high in the watershed until late in the season sometimes making access corridors critical for survival. These surveys are conducted in co-operation with MacMillan Bloedel Ltd., Chemainus Division, who own the land and have recommended intensive cutting, and the B.C. Fish and Wildlife Branch. By identifying required areas, proposed cutting plans may be altered to ensure the continued existence of healthy deer populations in the watershed. In addition to the aforementioned studies, the Nanimo Regional Office of the B.C. Fish and Wildlife Branch maintains elk sightings records and conducts aerial elk counts in the watershed. A map of elk distribution as well as data tables (age, sex ratio) is presently being prepared (D. Hebert, Regional Wildlife Biologist, pers. comm.).

On the alpine and sub-alpine areas surrounding the Nanaimo watershed may be found colonies of the relatively rare Vancouver Island marmot (*Marmota vancouverensis*). Their social behavior and ecology is presently being investigated (Heard, in

progr.) and the colony sites are under consideration as ecological reserves. No threat is presently posed, as the colonies are located on private lands owned by MacMillan Bloedel and Crown Zellerbach, who are aware of their existence and have pledged protection (B. Foster, Coordinator of Ecological Reserves, pers. comm.).

9 (viii) WILDLIFE AND HUMAN INTERACTIONS

The Nanaimo River estuary and watershed, which supports a variety and abundance of wildlife, offers considerable recreational value and potential for much more. The waterfowl, game birds and mammals of the area are highly prized by hunters and naturalists alike.

Hunting on and around the estuary is primarily directed towards waterfowl, though pheasant and grouse are also important. An estimated 800 man-days per year are spent hunting on the estuary (Narver, 1972). The Canadian Wildlife Service reported an estimated (minimal) 77 man-days of hunting resulting in a kill of an estimated (minimal) 162 ducks on the three day opening weekend of the 1973-74 season (2 ducks per hunter per day). Klopfenstein (1976) reported an average of 1.9 ducks per hunter per day for the 1975-76 season for those hunters field checked. The hunter bag increased from October to December and the season was relatively poor due to inclement weather. The hunter bag was comprised mainly of widgeon (*Anas americana, A. penelope*), mallard (*A. platyrhynchos*), pintail (*A. acuta*) and green-winged teal (*A. crecca*). Other dabbling and diving ducks, Canada geese, band-tailed pigeon, snipe and crows were also shot.

The city of Nanaimo expanded its city limits in January, 1975 to include the estuary and foreshore, whereupon the area was to be closed to hunting owing to bylaws prohibiting the discharge of firearms (S. Devereux, Fish and Wildlife Branch, pers. comm.).

An intensive enforcement program, similar to the one in effect on the Cowichan River estuary (Devereux and Caskey, 1975), was implemented for the 1975-76 hunting season in order to keep the estuary open for hunting. The auxiliary conservation officer patrolling the estuary reported no major offenses, violations generally resulting from ignorance of hunting regulations, and an improvement in the degree of littering on the estuary over the season (Klopfenstein, 1976).

The Nanaimo watershed supports substantial hunter activity, a measure of which is provided in "Gate Access Records" (B.C. Dept. Rec. and Cons., 1975a,b). In 1975, 186 grouse hunters bagged a total grouse harvest of 144 birds. Opening weekend resulted in a bag of 1 grouse per hunter per day. The 1,422 deer hunters checked (25 check days in the 1975 season) in and out of the Nanaimo watershed, harvested 88 bucks (this is a bucks-only hunting area) and 2 black bears for a hunter-day success rate of 6.2%.

The Nanaimo area has a relatively high hunter density as is evidenced by the large (650 members) and enthusiastic membership of the Nanaimo Fish and Game Club and Protective Association. The club provides trap and range facilities, dog training runs, hunter safety courses, hunter questionnaires and is active in promoting conservation measures.

The Nanaimo estuary and river corridor offer excellent recreation opportunity for natural history groups and photographers. School groups and adult education classes learn about and conduct field trips on the estuary (M. Byrne, Nanaimo Senior Secondary School, pers. comm.). The lower river and estuary is a favourite of canoeists and kayakers because of the abundant wildlife. The Nanaimo District Naturalists Club is a recently formed group (membership 60) that conducts regular outings to the estuary and such activities as Christmas bird counts. No doubt, as this group becomes more established, larger conservation minded projects will be undertaken.

An 18 ha (45 acre) marsh, originally to be infilled, has recently been leased by the B.C. Fish and Wildlife Branch through the National 2nd Century Fund and is to be developed into a wildlife viewing and interpretation/education centre (S. Devereux, Fish and Wildlife Branch, pers. comm.). Buttertub Marsh as it is called (see Figure 1.1), will become an intensive waterfowl production area, thereby enhancing the attractiveness of the region to waterfowl, pending habitat improvement by Ducks Unlimited. Naturalists, senior citizens from the neighbouring senior citizens complex, school groups, tourists and the general public will be able to view and learn about waterfowl first hand and in close proximity.

The Nanaimo Lakes watershed area is an important recreation area. Fishing, hunting, skiing, sightseeing, hiking, berry picking, photography, rock collecting and other recreational pursuits are important uses of the area. The abundant wildlife of the area, no doubt, contributes to its attractiveness.

10. LAND AND WATER USE

10 (i) GENERAL

Three recent reports, two by AVG Management Science Ltd. (1971, 1973), and one by the Regional District of Nanaimo (1970) provide a comprehensive overview of the economy, the patterns of living, and the structure of local government in the Nanaimo area.

The Regional District of Nanaimo, established in 1967, covers an area of just over 204,000 ha (788 sq. mi.) (Statistics Canada, 1973a). It includes approximately 90 km (56 mi.) of the eastern coastline of Vancouver Island, from Deep Bay in the north, to a point about 3 km (1.9 mi.) north of Ladysmith Harbour in the south.

The city of Nanaimo is the dominant community in the Regional District. In January 1975, the city limits were extended to include Starks and Harmac in the south, and up to (but not including) Lantzville in the north (Figure 10.1). This resulted in a ten-fold increase in the land area of the city, from 907 ha (3.5 sq. mi.) prior to 1975, to 9,065 ha (35 sq. mi.) after the redesignation of the city limits (Regional District of Nanaimo - pers. comm.).

The total population of the Nanaimo Regional District (Nanaimo Census Subdivision) was 24,099 in 1951, 33,076 in 1961, and by 1971 had increased to 48,006 (Table 10.1). The population was made up largely from the greater Nanaimo area, which, in 1966, accounted for 29,000 people of the approximately 40,000 living in the Regional District (Statistics Canada, 1967). At that time (1966), 83 percent of the total population of the Regional District, were located within 16 km (10 mi.) of the city of Nanaimo (AVG Management Science Ltd., 1973).

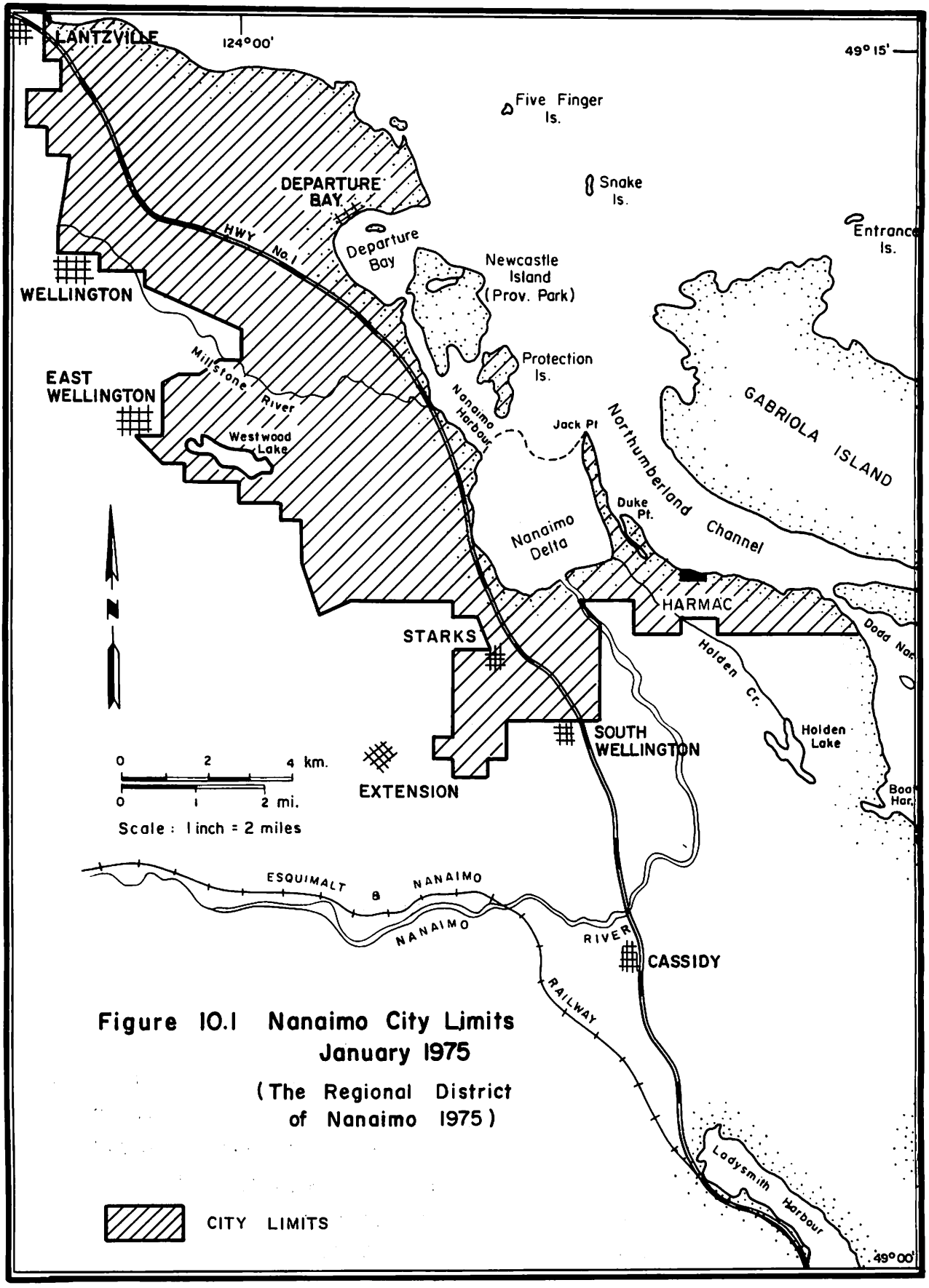


Figure 10.1 Nanaimo City Limits January 1975

(The Regional District of Nanaimo 1975)

The area has shown a relatively steady rate of growth, with the highest recent rate of growth occurring between the 1966 and 1971 census periods, when the rate of growth was 3.9 percent per year. The long-term average growth rate has been calculated at 3 percent per year (AVG Management Science Ltd., 1973).

Table 10.1. Population changes 1951 to 1971 - Nanaimo census subdivision (Statistics Canada, 1973b).

	1951	1961	1971
Subdivision A	10,103	13,279	24,332
Subdivision B	4,750	3,225	4,841
Indian Reserves	397	495	471
City of Nanaimo	7,196	14,135	14,948
Village of Parksville	882	1,183	2,169
Village of Qualicum	771	759	1,245
Total Nanaimo census subdivision	24,099	33,076	48,006

Prior to 1950, coal mining was the primary industry of the Nanaimo area and provided employment for the majority of the local residents. In 1971, tertiary industries (commercial business establishments, utilities and transportation services) provided employment for 64 percent of the population of the region. Forestry and forest products manufacturing, the dominant primary and secondary industries employed an additional 24 percent. Construction (8%), commercial fishing (3%) and agriculture (1%) accounted for the employment of the remaining 12 percent of the working population (AVG Management Science, 1973).

The land and water use pattern in the Nanaimo area has been described by Matheson (1950) and more recently by the Regional District of Nanaimo (1970), and AVG Management Science Ltd. (1971, 1973). Much of the data used in the following subsections are contained in these references.

10 (ii) MINING AND MINERAL RESOURCES

The early use of land in and adjacent to the city of Nanaimo was controlled by the regional geology, and the location of coal seams mined commercially from 1852 to 1953. Coal mining was for more than one hundred years the main industry of the area (Muller and Atchison, 1971). When the last mine closed in the mid 1950's, the Nanaimo mines had produced a total of almost 50 million tons of coal (Robinson, 1965). The relationship of the coal-mining industry to the economic and cultural development of the Nanaimo area has been documented by Matheson (1950). A detailed study of the industry from 1889 to 1929, is being undertaken by the Curator of History, British Columbia Provincial Museum (Gallacher, Ph.D. Thesis in progress).

The type, extent and location of sand and gravel deposits used commercially as a source of aggregate material, have been documented by Leaming (1968). The main deposits occur along the Nanaimo River, from the mouth to a point about 16 km (10 mi.) upstream. Gravel deposits on both sides of the Island Highway north of Cassidy, underlie 1,886 ha (4,600 ac.) and are estimated to contain 122 million m^3 (160 million cu. yd.).

Fifteen pits in the vicinity of Cassidy supply aggregate for a variety of commercial uses, including a ready-mix concrete plant, an asphalt paving plant, road-bed material for the city of Nanaimo and the Department of Highways, and rail ballast for the Canadian Pacific Railway. During 1961, production of sand and gravel from pits in the Nanaimo River valley

was valued at more than $197,000 (British Columbia Minister of Mines and Petroleum Resources, Annual Report, 1961).

Commercially viable deposits of gravel exist in the inner estuary, on the Nanaimo Estuary Farm Property owned by La-Farge Cement Limited, Vancouver (R.D. McGinn - Pers. Comm.). At the present time, however, they are non-removeable under the Provincial Land Commission Act.

Copper was mined in the Nanaimo Region before the first World War. Some $20 million worth was removed south of Nanaimo (AVG Mangement Science Ltd., 1973). Recent mineral deposits discovered in the Nanaimo area are the MacMillan copper-arsenic deposits near the Nanaimo Lakes, and some unidentified gold-quartz veins between Nanaimo and Nanoose Harbour (Carson, 1969).

10.(iii) FORESTRY

Utilization of the forest resources of the Nanaimo Region for buildings and mine timbers commenced at the same time as the establishment of the coal-mining industry in Nanaimo (Matheson, 1950).

Logging operations still exist in the Nanaimo Lakes area, but on a reduced scale. Logging employment in 1971 accounted for only 670 persons (AVG Management Science, 1973). Approximately half of the forest area lies within the boundaries of privately managed tree farm licences. The following is a description of the present B.C. Forest Service control of the forested areas, from a report by AVG Management Science Ltd. (1973).

"The Esquimalt and Nanaimo Railway land grant areas were treated as private land which was sold to various companies for logging, or was logged by subsidiaries of the C.P.R., such

as the Pacific Logging Co., Ltd. The B.C. Forest Service now controls the area, similar to the rest of the Province. Within the Region they have created part of Tree Farm Licence No. 2 (Crown Zellerbach) which covers some 15,540 ha (60 sq. mi.) and part of Tree Farm Licence No. 20 (MacMillan Bloedel) which covers about 10,360 ha (40 sq. mi.). Other areas have reverted to the Crown after they have been logged."

Douglas-fir from the Nanaimo Lowland, and western hemlock from the mountainous regions in the Nanaimo Lakes area, are the main species logged (see Section 8 and Figure 8.2 for further details).

In 1948, seventy-five percent of the cut in the Nanaimo area was third grade Douglas-fir, the remainder being western hemlock (Matheson, 1950). The annual cut of timber in 1973 was 1274 M dm^3 (45 M cu. ft.), and it was estimated that at that rate, there were 10 to 15 years of mature timber left to cut (AVG Management Science Ltd., 1973).

In 1950, construction was completed for the MacMillan Bloedel Limited kraft pulp mill at Harmac, approximately 6 km (4 mi.) southeast of the city of Nanaimo.

The initial capacity of the mill was 250 tons per day of bleached kraft pulp. By 1975, the capacity had been increased to 1250 tons per day, and facilities added to produce 538 M dm^3 (228 MMbm) of lumber a year. In 1975, the MacMillan Bloedel Harmac mill employed 1,200 people from the Nanaimo area and was the largest single employer in the region. A total of 17 million dollars was paid in wages and fringe benefits, contributing substantially to the economy of the area (MacMillan Bloedel Limited, Public Relations Department, Vancouver - pers. comm.).

Three lumber mills (C.I.P.A. Lumber Co., Mayo Lumber Co., and G.W. Dorman Pulp Chip Co.) are located in the Nanaimo

Port area (Figure 10.2). The local forest resources supply only part of the timber for the mills, the remainder being obtained from other areas on Vancouver Island and the west coast of the mainland.

The C.I.P.A. Lumber Co. Ltd., located on the waterfront north of Assembly Wharf, was completed in January, 1960. It has an estimated annual production of 142 million cubic decimetres (60 million board feet) on a two shift basis, and exports solely to Japan (Nanaimo Harbour Commission - report of progress 1961-1970).

The Mayo Lumber Co. Ltd. was established in the early 1960's. It is one of the few land mills on Vancouver Island where logs are taken from the water by machines and fed directly to the mill, as opposed to the jack ladder system of the water-front mills.

The G.W. Dorman Pulp Chip Co. Ltd., is located on Newcastle Channel, and cuts lumber for the South African, Australian and United Kingdom markets.

10 (iv) AGRICULTURE

The use of land for farming in the Nanaimo area is limited by the availability of arable land. Rock outcrops and poor soil limit the extent of land suitable for cultivation. Farms are mainly concentrated in the valley of the Millstone River (East Wellington and Northfield Districts), and the lowland between the Nanaimo River estuary and Ladysmith Harbour. An agricultural capability map, based on the soil capability classification for agriculture (Can. Dept. Env., 1965), has been made for Nanaimo and the surrounding areas (Canada Land Inventory Map 92G/4 Scale 1:50,000). Only about one-third of the Nanaimo Lowland is classified as having arable soils (Robinson, 1965).

The isolated location of the original settlement of Nanaimo, created a demand for produce from local farms. By 1876, there were farmers established in the districts of Wellington, Cranberry and Cedar, the latter being the only community where full-time farming has been a major activity throughout the whole period of its development (Matheson, 1950).

In 1971 there were 286 farms identified in the Nanaimo census subdivision. Of these, 150 were less than 29 ha (70 ac.) (Statistics Canada, 1973c). Dairy farms, livestock (cattle, hogs and sheep), and poultry farms make up the greatest number of farms having annual sales of 2,500 dollars or more. The B.C. Department of Agriculture reported that approximately 30 farmers were actively engaged in dairying in the Nanaimo Regional District in 1970, on more than 1,230 ha (3,000 ac.), with an annual production worth close to one million dollars (AVG Management Science Ltd., 1973).

The following is a description of horticulture and other production from the same report.

"Horticultural crops are grown commercially by approximately 15 growers on an estimated 103 hectares (250 acres), 86 hectares (210 acres) are in potatoes and the balance in cabbage, turnips, carrots and sweet corn. Because of excellent isolation, approximately 45 to 50 percent of the Vancouver Island certified seed potatoes are produced in the Nanaimo Regional District.

Honey production is estimated at $25,000. 15 to 20 percent of the Vancouver Island producers are located in the Region."

10 (v) FISHING

Although not a major industry of the area, commercial

fishing has always provided a livelihood for a small percentage of the population of the Nanaimo region. Nanaimo is the admistrative centre for a fishing district extending from French Creek in the north to Shoal Harbour, near Sidney, in the south.

In 1907, a whaling fleet operated from the Lagoon (Johnson, 1974). Today, some 200 commercial fishing boats operate from the area, fishing mainly in the Strait of Georgia, Johnstone Strait and on the west coast of Vancouver Island (AVG Management Science Ltd., 1973). Local herring catches are of considerable value and are the primary fish resource of the area. Details of the annual catches of the predominant species of fish, shrimps, crabs and shellfish, and their commercial value are summarized in Section 6 (invertebrates) and Section 7 (fish) of this report.

10 (vi) WATERFRONT USES

The Port of Nanaimo and the forest products industry are the principal users of the waterfront adjacent to the city of Nanaimo and the estuary. Newcastle Island Passage provides sheltered waters and an ideal location for such establishments as the Nanaimo Yacht Club, marinas, tank farms for oil transportation companies, ship chandlers and restaurants (Figure 10.2). The western terminal of the Vancouver (Horseshoe Bay) to Nanaimo ferry route is located at the south end of Departure Bay, while the Pacific Biological Station occupies an area of waterfront on the northern side of the Bay.

The Port of Nanaimo, managed by the Nanaimo Harbour Commission, was established in 1961. The Nanaimo Assembly Wharf located at the southern end of the harbour (Figure 10.2), provides 3 deep sea berths, 16 ha (40 ac.) for lumber storage, and 6,038 m^2 (65,000 sq. ft.) of warehouse space. Negotiations are currently underway with MacMillan Bloedel Ltd. to build an additional

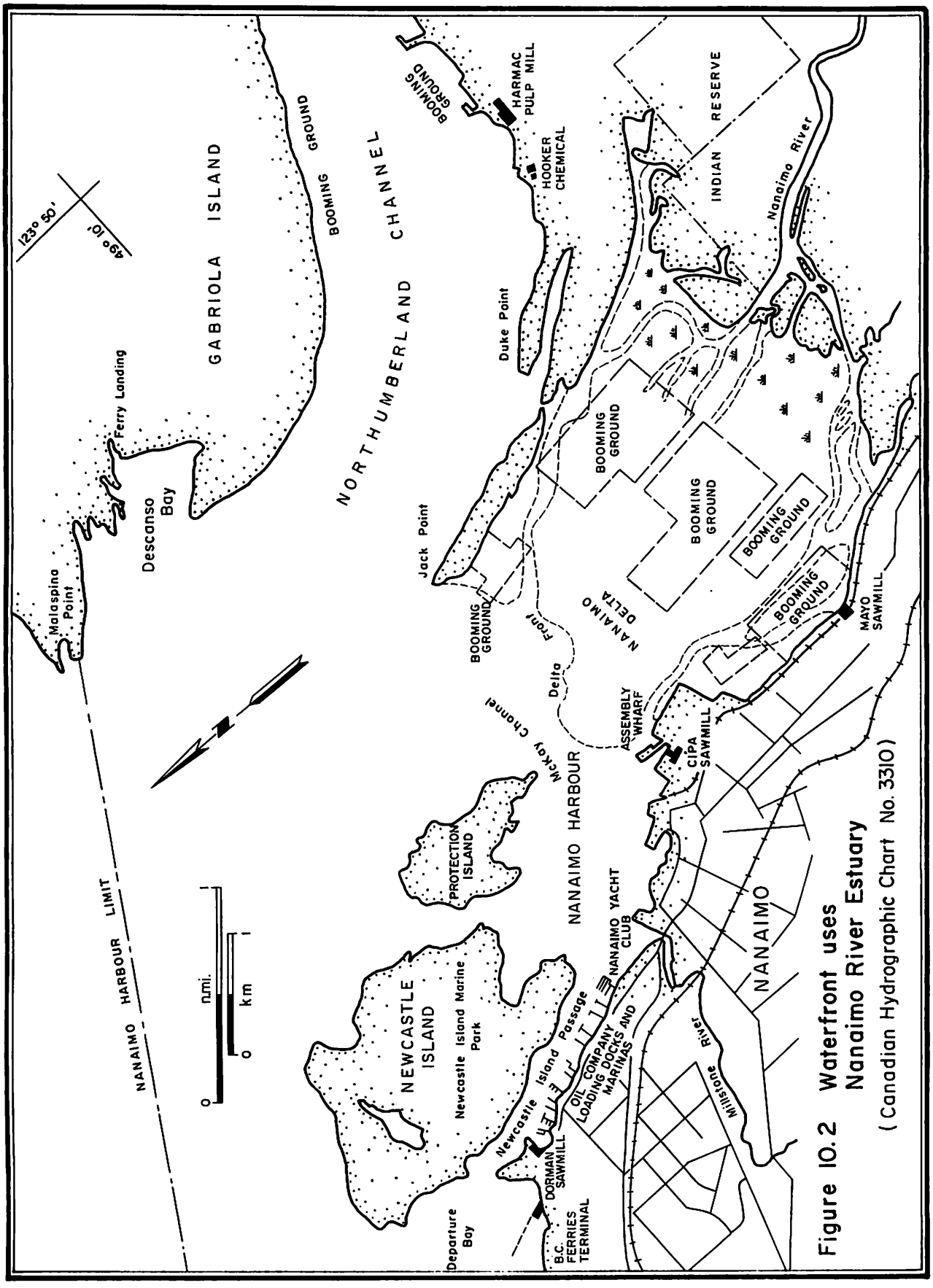


Figure 10.2 Waterfront uses
Nanaimo River Estuary
(Canadian Hydrographic Chart No. 3310)

3,716 m^2 (40,000 sq. ft.) of warehouse space (Nanaimo Harbour News, January 1976). This space will be used for the storage of pulp, newsprint, plywood and aspenite from MacMillan Bloedel and its subsidiaries.

Wood products, lumber and timber, plywood, pulp and paper for newsprint make up the bulk of commodities exported to foreign countries from the Port of Nanaimo. Over one million tons are loaded annually. The tonnages handled for the years 1972, 1973 and 1974 are shown below (Table 10.2).

Table 10.2. Total tonnages (metric) of cargoes handled at the Port of Nanaimo for export and import from foreign countries (Statistics Canada, 1974b, 1975b, 1975c).

	Tonnes Loaded	Tonnes Unloaded	Total
1972	963,465	131,835	1,095,300
1973	1,198,602	71,897	1,270,499
1974	917,137	60,169	977,306

Since 1970, a great deal of interest developed concerning the proposed enlargement of shipping facilities within Nanaimo Harbour. A substantial portion of the Nanaimo River delta was designated for a large forest products shipping terminal (Nanaimo Harbour Commission, 1971). There was sufficient reaction to this proposal that the various federal ministers initiated a coordinated federal response to the public criticism. A special meeting of the Canadian Ports and Harbours Planning Committee, with representation from the Nanaimo Harbour Commission, Environment Canada and other interested groups, was held in Ottawa on January 13, 1973. A case was presented at that time, based mainly on physical oceanographic observations (Waldichuk, MS. 1973), for preference of port development on Northumberland Channel over that in Nanaimo Harbour to minimize pollution and ecological disturbance. A public meeting held by the Canadian Ports and Harbours Planning

Committee in Nanaimo on January 25, 1973, heard among other briefs, one from the Fish and Wildlife Branch of the B.C. Department of Recreation and Conservation (Hatter, MS. 1973), and it was noted that this Branch is responsible, at least in part, for managing fish and wildlife in the Nanaimo River estuary. A plea was made that any plan for development take into account the ecological, economic, aesthetic and biological effects of proposals. The value of the estuary for fisheries and wildlife was detailed with some statistics (Hatter, MS. 1973) and its recreational assets were clearly indicated by the large number of man-days of sport fishing that takes place annually in the river. Arising out of these meetings and through the Directors of the Minister of the Department of the Environment, a Nanaimo Environmental Assessment Task Force was established to study the alternatives for port development (Can. Dept. Env. Lands Directorate, 1974).

Four alternative sites were proposed (Figure 10.3).

1. The Inner Harbour

This site covers 68 ha (165 ac.) and would reduce by approximately one half the seaward edge of the Nanaimo River delta.

2. Jack Point

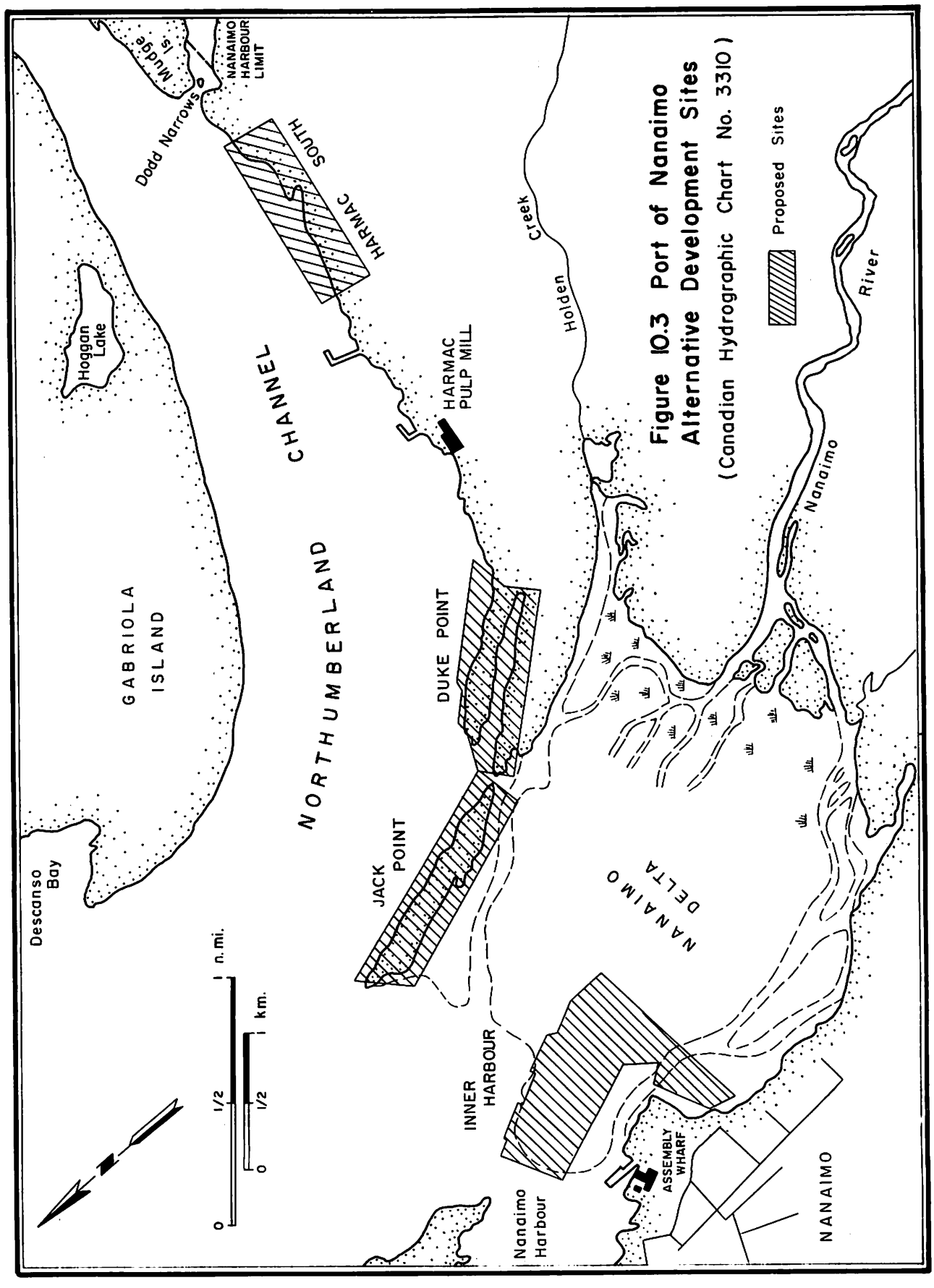
Plans for this site are to level the existing land, to construct a loading dock on the eastern side of the point, and to excavate a dredged barge channel on the western side adjacent to the tidal flats.

3. Duke Point

Two alternatives were assessed for this location. The first requires the dredging of a barge channel through the estuary to deep water, while the second does not.

4. Harmac South

Plans for this site, show the facility occupying the


Figure 10.3 Port of Nanaimo
Alternative Development Sites
(Canadian Hydrographic Chart No. 3310)
Proposed Sites
Mudge Is.
Dodd Narrows
NANAIMO HARBOUR LIMIT
HARMAC SOUTH
Hoggan Lake
CHANNEL
HARMAC PULP MILL
Holden Creek
Nanaimo River
GABRIOLA ISLAND
NORTHUMBERLAND
DUKE POINT
JACK POINT
NANAIMO DELTA
Descanso Bay
INNER HARBOUR
ASSEMBLY WHARF
Nanaimo Harbour
NANAIMO
1 n.mi.
1/2
0
1 km.
1/2
0

area east of Harmac toward Dodd Narrows.

The Duke Point site is currently regarded as the most favourable site for development, taking both economic and environmental factors into account. It is expected that a decision will be made in 1976, whether to construct the facility or not. The Duke Point location will include 49 ha (120 ac.) of land for storage and cargo handling compared to the 16 ha (40 ac.) now available at the Nanaimo Assembly Wharf (Nanaimo Harbour News, January, 1976).

The proposal to construct these facilities aroused a great deal of interest by the public, local and provincial governments and scientists concerned with damage to the environmental quality of the Nanaimo estuary and surrounding area. A summary of those individuals and groups concerned can be found in Section 12 (Effects of Development).

A major use of the estuaries of the British Columbia mainland and Vancouver Island is for log booming and storage (Hoos and Packman, 1974; Hoos and Vold, 1974; Hoos, 1975; Bell and Kallman, 1976). Foreshore leases for log storage in the Nanaimo estuary are controlled by the Nanaimo Harbour Commission. The principal leasees MacMillan Bloedel Ltd., H.R. MacMillan Export Company, and Eureka Sawmills Ltd., occupy approximately 32 percent of the estuary (262 ha) for log storage (Appendix 10.3, Figure 10.4).

For the most recent details on land use leases, the reader is referred to the British Columbia Lands Service, Departmental Reference Maps (Appendix 10.2). These maps are compiled from all available data and are updated as changes occur. They show departmental information, existing surveys and land status, including, Crown granted land, applications to purchase and lease, foreshore leases and timber leases.

For a list of selected maps, charts and aerial photographs of the study area, the reader is referred to Appendix 10.2.

10 (vii) MUNICIPAL SERVICES

The use of land and water for municipal services, such as power distribution lines, sewer and water systems is of grave concern to the local, and provincial government agencies responsible for the control of environmental quality of the areas subject to development.

While this section is intended to portray an overview of the extent of the systems, details of their impact on environmental parameters such as fish, wildlife and the quality of marine waters receiving sewage discharges and other industrial waste, are discussed in other sections of this report.

1. WATER SYSTEMS:

Water supply sources from rivers, aquifers and artesian wells, has already been discussed under Hydrology (Section 4 (iii)) of this report. For a description of the existing water system for the Greater Nanaimo Water District, the reader is referred to the "1968 Water Report" and a "Regional Water Study" (Associated Engineering Services Ltd. (1969, 1972). An up-date of the 1968 Water Report is expected to be complete by mid-1976 (Associated Engineering Services Ltd. - in progress).

The Greater Nanaimo Water District was incorporated in 1953. It included the city of Nanaimo and the districts of North Wellington, Departure Bay, Northfield, Harewood, Petroglyph and S.W. Extension. As of January 1975, these districts were incorporated within the extended limits for the city of Nanaimo.

The present water system commenced with the construction of the South Fork dam in 1931. In 1956 the original 24-inch diameter concrete pipeline to the No. 1 Reservoir was replaced with 30-inch supply line.

The Regional water study carried out by Associated Engineering Services Ltd. (1972), forecast that "By 1975, the available storage in the South Fork Reservoir and the capacity of the primary supply main to the No. 1 Reservoir, will be inadequate to meet the anticipated consumption of the GNWD". The report recommended the construction of an earth fill dam on Jump Creek, with the acquisition of land based on a maximum reservoir capacity of 9.46 Mm^3 (2.5 billion gal). The construction of the Jump Creek dam was completed in the Spring of 1976, thus providing the Greater Nanaimo Water District with the required additional storage capacity.

Stringent measures are maintained for the control of and releases of water from the Nanaimo reservoir system, to provide the necessary water requirements for the fisheries resource of the Nanaimo River system (Can. Dept. Env., 1973a).

2. WASTEWATER DISPOSAL SYSTEMS:

The Greater Nanaimo Sewerage and Drainage District was formed in 1959, and included the city of Nanaimo and the districts of Departure Bay, North Wellington, Harewood, and Northfield. In 1972 its functions were taken over by the Nanaimo Regional Districts, under a committee known as the Nanaimo Regional Sewer Authority.

A description of the existing sewerage facilities for the city of Nanaimo and the Nanaimo Regional District is contained in a report by Dayton and Knight Ltd. (1972). This report investigates the adequacy of existing facilities, reviews the principles of liquid waste disposal, discusses ocean disposal and design

criteria, and presents alternative plans and recommendations for wastewater disposal within the Regional District.

10 (viii) RECREATION

The use of the natural resources of the Nanaimo area for parkland and recreational facilities has been a prime concern of the citizens of the city of Nanaimo since its incorporation. Nanaimo has attained prominence as the Bath Tub capital of the world, attracting international competition in an annual race for motorized bath tubs, from Nanaimo to Vancouver, a distance of almost 50 km (30 mi.) across the Strait of Georgia. Green Mountain, 1466 m (4808 ft.) above sea level and 32 km (20 mi.) southwest of Nanaimo, provides a winter-sports area with good skiing facilities.

Prior to 1958, parks in the city were administered by the Engineer's office and maintained by the City Works Department. In 1958, the Civic Properties and Recreation Commission was formed for the programming of recreation facilities and parks. The Commission was renamed the Nanaimo Parks and Recreation Commission in 1969 (Regional District of Nanaimo, Report on Organized Recreation, 1969).

Maps showing the locations and classes of parks in the Nanaimo Regional District are available from the British Columbia Department of Recreation and Conservation, Parks Branch in Victoria. The British Columbia Provincial Park Act 1965, c31, s.1 (B.C. Dept. Recreation and Conservation, 1965) defines, amongst other terms, natural resources, parks and recreation areas, in the context of land use. The duties of the Provincial Parks Branch, the establishment of parks, park categories and protection of parks are also outlined in the Act.

There are 41 parks in the Nanaimo Regional District

totalling 1581 ha (3,904 ac.). Of these 11 are provincial parks representing 1358 ha (3,352 ac.). A detailed list of these parks and facilities provided is contained in Appendix D of a report on "Patterns of living in the Nanaimo Regional District" (AVG Management Science Ltd., 1971).

Bowen Park, located near the Nanaimo city centre is the largest of the parks within the city limits. At the western end of the park, a waterfowl sanctuary has been established, by the provincial Fish and Wildlife Branch, on 18 hectares (45 acres) of Buttertub Marsh on the Millstone River. See also, reference in Section 9 - Wildlife.

Two of the largest provincial parks in the region are Newcastle Island and Petroglyph Park. Newcastle Island, a 284 ha (700 ac.) island in Nanaimo Harbour, provides camping facilities, swimming and picnicking areas, and boat moorings. Access to the mainland is by ferry and no cars are allowed on the island. Petroglyph Park, a class 'A' park (B.C. Dept. of Rec. and Cons. Park Act, 1965), is located on the southern outskirts of Nanaimo adjacent to the estuary. It is on the site of prehistoric petroglyph carvings attributed to the original inhabitants of the northwest region of British Columbia.

With an increasing use of coastal waters of the Gulf Islands and the east coast of Vancouver Island, Nanaimo provides the sports fisherman and recreational boater with a wide variety of facilities. Five marinas are located in Nanaimo Harbour, the locations and facilities available are shown on the Strait of Georgia, small craft chart #3310, Victoria Harbour to Nanaimo (Canadian Hydrographic Service, 1973).

In 1973, a survey was made of the number of recreational boaters using the Strait of Georgia, including the southeastern coast of Vancouver Island (Mos and Harrison, 1974). The main

purpose of the survey was to provide baseline data pertaining to the number, value and use of privately-owned recreational boats, as previously reviewed in the Cowichan-Chemainus estuary study (Bell and Kallman, 1976). A summary of the participation in recreational boating by Nanaimo-Gabriola Island residents in 1973, showing numbers of types of boats and types of activity, is shown in Appendix 10.1.

Archeological sites in the Nanaimo area are described in a report of the archeological survey of the southwestern Gulf of Georgia (Acheson, Cassidy and Claxton, 1975). The type of sites and locations are described, as well as the degree to which they are being threatened by natural erosion or industrial and residential development. The report recommends that sites threatened by the possibility of port development in the vicinity of Harmac, should be watched carefully for possible preservation. It was also recommended that priority be given to sites threatened with a rapid rate of erosion, such as those on Protection Island and in the Cedar District.

The use of the Nanaimo River estuary and surrounding areas for recreational fishing and hunting is described in detail in Section 7 (fish) and Section 9 (wildlife).

11. POLLUTION

11 (i) WATER POLLUTION

Water pollution control is administered largely under Section 33 of the Fisheries Act federally and under the B.C. Pollution Control Act provincially. Pollution from ships, particularly oil pollution, is controlled through the federal Canada Shipping Act. The Ocean Dumping Control Act regulates the dumping of all materials for the purpose of disposal, including dredge spoils, into the sea. Various other pieces of federal and provincial legislation, as well as municipal bylaws control specific aspects of environmental pollution (Shaw and Reuben, 1974). For a review of legislation affecting the environment of British Columbia the reader is referred to Ince (1976).

The Environmental Emergency Branch (EEB) of the Environmental Protection Service is producing resource maps, which include the present study area, as part of the oil and chemical spill countermeasures series. These maps inventory some of the existing resource information and are compiled to aid in initial decision making and contingency planning in the event of an environmental emergency.

Water quality data for the rivers and creeks of the present study area are limited to the Nanaimo River only. It is significant to note that Nanaimo River water requires no treatment prior to being used in the pulping process at Harmac (S.M. Schofield, pers. comm.). Data collected during the period 1968 to 1971 for the Nanaimo River at the Harmac pumphouse below the Highway No. 1 bridge near Cassidy (Station No. 00BC08HB0001) are available in published form (Can. Dept. Env., 1974b). More recent monthly (until 1973) and quarterly (ongoing) data are available from the Water Quality Branch, Pacific and Yukon Region,

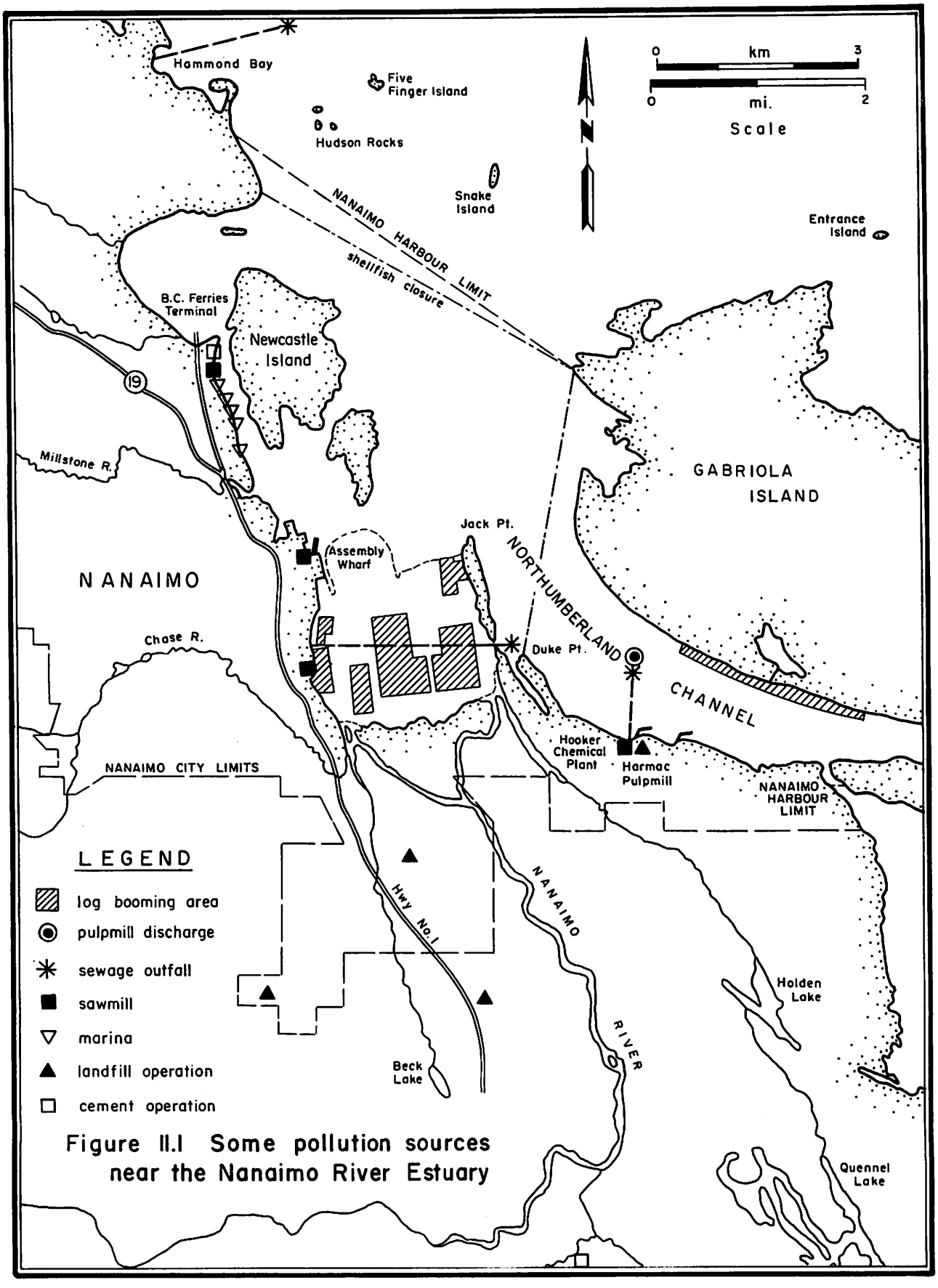


Figure II.1 Some pollution sources near the Nanaimo River Estuary

Inland Waters Directorate (W.E. Erlebach, IWD, pers. comm.). A short intensive water quality survey of the Nanaimo, Cowichan and Campbell rivers was conducted in 1973 as part of a large station evaluation program (Can. Dept. Env., unpublished data). This survey revealed that the routine sampling referenced above does not furnish a complete water quality picture, but serves merely as an indicator of gross changes, owing to temporal and spatial variation in water quality parameters.

For a description of water quality investigations in Northumberland Channel, as they apply to Harmac pulp mill pollution (Waldichuk, 1965; Beak, 1970a,b; Assoc. Eng. Serv. Ltd., 1973; H. A. Simons (International) Ltd., 1973; Melville, 1973, 1974; Ketcham, 1975), see the Pulp Mill subsection of Pollution. Water quality investigations related to the discharge of domestic sewage (Tully and Waldichuk, 1953; Waters, 1975 a,b,c; Arney and Kay, 1975) are discussed under that subsection.

Monitoring of effluent quantity and quality is often stipulated when B.C. Pollution Control Branch (PCB) effluent permits are issued. Computerized results of testing by both the permittee and PCB personnel, as well as permit listings, are available upon request from the PCB head office in Victoria. Major dischargers, such as Harmac are required to monitor their effluent in accordance with federal guidelines and submit their results to the Pollution Abatement Branch of the Environmental Protection Service.

1. DOMESTIC SEWAGE:

Prior to 1958, raw sewage was discharged directly into Nanaimo Harbour from three outfalls located at Assembly Wharf, behind the Malaspina Hotel and at the southern end of Newcastle Island Passage. Visible evidence of sewage all along the city waterfront and need for updated facilities resulted in the construction of two new outfalls for comminuted, raw sewage. The new

outfall located off the northeast coast of Newcastle Island served the northern half of Nanaimo and the other, discharging into Northumberland Channel just off Duke Point, served the southern half (Tully and Waldichuk, 1953).

During the late 1960's, provincial government policy required that discharges of untreated wastes to confined shorewaters be curtailed, and that municipalities plan for provision of sewage treatment facilities. The Greater Nanaimo Sewerage and Drainage District, established in 1958 but now under the auspices of the Regional District of Nanaimo, commissioned a survey and report (Dayton and Knight, 1969, 1972) and authorized the design and construction of facilities, providing adequate treatment and disposal for 50 years according to the recommended staged plan. The area to be serviced and centrally treated by the Hammond Bay sewage plant will extend from Nanoose Bay to the northern boundary of Ladysmith. Ocean disposal via the Five Finger Island outfall was ultimately considered best, because of the net offshore movement and degree of stratification of these waters (Giovando, 1973).

Water quality and biological monitoring (Waters, 1975 a,b,c) of the Five Finger Island outfall, which became operational in October, 1974, had been somewhat inconclusive. However, no significant change in physical or chemical surface water quality parameters was noted near the outfall. The effects that the waste water may have been having on the receiving area were limited to a local depression of biological activity and an increase in suspended solids levels in the vicinity of the outfall (Waters, 1975c). However, it should be noted that the outfall was discharging 18,000-27,000 m^3/day (4-6 million IGD) of untreated waste without the use of the diffuser during this period. The Duke Point outfall which discharges into the relatively well flushed waters of Northumberland Channel may still be used during peak overflow periods. The discontinued use of the Newcastle Island outfall has resulted in a marked reduction in coliform levels in the

vicinity and an improvement of the intertidal area from a recreational stand point.

A shellfish-growing-water sanitary survey of Gabriola Island and outlying areas (Arney and Kay, 1975) sampled the Five Finger Island area to evaluate the dispersion characteristics of the new outfall. Samples collected (54) did not exhibit significant fecal coliform levels. Samples taken off the old Newcastle Island outfall were also of acceptable water qualtiy. Closures of specific areas around Gabriola Island were recommended and sewage sources identified.

Visual observations of the Five Finger Island diffuser in operation were made during January, 1976. Observations were made from the submersible *Pisces* as part of an EPS water quality surveillance report (see Holman and Packman, Appendix 1.2). Packman (pers. comm.) reported large numbers of squat lobsters (*Munida quadraspina*) as well as rockfish (*Sebastes* sp.) and lingcod (*Ophiodon elongatus*) in the diffuser vicinity. Effluent rose in the water column and was visually dissipated within 10m (30 feet) of the diffuser. Cigarette butts and other litter, which passed through the treatment plant, were scattered abundantly over the seafloor. These diving observations were photodocumented using both still and moving pictures.

The Harmac pulp mill, which employs over 1,000 men on 3 shifts, has recently constructed and made operational a secondary treatment plant for all on-site domestic sewage (N. Eckstein, Harmac, pers. comm.). The treated wastes are then discharged into Northumberland Channel along with the total combined mill wastes via the newly constructed submarine diffuser. Prior to 1976, sewage generated within the mill was discharged raw via the alkaline sewer system. Raw sewage from the laboratory building and main office had separate outfalls and the No. 3 woodroom discharged via a septic tank outfall to Northumberland Channel. Bacteriological sampling in the vicinity of the outfalls was

conducted while the mill was shut down due to a labour dispute. The consequent 90% reduction in domestic sewage discharge no doubt contributed to the acceptable water quality reported for the area (Arney and Kay, 1975). A winter shellfish water quality survey was recommended in this report.

The entire Nanaimo Harbour is presently closed to the taking of shellfish owing to high coliform levels. Possible sources of contamination include landwash from septic systems and discharges from ships, fishing boats and pleasure boats. A winter shellfish water quality survey of the Nanaimo Harbour area has been recommended (Arney and Kay, 1975). This would identify pollution sources and possibly result in changes to the present closure of the area to the taking of shellfish. The Central Vancouver Island Health Unit of the B.C. Health Branch also monitors coliform levels along public beaches, in shellfish beds and near outfalls.

2. PULP MILL:

The MacMillan Bloedel Harmac pulp mill, situated on the west shore of Northumberland Channel, began operation in 1950 and originally produced 318 metric tons of full bleach kraft pulp per day (350 short tons). Production was increased to an average 680 metric tonnes per day (750 short tons) in 1954 and to 1225 metric tonnes per/day (1350 short tons) in 1963. Production averaged 997 metric tonnes per day (1098 short tons) in the first half of 1975 and Harmac remains the largest full bleach kraft pulp producer in B.C.

Mill effluent is discharged into Northumberland Channel, which has been described as a partially mixed tidal channel having relatively rapid replacement of its waters (Waldichuk, Meikle and Markert, 1968) (see Oceanography Section). The large-scale expansion of the mill in 1964, prompted an intensive study of the oceanography of Northumberland Channel to determine flushing

rates and predict the maximum permissible waste discharge that would maintain non-toxic conditions to fish with respect to toxicity and BOD (Waldichuk, 1965). Bioassays using mill effluent (Alderdice and Brett, 1957) were extrapolated to determine a maximum permissible waste discharge. Pulp production of 13,000 metric tonnes per day (14,300 short tons), was estimated to yield this maximum. BOD determinations (Greer, Gillespie and Trussell, 1956) were used to calculate that a maximum average daily production of 11,500 metric tonnes per day (12,720 short tons) would maintain a dissolved oxygen level of 5.0 mg/1. Waldichuk (1965) concluded that no serious oxygen depletion would occur in Northumberland Channel as a result of effluent oxidation, that the net transport was to the southeast and that almost all of the mill effluent leaves through Dodd Narrows.

Process effluents are segregated into acid wastes, alkaline wastes, machine white water, woodroom wastes and fly ash wastes. Combined waste flow was estimated to be 2.8 m^3/sec (44,500 US gal./min.) (Eckstein, pers. comm.). Acid and alkaline wastes are collected in separate sewers and are mixed just prior to being discharged. Prior to the installation of the new submarine diffuser the combined acid, alkaline and fly ash wastes, as well as machine room white water and woodroom effluents, were discharged at the mill foreshore within a double foam retention boom. Wastes are now discharged via a 4-port diffuser running 1140 m (3800') offshore to a depth of 105 m (350'). The deep water discharge is calculated to result in plume trapping above 30 m (90') from November to May and between 40 and 70 m (140-210') from June to October giving adequate dilution, dispersion and evacuation in the predominant currents (H.A. Simons (International) Ltd., 1973).

Monthly monitoring data are collected by mill personnel in accordance with the federal regulation guideline system, and are submitted to the Pollution Abatement Branch of the Environmental

Protection Service. Data include daily production, water usage and operating days, as well as effluent temperature, BOD, suspended, volatile suspended, settleable, and total solids, colour, mercaptans, sulphides and resin acids.

An experiment to determine the effect of kraft mill effluent (KME) on oysters was conducted in 1962 in the Harmac vicinity. Significant reductions in condition factor and growth rate in oysters experimentally planted were noted (Quayle, 1969). Oysters were collected from Malaspina Bay (on Gabriola Island) and Joan Point (Dodd Narrows) and analyzed (Beak, 1970b). Oysters from Joan Point, considered as being within the mill's influence were slower growing and less well nourished than the controls. These observations correlated with field observations.

A number of biological surveys determining the effect of mill effluent on the intertidal biota of the receiving waters using artificial substrates have been conducted. Beak (1970b) reported heavy periodic barnacle mortalities during June and July and poor algal growth at stations approximately 1 km to the west and 2 km to the east of the mill. The four biological surveys conducted in 1972 (Melville, 1973) concluded that there was measurable detrimental effect on intertidal plant and animal life from Duke Point (2 km northwest) to Joan Point (2.7 km southeast). Intertidal areas southeast of the plant appeared most affected, showing measurable decreased speciation and abundance of invertebrates and algae. Effects were also noted at stations on Mudge and Gabriola Islands in the vicinity of False Narrows. A concurrent water quality survey reported no significant changes in physical characteristics other than slight discolouration of surface waters. This biological program was repeated in 1973 (Melville, 1974) with the addition of a diatom survey conducted during and after a two-week shutdown in the fall of 1973. A decrease in overall speciation and a change in dominant diatom species occurred after resumption of mill activity. The 1974 biological survey (Ketcham, 1975) reported no appreciable difference in

receiving water quality from previous years. The results of four routine, in plant, 96 hour, static biossays are included in this report. A 1975 survey of receiving waters was not conducted. However, receiving water quality will be monitored by Harmac and possibly EPS (G. Tanner, pers. comm.) personnel in 1976 to determine the effect of the new disposal method.

Gas volumes and composition from pulp wood degradation at all coastal pulp mills were studied by Werner in 1967. A small waste bed in Northumberland Channel was found to have a low yield (1.87 l/m^2) relative to other B.C. pulp mill sites (Werner, 1968; Werner and Hyslop, 1968a). Some sediments in the Harmac vicinity were analyzed for composition (Werner and Hyslop, 1968b).

The Harmac mill uses a minimum 264,600 m^3 (70 million US gallons) of fresh water a day (S.M. Schofield, pers. comm.), some of which is obtained directly from the Nanaimo River. Summer river flows are augmented by drawdown of a reservoir on Fourth Lake in accordance with the rule curve formula set by the B.C. Water Rights Branch. Close liason is kept with the Federal Fisheries to ensure that the needs of Nanaimo River fishes are met, particularly below the mill pumphouses. Low summer flows can lead to increased competition between juvenile salmonids for food and rearing space, increased predation, and elevated water temperatures (Lill and Hamilton, 1973).

3. LOGGING, LOG HANDLING AND STORAGE:

The Nanaimo River watershed, once heavily forested, has been actively logged since the late 1800's and is now largely covered in second growth in varying stages of maturity. Though the watershed remains the most heavily forested of all eastern Vancouver Island streams, logging has probably contributed to a less stable flow regime. The resultant increases in erosion and sedimentation rates can adversely affect fish production by smothering or dislodging incubating eggs or fry, by disrupting benthic

invertebrates (fish food) and by decreasing organic input essential for fish food production (Hooton, 1974). Qualitative changes in estuarine sedimentation have been suggested. Indians have reported that the flats were once much sandier than at present, particularly prior to logging and coal mining in the watershed. The increase in silt would be expected from logging activities, especially below the series of lakes (Can. Dept. Env., 1974a). Trethewey (1974), suggested that increased deltaic accretion of river sediment loads on the inner and central estuary may have raised the level of the estuary floor, thereby decreasing the amount of suitable eelgrass habitat available.

In a survey of possible effects of logging, conducted in Jump Creek (Nanaimo River watershed) and Wolf Creek (Stamp River watershed), Narver (1972a) reported a considerable reduction in late summer trout standing stock estimates in the logged portions of Jump Creek. However, juvenile coho and particularly steelhead standing stocks in Wolf Creek were greatest in logged sections. Other effects reported included higher stream temperatures, larger fish size (probably related to faster pre-emergent fry growth and earlier emergence) and changes in stream morphology.

The Nanaimo estuary is extensively utilized as a log booming area for the local sawmills (C.I.P.A. Lumber Co., Mayo Lumber Co., and G.W. Dorman Pulp Chip Co.) and the Harmac pulp mill. Booming leases on the estuary and in Northumberland Channel are illustrated in Figure 11.1. Since log booming commenced on the estuary in 1948, bark has accumulated and mixed with sediments forming thick beds in some areas (Can. Dept. Env., 1974). However, the central and outer portions of the estuary are relatively clean of wood debris. Booming activity has been blamed for the destruction of eelgrass over much of the estuary through shading and grounding (Narver, 1972b). Towboat activity is manifested in "striations" of the lower delta, where either propeller wash or dragged logs have gouged the substrate in and near the

largest beds of eelgrass (Trethewey, 1974).

4. CHEMICAL INDUSTRY:

Hooker Chemical Co. is located on Northumberland Channel next to the Harmac plant, produces chlorine and caustic soda, chemicals used in the pulping process, from salt and discharges up to 9,191 m^3/day (2,020,000 IGD) of waste water into Northumberland Channel. The plant went into operation around 1962 and the only recorded fish kills from chlor-alkali plants in B.C. occurred near this plant. The first was recorded in 1964 and was attributed to high chlorine content, apparently as a result of start up problems. A second kill occurred in 1966, again attributed to high chlorine content of the mill discharge. In March of 1969, discharges of residual sodium hypochlorite and possibly caustic soda into Northumberland Channel at a time when tides were unfavourable for rapid dispersion, and fish were in the area, resulted in a reported kill of 20,000 herring. No fish kills have been reported since 1969 (Landucci, 1974). The plant uses material recovery and recycling systems to maintain effluent quality such that surface water chlorine concentrations are less than 0.1 mg/l at all times, near the outfall.

The Stauffer Chemical Co. of Canada have their highly automated salt cake receiving and trans-shipment warehouse at the Assembly Wharf. The facility was constructed in 1957 and receives material from deep-sea vessels. The salt cake is then trucked out to pulp mills in various parts of Vancouver Island.

5. SHIPPING:

Apart from sewage discharges previously discussed, shipping poses a definite oil pollution threat to the estuary and nearby area. Though the waters are patrolled by the Harbour Master, and activities are supervised under the Nanaimo Harbour Commission, numerous oil spills have occurred in Nanaimo Harbour and Departure Bay. In the event of a spill occurring, manpower and

physical resources (boats, booms, gear, etc.) required for the job can be mustered from a variety of sources at short notice, as there is more than $1 million worth of oil spill cleanup equipment on standby in Vancouver, Victoria and Prince Rupert (J. Dunham, Port Manager, pers. comm.).

Pollution by oil from ships is controlled under the Canada Shipping Act. Charges are laid against offending ships and fines levied can range to $100,000. Pollution from oil in tanks on the shore of Newcastle Island Passage is controlled under the federal Fisheries Act, and would be enforced by either Fisheries Operations (Fisheries and Marine Service) or the Environmental Protection Service of Environment Canada.

Bilge pumping may occasionally illegally occur in harbour waters, though out of port, discharge into Strait of Georgia waters would be more likely. No bilge pumping and treatment facilities, which would eliminate a good portion of this pollution threat, presently exist on Vancouver Island (Pond, 1974).

6. CEMENT OPERATIONS:

Ocean Construction Supplies Limited operates a redi-mix concrete plant next to the B.C. Ferries Terminal on Departure Bay. Process rinse waters containing suspended particulates are treated via a settling pond before being discharged.

Lafarge Canada Limited owns a parcel of land which contains the remains of the old Cassidy coal slack pile, which is used as raw material and fuel for the production of cement. Runoff from the property and upstream properties is intercepted by a series of three small holding ponds before being discharged into Haslam Creek. However, because the ponds could overflow during periods of moderate to heavy rainfall (Dayton and Knight 1976; Toporowski, 1976), thereby introducing coal slack and other sediments into Haslam Creek, excavation of the slack pile will

proceed only during dry weather periods (J. Clarke, PCB, pers. comm.). A PCB effluent permit is presently being processed for this discharge.

7. WASTES FROM RECREATIONAL ACTIVITY:

The Nanaimo area supports considerable water oriented recreational activity. Almost one third of the resident population owns a boat (see Appendix 10.1) and Nanaimo is a favourite stop of cruising yachtsmen from the lower mainland and the United States. The Nanaimo Yacht Club and five privately owned marinas can be found along Newcastle Island Passage and Commercial Inlet. They are crowded with pleasure boats throughout the summer. Though onshore facilities are provided at all these locations, some raw sewage and litter inevitably end up in the receiving waters. Fuel and oil are introduced into marine waters through operation of marine motors (outboards in particular) and through spillage.

Hunting has resulted in a considerable amount of spent shot and numerous shell casings littering the estuary. Lead shot can cause fatal lead poisoning when ingested by waterfowl, depending on the state of the bird's nutrition. As little as a single shot can kill a poorly fed bird (B. Harris, CWS, pers. comm.). Shell-casing litter decreased markedly last season, presumably because of hunter awareness and the special enforcement program (Klopfenstein, 1976).

8. STREAM CHANNELIZATION:

It is a natural process for streams to meander and create new channels; however, it does cause problems when private property is being eroded. The River-bank Protection Act provides means whereby owners of property bordering a riverbank, lake or watercourse, artificial or natural, can apply to the provincial cabinet to construct works to prevent the deterioration of riverbanks (Ince, 1976).

In August, 1974, remedial channelization work on a section of Haslam Creek below the Island Highway bridge was carried out by the provincial Water Investigations Branch. The stream was considered prime juvenile salmonid rearing habitat prior to construction. Fish sampling in the stream indicated temporary elimination of fish fauna with subsequent recolonization. Sculpins, unlike coho and trout, appeared most sensitive to stream disruption, probably due to their direct reliance on benthic food resources (Glova, 1974). This section and downstream sections of Haslam Creek are presently being studied experimentally by the provincial Fish and Wildlife Branch to determine the effects that different substrates have on salmonid rearing capacity and fish biomass. Bimonthly sampling (electroshocking) of the stream has been carried out since August, 1974, and is to continue until August, 1977. Unlogged and unchannelized streams are being studied concurrently and it is hoped that information generated by this program will be used in future stream enhancement programs (G. Reid, Regional Fish Biologist, pers. comm.).

The effects of stream channelization are not confined to the given stream section. Channelization increases the stream gradient thereby increasing water velocity and erosion both upstream and down (Funk and Ruhr, 1973). Channel realignments which cut off natural meanders, side channels and sloughs, remove habitats essential to fish production (Bayless and Smith, 1967; Bustard, 1973). Removal of cover in the way of the natural riffle-pool sequence and streamside vegetation is the single greatest factor affecting fish production in streams (Mundie, 1969; Tarplee, Louder and Webber, 1971).

11 (ii) AIR POLLUTION

The most obvious single source of air pollution in the Nanaimo area is undoubtedly the Harmac pulp mill. Emissions are not under permit with the Pollution Control Branch (there are

no emission permits presently in effect for the Nanaimo area). Hydrogen sulphide, mercaptans and other sulphur containing compounds are generally responsible for the notoriety of kraft pulp mills in atmospheric pollution (Waldichuk, 1962). An assessment of the environmental impact of sodium chloride from hog fired power boilers was commissioned by the Harmac division (Envirocon, 1975) and after two years of study (1973 to 1975), the following conclusions were drawn:

Dustfall

1. The total dustfall monitored in all stations external to the mill site does not exceed the British Columbia objective for residential areas.

2. The sulphate and chloride fallouts were higher than background levels along the predominant wind directions of the mill. The chloride fallout from the mill is more significant than the coastal influence within 3.2 km (2 miles) of the mill in the predominant wind direction. The area of influence due to sulphate fallout of the mill covers a wider region than the predominant wind direction. Both sulphate and chloride fallout are reduced to the background level in less than 1.6 km (1 mile).

3. A material balance study indicated that less than 15 percent of chloride emissions from the Harmac mill becomes dustfall within 4.8 km (3 mile) radius of the source. It is concluded that over 85% of the chloride emissions remain suspended in the atmosphere.

Suspended Particulates

1. The total suspended particulates recorded in the study indicated compliance with the level A objective of

the British Columbia Pollution Control Branch for the mining industry.

2. The suspended chloride concentration in the mill vicinity is below 5 $\mu g/m^3$. In the winter, the highest suspended chloride concentration was found at the coastal station arising from storm activities.

Corrosion

The short term corrosion study indicates that the chloride corrosion in the mill vicinity is not significantly different from that observed in a pure marine environment. The sulphate corrosion in the mill vicinity is less than the rate recorded at the CPR Wharf in downtown Nanaimo, owing to the considerable industrial activity in the wharf area.

Vegetation

The vegetation study conducted in the summer showed that there was no visible foliage damage in the Harmac vicinity that could be attributed to the mill activities. Considering visible damage on foliage occurs at a suspended chloride level of 100 $\mu g/m^3$ and measured levels are below 5 $\mu g/m^3$ in the mill vicinity, the vegetation in the local environment of Harmac would be unaffected by the existing chloride in the ambient air.

Soils

Soil analysis surveys conducted during December 1973 and July 1975 concluded that there was to visible effect of sodium chloride accumulation or soil damage attributable to mill activities.

Background

During the background study in the fall of 1975, when the mill was not in operation, it was found that the mill activities did influence the ambient chloride and sulphate levels in the mill vicinity. The range of influence varied widely depending on the direction and distance from the sampling station.

Impact

On the basis of this study, it is concluded that the sodium chloride emissions from the hog fuel boilers at Harmac show no significant impact on the surrounding environment (the reader should note that the power boilers contribute only half of the mill's total sodium chloride emissions).

As there are no emission permits presently in effect for the Nanaimo area with the B.C. Pollution Control Branch, other air pollution sources are not identified in the present report. No ambient air quality monitoring has been conducted in the Nanaimo area by either the B.C. Pollution Control Branch (Gow, pers. comm.) or the Environmental Protection Service (Witsuchek, pers. comm.). The reader is referred to the Climatology Section of this report for a discussion of atmospheric conditions and air pollution potential.

Air pollution control is administered under the Clean Air Act at the federal level and the B.C. Pollution Control Act provincially.

12. EFFECTS OF DEVELOPMENT

The burgeoning city of Nanaimo, situated adjacent to the Nanaimo River estuary, is placing increasingly greater demands on its surrounding natural environment. Some specific effects of development, as applied directly to the estuary, have been discussed in the appropriate sections of this report. This section summarizes the more major effects.

The early development of the Nanaimo area, was controlled to a large extent by coal-mining, the primary industry of the time (Matheson, 1950). The geographical distribution of local coalfields resulted in a changing pattern of population distribution. As mines closed in the north and opened in the south, the mine workers moved accordingly, and when the industry eventually closed in the 1950's, the population distribution changed again. The subsequent establishment of Nanaimo as a major transportation and service centre, resulted in a large build up of population within the city and its environs. Waterfront development resulted in the infilling of portions of the Millstone and Nanaimo River deltas and the Nanaimo Harbour foreshore. Construction of ship berthing facilities and sawmills on the estuary necessitates periodic dredging.

In 1971, announcement of port expansion plans by the Nanaimo Harbour Commission caused concern over the effects of development on the natural resources of the estuary and evoked responses from government agencies, city officials and concerned environmental groups (Can. Dept. Env., 1974; Can. Soc. Env. Biol., 1973; Corp. City of Nanaimo, 1973a, 1973b; Leynard, 1972; Nanaimo and District Fish and Game Prot. Assoc., 1972; Pacific Biological Station, 1973; Secter, 1974; SPEC Nanaimo, 1972; Hatter, 1973). Subsequent research effort, stimulated by the need for further environmental input, brought to light the importance of the estuary to fish and wildlife resources. The environmental assessment of port

alternatives prepared by the Lands Directorate (Can. Dept. Env., 1974) recommended that the inner harbour and Jack Point sites be declared inviolate owing to the serious environmental consequences of their development. Harmac south was selected as the most favourable site with Duke Point as the second alternative.

Domestic and industrial water requirements have conflicted with the requirements of the natural renewable resources of the Nanaimo river system. Water demands have reduced river flows, particularly below the Harmac mill intakes. A proposal to increase water storage capacity for the Nanaimo Water District's primary water supply resulted in a study of Nanaimo River water uses (Can. Dept. Env., 1973). Findings have been discussed in both the Hydrology and Land and Water Use Sections.

The disposal of ever increasing amounts of sewage (discussed in the Pollution Section) necessitated a long-term plan for the Regional District of Nanaimo (Dayton and Knight, 1971, 1972). The construction of the Hammond Bay treatment plant and Five Finger Island effluent diffuser will provide adequate facilities for the next 50 years, according to the recommended staged plan. The new disposal method has resulted in the improvement of water quality along the Newcastle Island (a marine park) and Duke Point foreshores. No deleterious environmental effects are reported around the new effluent diffuser. Secondary treatment facilities have recently (1976) been constructed at Harmac and wastes are discharged with the total combined mill wastes via a submarine diffuser into Northumberland Channel.

The construction of a proposed B.C. Hydro gas pipeline on Vancouver Island would result in a crossing of the Nanaimo River. The effects of such a crossing on the fisheries resource have been assessed and procedures necessary to minimize impact have been documented (Paish, 1974).

A proposal to build an additional berth at the Departure

Bay ferry terminal west of existing berths has caused concern with respect to local herring spawning areas. Dredging required to deepen existing berths, and future increases in ferry and vehicular traffic, also create deleterious environmental effects (Can. Dept. Env., 1975).

13. CONCLUSION

Proposed development on the Nanaimo River estuary prompted investigations into the natural renewable resources of the area. Based on the existing environmental knowledge compiled in this report, the following conclusions are drawn:

1. A federal interdisciplinary task force examined alternatives for proposed Nanaimo port development. To minimize disruption to the natural estuarine ecosystem, the Duke Point site has been selected as the best for future development, based on a compromise of economic and environmental considerations.

2. Log booming and storage is believed to be responsible for intertidal habitat disruption on the estuary; however, no quantitative evidence exists to substantiate this claim.

3. The estuary is one vital link in the life cycle of Nanaimo River salmon, and the continued existence of these fish stocks depends to a great extent upon the existence of a natural estuarine environment.

4. Sewage pollution has led to a ban on shellfish harvesting in the area because of the danger of transmittal of pathogens through consumption of raw or partially cooked contaminated shellfish.

5. The natural flushing seaward of substances introduced into the estuary - harbour area is slow because of the configuration and general topography of Nanaimo Harbour. On the other hand, the rate of flushing in the upper 20 metres of Northumberland Channel is comparatively fast because of stronger tidal currents and more vigorous wind-driven currents and mixing.

6. The food resources of the estuary are critical for the survival of waterfowl over wintering in the Nanaimo area when

severe winter weather freezes or covers freshwater feeding habitats with snow.

7. The control of present use of the river systems for water supply to both the Regional District of Nanaimo and the Harmac pulp mill must be maintained to ensure adequate flows for the resident and migratory fish populations of the river.

8. Primary industry remains a significant factor in the economy of Nanaimo and surrounding areas. Future development will be based on the expansion of secondary and tertiary industries, such as manufacturing, commercial business establishments, transportation, recreation and tourism.

Finally, the use of an integrated interdisciplinary task force to assess the impact of proposed port development ensures the best possible use of existing area resources. Such studies provide useful working documents for government agencies, regional districts, municipalities and industry engaged in promoting and planning development of the natural environment.

14. APPENDICES

Appendix 1.1. Sources of Information

The references and data used in this summary of environmental information on the Nanaimo River estuary were gathered from many sources, particularly the members of the Estuary Working Group. The following is a list of agencies, whose personnel and libraries provided much information and advice, and aided in the compilation of literature.

1. Canada, Department of the Environment

   Environmental Protection Service, Pacific Region
   - Pollution Abatement Branch
   - Environmental Emergency Branch
   - Ecological Protection Branch

   Fisheries and Marine Service
   - Fisheries Management
   - Pacific Biological Station
   - Pacific Environment Institute
   - Southern Operations Branch

   Ocean and Aquatic Sciences

   Environmental Management Service
   - Canadian Forestry Service
   - Canadian Wildlife Service
   - Inland Waters Directorate
   - Lands Directorate

   Atmospheric Environment Service

2. Canada, Department of Energy, Mines and Resources

   Geological Survey of Canada (Coastal and Terrain Sciences)

3. Province of British Columbia

   Department of Recreation and Conservation
   - Fish and Wildlife Branch
   - Provincial Parks Branch
   - Surveys and Mapping Branch
   - Provincial Museum

   Department of Lands, Forests and Water Resources
   - Water Investigations Branch
   - Pollution Control Branch
   - Environment and Land Use Committee Secretariat
   - British Columbia Forest Service

Appendix 1.1. (cont'd).

Department of Municipal Affairs

Department of Industrial Development, Trade and Commerce

Department of Agriculture

Department of Mines and Petroleum Resources

4. MacMillan Bloedel Limited
   Harmac Division
   Forestry Division

5. Environmental and Engineering Consultants

   Associated Engineering Services Limited
   T.W. Beak Consultants Limited
   Dayton and Knight Ltd.
   H.A. Simons (International) Limited

6. B.C. Research, the technical arm of the British Columbia Research Council

7. University of British Columbia

   Institute of Oceanography
   Institute of Animal Resource Ecology
   Westwater Research Institute
   Departments of Biology, Botany, Zoology, Soil Science, Geological Sciences and Geography
   Faculty of Forestry

8. Simon Fraser University

9. University of Victoria

10. Libraries

   University Libraries and Reading Rooms
   City of Vancouver and Municipal Public Libraries
   Vancouver Island Regional Library
   Federal and Provincial Government Departmental Libraries

Appendix 1.1. (cont'd).

11. Nanaimo District Naturalists Club

12. Nanaimo and District Fish and Game Club and Protective Association

Appendix 1.2. On-going research in the Nanaimo River estuary and area.

Arai, M.N. (PBS): Studies of the behavior and feeding of hydromedusae collected from Departure Bay, B.C.

___, and A. Brinckmann-Voss (PBS): Hydromedusae of British Columbia. Bull. Fish. Res. Board Can.

Barraclough, W.E. (PBS): Non-salmonid fishes found in association (as competitors or predators) with Nanaimo River salmonids in the Nanaimo vicinity.

Brown, T. (PBS): Heterotrophic activity on the Nanaimo River estuary. (*In situ* bacterial uptake of labeled sugars).

Conlan, K.E. (U Vic): The biological effects of log dumping and storage in southern British Columbia. M.Sc. Thesis in progress, Biology Dept.

Dept. Geol. Sci. (UBC): Sediment sampling and grain size analysis in conjunction with study of meiofauna of the Nanaimo Delta (Sibert, in progress).

Gallacher, D.T. (UBC): Innovation, efficiency, monopoly, their necessity and relative importance in Vancouver Island's coal industry, 1889-1929 (working title for Ph.D. Thesis in progress).

Groot, K. (PBS): Study of the enhancement potential of the Nanaimo River. Watershed management for salmon enhancement - a case study for a total resource scheme.

Healy, M. (PBS): Distribution and abundance of young salmon from the Nanaimo River in the Nanaimo area in 1975.

Heard, D.C. (UBC): Ecology and social behavior of the Vancouver Island marmot (M.Sc. Thesis in progress, Dept. of Zoology).

Hebert, D. and D. Janz (Fish and Wildlife Branch): Nanaimo River watershed elk sightings map and data tables.

Holman, N. and G.A. Packman (EPS): Water quality and biological investigations in the Nanaimo area during February, 1976. (Sampling stations around Five Finger and Newcastle Islands and in Northumberland Channel).

Kabata, Z. (PBS): Parasite load and fauna of commercially important fishes in the Strait of Georgia.

Kask, B. (PBS): The distribution of plankton with respect to haloclines in the vicinity of the Nanaimo River estuary as sampled from July, 1972 to March, 1973.

Appendix 1.2. (cont'd).

Ketcham, K. (Harmac): 1976 biological monitoring of Harmac receiving waters.

LeBrasseur, R.J. (PBS): Zooplankton observations from March, 1975 to July, 1975 in the Nanaimo area.

___: Micro-zooplankton studies. Availability and significance as food for larval fish in the Nanaimo area, January, 1973 and on-going.

Sibert, J. (PBS): Data record, 55 two boat trawls conducted between Departure Bay and Harmac in June and July, 1973.

___: Meiofauna and sediment analysis on the Nanaimo River delta.

___: Oceanographic studies in the Nanaimo area (drogue studies).

Wards, A.B. (for EPS): Study of existing and historical ocean dump sites in the Pacific region, March, 1976 (draft).

Appendix 1.3. Metric Conversion Factors

ENGLISH UNIT	x CONVERSION FACTOR =	METRIC UNIT
acres	0.40	hectares
acre feet (1 acre-foot = 1 acre x 1 ft.)	1,233.5	cubic metres
cubic feet per second	0.028	cubic metres per second
cunit (100 cubic feet)	2.831	cubic metres
degrees Fahrenheit	5/9 (F-32)	degrees Celsius
fathom (6 feet)	1.83	metres
feet	0.305	metres
feet per second	30.48	centimetres per second
gallons (Imp.)	4.546	litres
gallons (U.S.)	3.785	litres
grains per standard cubic foot	2.188	grams per cubic metre
inches	2.54	centimetres
inches of mercury	3.386	kilopascals (kPa)
knots (nautical miles per hour)	51.444	centimetres per second
miles	1.61	kilometres
miles per hour	1.61	kilometres per hour
nautical miles (Int.)	1.852	kilometres
ounces (fluid British)	28.41	cubic centimetres
ounces (fluid U.S.)	29.57	millilitres
parts per million	1.0	milligrams per litre
pound	0.4536	kilograms
pounds per cunit	0.02	kilograms per cubic metre (solid wood)
quart (British)	1.136	litres
square miles	259	hectares
standard cubic foot per minute (air pollution)	1.2	moles per second

Appendix 1.3. Metric Conversion Factors (cont'd)

ENGLISH UNIT	x CONVERSION FACTOR =	METRIC UNIT
standard cubic foot per minute (water pollution)	0.0005	cubic metres per second
ton (2,000 lbs)	0.9072	metric ton (1,000 kg)

Note: Metric equivalents of measurements for use in hydraulic computations are taken from list on page v in, Environment Canada, Surface Water Data, B.C. 1974, Water Survey of Canada, Ottawa. The common usage of metric units, by the Water Survey of Canada and the United States Water Resources Division is currently under discussion.

Appendix 2.1 Geologic Time Scale

ERA	PERIOD	APPROXIMATE NUMBER OF YEARS AGO*
Cenozoic	Quaternary Recent Pleistocene (Ice Age)	Last 10,000 10,000 to 1,000,000
	Tertiary Pliocene Miocene Oligocene Eocene Paleocene	(Millions) 1 to 13 13 to 25 25 to 36 36 to 58 58 to 63
Mesozoic	Cretaceous Jurassic Triassic	63 to 135 135 to 181 181 to 230
Palæozoic	Permian Pennsylvanian and Mississippian Devonian Silurian Ordovician Cambrian	230 to 280 280 to 345 345 to 405 405 to 425 425 to 500 500 to 600
Proterozoic	Keweenawan Huronian	600 to 2,000
Archæan	Temiskaming Keewatin	2,000 to 4,800

* *Science, April 14, 1961, p.1111.*

Appendix 4.1. Nanaimo River Estuary Streamflow Data (Can. Dept. Env., 1976)

STATION NO.	NAME	GAUGE LOCATION	DISCHARGE RECORDS (Misc. meas.#)
08HB033	Nanaimo River above Rockyrun Creek	49° 05' 02" 124° 23' 53"	63-64 65-68#
08HB005	Nanaimo River near Extension	49° 04' 20" 123° 55' 25"	12# 65# 13-27, 48-64
08HB034	Nanaimo River near Cassidy	49° 04' 07" 123° 53' 13"	49-50# 65-76
08HB003	Haslam Creek near Cassidy	49° 02' 24" 123° 54' 28"	14-15, 49-56 57-62
08HB041	Jump Creek near the Mouth	49° 02' 12" 124° 09' 55"	70-76
08HB027	Millstone River near Wellington	49° 12' 22" 124° 03' 08"	61-64, 65-68# 69-76
08HB032	Millstone River at Nanaimo	49° 10' 38" 123° 58' 04"	61-66

Appendix 6.1.

List of Benthic Invertebrates Observed in the Nanaimo River Estuary in August of 1973 (Can. Dept. Env., 1974).

PHYLUM PORIFERA
- Foraminifera spp.

PHYLUM PORIFERA
- *Haliachondria panicea*

PHYLUM PLATYHELMINTHES
- polyclad worm (*Freemania litoricola*)

PHYLUM NEMERTEA
- *Cerebratulus* sp.
- *Emplectonema* cf. *gracile*

PHYLUM ANNELIDA
- *Axiothella* cf. *rubrocincta*
- *Hemipodus borealis*
- *Mesochaetopterus* sp.
- *Nereis virens*

PHYLUM MOLLUSCA
- Class Amphineura
  - *Mopalia ciliata*
- Class Gastropoda
  - *Collisella pelta*
  - *Haminoea vesicula*
  - *Lacuna porrecta*
  - *Littorina scutulata*
  - *L. sitkana*
  - *Notoacmea scutum*
  - *Thais lamellosa*

Appendix 6.1 (cont'd).

- Class Bivalvia
  - *Clinocardium nuttalli*
  - *Crassostrea gigas*
  - *Cryptomya californica*
  - *Hiatella arctica*
  - *Macoma inconspicua*
  - *M. nastua*
  - *M. secta*
  - *Mya arenaria*
  - *Mytilus edulis*
  - *Protothaca staminea*
  - *Saxidomus nuttalli*
  - *Solen sicarius*
  - *Tresus capax*
  - *Venerupis japonica*

PHYLUM ARTHROPODA

- Class Crustacea
  - Subclass Cirripedia
    - *Balanus glandula*
    - *Chthamalus dalli*
  - Subclass Malacostraca
    - Order Isopoda
      - *Gnorimosphaeroma oregonensis*
      - *Pentidotea wosnosenskii*
    - Order Amphipoda
      - *Anisogammarus confervicolus*
      - *Corophium spinicorne*
    - Order Decapoda
      - *Callianassa californiensis*
      - *C. gigas*
      - *Cancer gracilis*
      - *C. magister*
      - *C. productus*
      - *Hemigrapsus oregonensis*

Appendix 6.1 (cont'd).

Upogebia pugettensis

PHYLUM ECHINODERMATA

Pisaster ochraceus

Appendix 6.2.

List of Benthic Invertebrates Observed in the Duke Point Lagoon in August of 1973 (Can. Dept. Env., 1974).

PHYLUM NEMERTEA
- *Paranemertes* cf. *peregrina*

PHYLUM CNIDARIA
- *Obelia longissima*
- *Plumularia* sp.

PHYLUM ANNELIDA
- *Amphitrite robusta*

PHYLUM MOLLUSCA
- Class Amphineura
  - *Cyanoplax dentiens*
  - *Mopalia ciliata*
  - *Tonicella lineata*
- Class Gastropoda
  - *Anisodoris nobilis*
  - *Bittium* cf. *challisae*
  - *Chioraea leonina*
  - *Collisella pelta*
  - *Corambe pacifica*
  - *Haminoea vesicla*
  - *Lacuna porrecta*
  - *Littorina scutulata*
  - *L. sitkana*
  - *Nassarius mendicus*
  - *Polinices lewesi*
  - *Searlesia dira*
  - *Tachyrhynchus lacteolus*
  - *Thais lamellosa*

Appendix 6.2 (cont'd).

Class Bivalvia
Crassostrea gigas
Entodesma saxicola
Hiatella arctica
Macoma secta
Mya arenaria
Mytilus edulis
Pododesmus macroschisma
Protothaca staminea
Psephidia lordi
Transenella tantilla

PHLYUM ARTHROPODA
Class Crustacea
Subclass Cirripedia
Balanus cariosus
B. glandula
Chthamalus dalli
Subclass Malacostraca
Order Isopoda
Idothea resecata
Order Amphipoda
Caprella cf. *californica*
Order Decapoda
Cancer oregonensis
Hemigrapsus nudus
Hippolyte clarki
Pagurus granosimanus
Pugettia gracilis
Upogebia pugettensis

PHYLUM ECHINODERMATA
Dermasterias imbricata
Pisaster ochraceus

Appendix 6.2 (cont'd).

Cucumaria miniata
Eupentacta quiquesemita
Ophiopholis aculeata
Strongylocentrotus droebachiensis

APPENDIX 7.1.

Nanaimo River Anadromous Fish Escapement Data

(Fisheries and Marine Service, Pacific Region, Vancouver, B.C.)

Species	Years of Enumeration	Average Annual Escapement 1964-1975	Date and Size of Max. Escapement	Date and Size of Min. Escapement	Period of Spawning (Peak Underlined)
SOCKEYE	1937-8 1940-1942 1948-1949 1951 1957-1958 1967-1968	Transient	(1957) 1-50	(Many Years) Unknown	Sept.
CHINOOK	1930-1935 1937-1942 1947-1975	2,125	(1939) 10,000-20,000	(1975) 525	May-Sept.-Nov.
COHO	1930-1935 1937-1942 1947-1975	4,300	(1938) 50,000-100,000	(1968) 800	Aug.-Oct.-Dec.
PINK	1930-1935 1937-1942 1947-1960	None observed after 1960	(1937) 5,000-10,000	(1961-1972) 0	(Sept.-Oct.) No fish after 1960
STEELHEAD	1930-1935 1937-1942 1947-1975	Present but in unknown numbers	(1958) 2,000-5,000	(1964) 1-50	Nov.-Jan.-April
CHUM	1930-1935 1937-1942 1947-1975	35,055	(1950) 100,000+	(1963) 2,000-5,000	Sept.-Oct.-Dec.

Most Recent Max. and Min. Figures Stated in Cases of a Tie.

Appendix 7.2.

List of Fish Species Occurring in the Nanaimo River Estuary Area (Can. Dept. Env., 1974).

1. *Acipenser medirostris* (green sturgeon)
2. *Agonus acipenserinus* (sturgeon poacher)
3. *Ammodytes hexapterus* (Pacific sandlance)
4. *Apodichthys flavidus* (penpoint gunnel)
5. *Artedius fenestralis* (padded sculpin)
6. *A. lateralis* (smoothhead sculpin)
7. *Aulorhynchus flavidus* (tube-snout)
8. *Blepsias cirrhosus* (silverspotted sculpin)
9. *Chitonotus pugetensis* (roughback sculpin)
10. *Citharichthys sordidus* (Pacific sandab)
11. *C. stigmaeus* (speckled sandab)
12. *Clinocottus acuticeps* (sharpnose sculpin)
13. *Clupea harengus pallasi* (Pacific herring)
14. *Coryphopterus nicholsi* (blackeye goby)
15. *Cottus asper* (prickly sculpin)
16. *Cymatogaster aggregata* (shiner perch)
17. *Engraulis mordax mordax* (northern anchovy)
18. *Gasterosteus aculeatus* (threespine stickleback)
19. *Hexagrammos decagrammus* (kelp greenling)
20. *H. lagocephalus* (rock greenling)
21. *H. stelleri* (white-spotted greenling)
22. *Hippoglossoides elassodon* (flathead sole)
23. *Hypomesus pretiosus* (surf smelt)
24. *Lampetra tridentatus* (Pacific lamprey)
25. *Lepidopsetta bilineata* (rock sole)
26. *Leptocottus armatus* (Pacific staghorn sculpin)
27. *Liparis florae* (tidepool snailfish)
28. *Lumpenella longirostri* longsnout prickleback)
29. *Lumpenus sagitta* (Pacific snake prickleback)
30. *Lyopsetta exilis* (slender sole)
31. *Mallotus villosus* (capelin)

Appendix 7.2 (cont'd).

32. *Microgadus proximus* (Pacific tomcod)
33. *Myoxocephalus polyacanthocephalus* (great sculpin)
34. *Oligocottus maculosus* (tidepool sculpin)
35. *O. rimensis* (saddleback sculpin)
36. *Oncorhynchus gorbuscha* (pink salmon)
37. *O. keta* (chum salmon)
38. *O. kisutch* (coho salmon)
39. *O. nerka* (sockeye salmon)
40. *O. tshawytscha* (chinook salmon)
41. *Ophiodon elongatus* (lingcod)
42. *Parophrys vetulus* (English sole)
43. *Pholis laeta* (crescent gunnel)
44. *P. ornata* (saddleback gunnel)
45. *Platichthys stellatus* (starry flounder)
46. *Porichthys notatus* (plainfin midshipman)
47. *Psettichthys melanosticus* (sand sole)
48. *Rhacochilus vacca* (pile perch)
49. *Rhamphocottus richardsoni* (grunt sculpin)
50. *Salmo clarki clarki* (coastal cutthroat trout)
51. *S. gairdneri* (steelhead trout)
52. *Scorpaenichthys marmoratus* (cabezon)
53. *Sebastes caurinus* (copper rockfish)
54. *Squalus acanthias* (spiny dogfish)
55. *Syngnathus griseolineatus* (bay pipefish)
56. *Theragra chalcogramma* (walleye pollock)
57. *Xiphister atropurpureus* (black prickleback)

APPENDIX 7.3.

Annual reported landed values in $000's for Area 17 (compiled from Area Worksheets, Economics Branch, Fisheries Operations, Pacific Region, Vancouver).

Year	Salmon	Herring	Halibut	Sole	Red and Rock Cod	Ling Cod	Grey Cod	Black Cod	Dogfish	Area Total **
1975	401	1,129	1	12	5	64	26	*	18	1,766
1974	901	784	*	7	6	80	35	1	67	2,003
1973	529	614	1	6	5	51	27	2	178	1,663
1972	483	187	*	3	5	44	47	3	3	973
1971	598	41	1	3	4	58	56	2	2	949
1970	228	10	3	3	4	59	14	1	*	463
1969	154	37	*	5	2	28	6	*	*	405
1968	108	26	*	4	3	28	14	*	11	433
1967	126	13	*	5	1	17	17	*	10	442

* nil value

** all species including shellfish

Appendix 7.4. Salmon sport catch, fishing effort and success for tidal waters in Area 17, Ladysmith-Nanaimo (compiled from Salmon Sport Fishing Catch Statistics for B.C. Tidal Waters, Annual Reports 1967-1975, Can. Dept. Env., Fish and Mar. Serv., Pac. Reg.).

Period	Springs	Jacks	Coho	Spring Grilse	Coho Grilse	Pinks & Others	Total	Effort (Boat Days)	Average catch per boat day
1975	2,635	12,325	12,335	8,480	7,555	290	49,625	39,927	1.2
1974	1,970	4,075	27,425	4,170	13,875	435	51,950	33,149	1.6
1973	1,870	3,250	7,420	5,680	12,065	345	30,630	22,225	1.4
1972	3,710	6,145	5,105	6,730	5,415	320	27,425	23,763	1.2
1971	2,305	3,315	29,853	2,590	14,550	103	52,716	28,373	1.9
1970	1,275	2,450	10,600	3,425	13,900		31,650	25,275	1.2
1969	2,950	5,100	10,950	2,850	6,625	100	28,575	26,325	1.1
1968	2,820	4,070	8,480	15,070		160	30,600	20,050	1.5
1967	2,675	3,475	5,700	10,450		150	22,450	19,950	1.1

Appendix 7.5. Steelhead Catch Data for the Nanaimo River (compiled from Steelhead Harvest Analysis, B.C. Department of Recreation and Conservation, 1967-1976).

Year	Days Fished		No. Anglers		Kill		Released		Kill/Day	Catch/Day
	Rept.	Est.	Rept.	Est.	Rept.	Est.	Rept.	Est.		
1974-75	1258	4305	187	640	205	698	107	363	0.163	0.248
1973-74	1106	4522	177	712	182	741	61	248	-	0.165
1972-73	1350	4809	199	716	298	1057	175	620	-	0.221
1971-72	964	3508	168	605	235	836	74	255	-	0.244
1970-71	720	3405	134	601	143	664	21	98	-	0.199
1969-70	1289	7057	177	961	166	910	-	-	-	0.129
1968-69	1473	6608	199	871	305	1341	-	-	-	0.207
1967-68	1116	4507	206	815	309	1235	-	-	-	0.276
1966-67	1416	5446	340	1308	692	2661	-	-	-	0.49

- no value reported
Rept. = reported
Est. = estimated

Appendix 7.6. Steelhead Catch Data for the Chase River (compiled from Steelhead Harvest Analysis, B.C. Department of Recreation and Conservation, 1967-1976).

Year	Days Fished		No. Anglers		Catch		Released		Catch/Day
	Rept.	Est.	Rept.	Est.	Rept.	Est.	Rept.	Est.	
1974-75	-	-	-	-	-	-	-	-	-
1973-74	15	61	1	4	2	8	0	0	0.133
1972-73	-	-	-	-	-	-	-	-	-
1971-72	3	10	3	10	0	0	0	0	0
1970-71	1	4	1	4	0	0	0	0	0
1969-70	6	3	2	11	0	0	-	-	0
1968-69	36	166	13	60	3	13	-	-	0.083
1967-68	35	144	5	20	2	8	-	-	0.057
1966-67	17	65	13	50	4	5	-	-	0.24

- no value reported

Rept. = reported

Est. = estimated

Appendix 8.1.

List of Floral Species Identified from Communities Described on the Nanaimo River Estuary.

(i) INTERTIDAL ALGAE (Foreman, 1975)

Acrochaetium pacificum
Blidingia minima v. *minima*
Cladophora sp.
C. microcladioides
Diatoms
Enteromorpha sp.
E. clathrata v. *crinita*
E. compressa
E. intestinalis
E. intestinalis v. *cylindracea*
E. linza
E. prolifera
E. torta
E. tubulosa
Erythrotrichia carnea
E. parksii v. *minor*
Fucus distichus
F. distichus ssp. *evanescens*
Gigartina papillata
Goniotrichum elegans
Gracilaria verrucosa
Monostroma sp.
M. fuscum
Petalonia fascia
Phaeostrophion irregulare
P. torreyi
Polysiphonia mollis
Porphyra sp.
Pterosiphonia dendroidea

Appendix 8.1 (cont'd).

Punctaria hesperia
Pylaiella littoralis
Smithora naiadium
Ulva sp.
U. expansa
U. fenestrata
U. lactuca

(ii) SEDGE COMMUNITY (Forbes, 1972)

Achillea millefolium (yarrow)
Agrostis palustris (creeping bent-grass)
Alisma triviale (water plantain)
Bidens cernua (bur marigold)
Carex lyngbyei (Lyngbye's sedge)
Chenopodium album (lamb's quarters or pigweed)
Deschampsia caespitosa (tufted hair grass)
Distichlis stricta (seashore saltgrass)
Eleocharis palustris (creeping spike-rush)
Festuca rubra (red fescue)
Glaux maritima (sea milkwort)
Glyceria striata (fowl mannagrass)
Grindelia integrifolia (gumweed)
Hypericum perforatum (common St. John's wort)
Juncus articulatus (jointed rush)
J. gerardii (black grass)
Lysichitum americanum (yellow skunk cabbage)
Phyllospadix scouleri (Scouler's surf-grass)
Plantago lanceolata (English plantain)
P. maritima (seaside plantain)
Potentilla pacifica (Pacific silver cinquefoil)
Sagittaria cuneata (arrowhead or wapato)
Salicornia virginica (glasswort)
Scirpus robustus (saltmarsh bulrush)
Sium suave (hemlock water parsnip)

Appendix 8.1 (cont'd).

Sonchus arvensis (annual sow thistle)
Triglochin maritimum (seaside arrow-grass)

(iii) GRASS AND FORB COMMUNITY (Forbes, 1972)
Achillea millefolium (yarrow)
Agropyron spp. (wheatgrass)
A. repens (quackgrass)
Agrostis spp. (bentgrass)
A. alba (spiked redtop)
Alnus rubra (red alder)
Anaphalis margaritaceae (pearly everlasting)
Arctium minus (common burdock)
Artemisia douglasiana (common wormwood)
Aster eatonii (Eaton's aster)
Athyrium felix-femina (lady fern)
Atriplex patula (common orache)
Bidens cernua (bur marigold)
Brassica spp. (mustard)
Cakile edentula (sea rocket)
Carex lyngbyei (Lyngbye's sedge)
Cerastium arvense (field chickweed)
Cirsium vulgare (bull thistle)
C. undulatum (wooly thistle)
Convolvulus arvensis (small bindweed)
Crataegus douglasii (Douglas' hawthorn)
Cystisus scoparius (scotch broom)
Dactylis glomerata (orchard grass)
Deschampsia caespitosa (tufted hair grass)
Distichlis stricta (seashore saltgrass)
Epilobium angustifolium (fireweed)
Equisetum arvense (common horsetail)
Festuca ovina (sheep fescue)
F. rubra (red fescue)
Glaux maritima (sea milkwort)

Appendix 8.1 (cont'd).

Grindelia integrifolia (gumweed)
Heracleum lanatum (cow parsnip)
Holcus lanatus (velvet grass)
Holodiscus discolor (ocean-spray)
Hordeum sp. (barley)
Hypochaeris glabra (smooth cat's ear)
H. radicata (hairy cat's ear)
Juncus gerardii (black grass)
Lactuca serriola (lobed prickly lettuce)
Lathyrus nevadensis (purple pea)
Matricaria matricarioides (pineapple-weed)
Medicago sativa (alfalfa)
Mentha arvensis (Canada mint)
Phleum pratense (timothy)
Plantago lanceolata (English plantain)
P. maritima (seaside Plantain)
Poa spp. (blue grass)
Polygonum amphibium (water persicaria)
Polystichum munitum (swordfern)
Potentilla pacifica (Pacific silver cinquefoil)
Quercus garryana (garry oak)
Rorippa obtusa (blunt-leaved yellow-cress)
Rubus parviflorus (thimbleberry)
R. spectabilis (salmonberry)
R. ursinus (trailing blackberry)
Rumex crispus (curled dock)
R. occidentalis (western dock)
Salicornia virginica (glasswort)
Solidago canadensis (goldenrod)
Sonchus oleraceus (sow thistle)
Stellaria media (common chickweed)
Symphoricarpos albus (snowberry)
Taraxacum officinale (common dandelion)
Trifolium pratense (red clover)

Appendix 8.1 (cont'd).

Triglochin maritimum (seaside arrow-grass)
Typha latifolia (cattail)
Vicia sativa (common vetch)

(iv) WOODLAND COMMUNITY (Forbes, 1972)
Abies amabilis (balsam fir)
A. grandis (grand fir)
Acer macrophyllum (broadleaf maple)
Achillea millefolium (yarrow)
Agrostis spp. (bentgrass)
Alnus rubra (red alder)
Anaphalis margaritaceae (pearly everlasting)
Arbutus menziesii (arbutus or madrona)
Arctium minus (common burdock)
Arctostaphylos columbiana (hairy manzanita)
Athyrium felix-femina (lady fern)
Convolvulus arvensis (small bindweed)
Cornus stolonifera (red osier dogwood)
Crataegus douglasii (Douglas' hawthorn)
Cystopteris fragilis (fragile fern)
Cytisus scoparius (Scotch broom)
Dryopteris austriaca (spiney wood-fern)
Equisetum arvense (common horsetail)
Gaultheria shallon (salal)
Holcus lanatus (velvet grass)
Holodiscus discolor (ocean-spray)
Hypericum perforatum (common St. John's wort)
Hypochaeris radicata (hairy cat's ear)
Juniperus scopulorum (Rocky Mountain juniper)
Lactuca biennis (tall blue lettuce)
Lonicera dioica var. *glaucescens* (red honeysuckle)
Lycopodium clavatum (running club moss)
Phleum pratense (timothy)
Plantago lanceolata (English plantain)

Appendix 8.1 (cont'd).

Polypody spp. (polypody)
Polystichum munitum (swordfern)
Prunus emarginata (bitter cherry)
Pseudotsuga menziesii (Douglas fir)
Pteridium aquilinum (bracken)
Pyrus fusca (western crabapple)
Quercus garryani (garry oak)
Rhamnus purshiana (cascara)
Rhus diversiloba (poison oak)
Rosa spp. (rose)
Rubus parviflorus (thimbleberry)
R. spectabilis (salmonberry)
R. ursinus (trailing blackberry)
Rumex crispus (curled dock)
Salix lasiandra (red willow)
Spiraea douglasii (hardhack)
Struthiopteris spicant (deer fern)
Thuja plicata (western red cedar)
Trifolium pratense (red clover)
Tsuga heterophylla (western hemlock)
Vaccinium parvifolium (red huckleberry)
Woodsia spp. (woodsia)

Appendix 9.1.

Species Lists of Birds, Mammals, Amphibians and Reptiles from the Nanaimo River Estuary and Area, 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. *Podiceps grisegena* (red-necked grebe)
6. *P. auritus* (horned grebe)
7. *P. nigricollis* (eared grebe)
8. *Aechmophorus occidentalis* (western grebe)
9. *Podilymbus podiceps* (pied-billed grebe)
10. *Phalacrocorax auritus* (double-crested cormorant)
11. *P. penicillatus* (Brandt's cormorant)
12. *P. pelagicus* (pelagic cormorant)
13. *Ardea herodias* (great blue heron)
14. *Butorides virescens* (green heron)
15. *Olor columbianus* (whistling swan)
16. *O. buccinator* (trumpeter swan)
17. *Cygnus olor* (mute swan)
18. *Branta canadensis* (Canada goose)
19. *B. bernicla nigricans* (black brant)
20. *Anser albifrons* (white-fronted goose)
21. *Chen caerulescens* (snow goose)
22. *Anas platyrhynchos* (mallard)
23. *A. strepera* (gadwall)
24. *A. acuta* (pintail)
25. *A. crecca* (green-winged teal)
26. *A. discors* (blue-winged teal)

* order and nomenclature based on Godfrey (1966) and American Ornithologists Union (1973).

Appendix 9.1 (cont'd).

27. *Anas cyanoptera* (cinnamon teal)
28. *A. penelope* (European wigeon
29. *A. americana* (American wigeon)
30. *A. clypeata* (northern shoveler)
31. *Aix sponsa* (wood duck)
32. *Aythya americana* (redhead)
33. *A. collaris* (ring-necked duck)
34. *A. valisineria* (canvasback)
35. *A. marila* (greater scaup)
36. *A. affinis* (lesser scaup)
37. *Bucephala clangula* (common goldeneye)
38. *B. islandica* (Barrow's goldeneye)
39. *B. albeola* (bufflehead)
40. *Clangula hyemalis* (oldsquaw)
41. *Histrionicus histrionicus* (harlequin duck)
42. *Melanitta deglandi* (white-winged scoter)
43. *M. perspicillata* (surf scoter)
44. *M. nigra* (black scoter)
45. *Oxyura jamaicensis* (ruddy duck)
46. *Lophodytes cucullatus* (hooded merganser)
47. *Mergus merganser* (common merganser)
48. *M. serrator* (red-breasted merganser)
49. *Cathartes aura* (turkey vulture)
50. *Accipiter gentilis* (goshawk)
51. *A. striatus* (sharp-shinned hawk)
52. *A. cooperii* (Cooper's hawk)
53. *Buteo jamaicensis* (red-tailed hawk)
54. *B. lagopus* (rough-legged hawk)
55. *Haliaeetus leucocephalus* (bald eagle)
56. *Circus cyaneus* (marsh hawk)
57. *Pandion haliaetus* (osprey)
58. *Falco peregrinus* (peregrine falcon)
59. *F. columbarius* (merlin)

Appendix 9.1 (cont'd).

60. *Falco sparverius* (sparrow hawk or American kestrel)
61. *Dendragapus obscurus* (blue grouse)
62. *Bonasa umbellus* (ruffed grouse)
63. *Lophortyx californicus* (California quail)
64. *Phasianus colchicus* (ring-necked pheasant)
65. *Rallus limicola* (Virginia rail)
66. *Porzana carolina* (sora)
67. *Fulica americana* (American coot)
68. *Haematopus bachmani* (black oystercatcher)
69. *Charadrius semipalmatus* (semipalmated plover)
70. *C. vociferus* (killdeer)
71. *Pluvialis dominica* (American golden plover)
72. *P. squatarola* (black-bellied plover)
73. *Aphriza virgata* (surfbird)
74. *Arenaria interpres* (ruddy turnstone)
75. *A. melanocephala* (black turnstone)
76. *Capella gallinago* (common snipe)
77. *Numenius phaeopus* (whimbrel)
78. *Actitis macularia* (spotted sandpiper)
79. *Heteroscelus incanus* (wandering tattler)
80. *Tringa solitaria* (solitary sandpiper)
81. *T. melanoleuca* (greater yellowlegs)
82. *T. flavipes* (lesser yellowlegs)
83. *Calidris canutus* (red knot)
84. *C. ptilocnemis* (rock sandpiper)
85. *C. melanotos* (pectoral sandpiper)
86. *C. bairdii* (Baird's sandpiper)
87. *C. minutilla* (least sandpiper)
88. *C. alpina* (dunlin)
89. *C. pusillus* (semipalmated sandpiper)
90. *C. mauri* (western sandpiper)
91. *C. alba* (sanderling)

Appendix 9.1 (cont'd).

92. *Limnodromus griseus* (short-billed dowitcher)
93. *L. scolopaceus* (long-billed dowitcher)
94. *Lobipes lobatus* (northern phalarope)
95. *Stercorarius parasiticus* (parasitic jaeger)
96. *Larus glaucescens* (glaucous-winged gull)
97. *L. occidentalis* (western gull)
98. *L. argentatus* (herring gull)
99. *L. thayeri* (Thayer's gull)
100. *L. californicus* (California gull)
101. *L. canus* (mew gull)
102. *L. philadelphia* (Bonaparte's gull)
103. *L. pipixcan* (Franklin's gull)
104. *L. heermanni* (Heerman's gull)
105. *Sterna hirundo* (common tern)
106. *Uria aalge* (common murre)
107. *Cepphus columba* (pigeon guillemot)
108. *Brachyramphus marmoratus* (marbled murrelet)
109. *Synthliboramphus antiquus* (ancient murrelet)
110. *Cerorhinca monocerata* (rhinoceros auklet)
111. *Ptychoramphus aleuticus* (Cassin's auklet)
112. *Columba fasciata* (band-tailed pigeon)
113. *C. livia* (rock dove)
114. *Zenaida macroura* (mourning dove)
115. *Tyto alba* (barn owl)
116. *Otus asio* (screech owl)
117. *Bubo virginianus* (great horned owl)
118. *Nyctea scandiaca* (snowy owl)
119. *Glaucidium gnoma* (pygmy owl)
120. *Asio flammeus* (short-eared owl)
121. *Aegolius acadicus* (saw-whet owl)
122. *Chordeiles minor* (common nighthawk)
123. *Cypseloides niger* (black swift)
124. *Chaetura vauxi* (Vaux's swift)

Appendix 9.1 (cont'd).

125. *Selasphorus rufus* (rufous hummingbird)
126. *Megaceryle alcyon* (belted kingfisher)
127. *Colaptes auratus* (common flicker)
128. *Dryocopus pileatus* (pileated woodpecker)
129. *Sphyrapicus varius* (yellow-bellied sapsucker)
130. *Dendrocopos villosus* (hairy woodpecker)
131. *D. pubescens* (downy woodpecker)
132. *Empidonax traillii* (Traill's flycatcher)
133. *E. difficilis* (western flycatcher)
134. *Contopus sordidulus* (western wood peewee)
135. *Nuttallornis borealis* (olive-sided flycatcher)
136. *Eremophila alpestris* (horned lark)
137. *Tachycineta thalassina* (violet-green swallow)
138. *Iridoprocne bicolor* (tree swallow)
139. *Stelgidopteryx ruficollis* (rough-winged swallow)
140. *Hirundo rustica* (barn swallow)
141. *Petrochelidon pyrrhonota* (cliff swallow)
142. *Progne subis* (purple martin)
143. *Perisoreus canadensis* (gray jay)
144. *Cyanocitta stelleri* (Steller's jay)
145. *Corvus corax* (common raven)
146. *C. caurinus* (northwestern crow)
147. *Nucifraga columbiana* (Clark's nutcracker)
148. *Parus rufescens* (chestnut-backed chickadee)
149. *Psaltriparus minimus* (bushtit)
150. *Sitta canadensis* (red-breasted nuthatch)
151. *Certhia familiaris* (brown creeper)
152. *Cinclus mexicanus* (American dipper)
153. *Troglodytes aedon* (house wren)
154. *T. troglodytes* (winter wren)
155. *Thryomanes bewickii* (Bewick's wren)
156. *Telmatodytes palustris* (long-billed marsh wren)
157. *Turdus migratorius* (American robin)

Appendix 9.1 (cont'd).

158. *Ixoreus naevius* (varied thrush)
159. *Catharus guttata* (hermit thrush)
160. *C. ustulata* (Swainson's thrush)
161. *Sialia mexicana* (western bluebird)
162. *S. currucoides* (mountain bluebird)
163. *Myadestes townsendi* (Townsend's solitaire)
164. *Regulus satrapa* (golden-crowned kinglet)
165. *R. calendula* (ruby-crowned kinglet)
166. *Anthus spinoletta* (water pipit)
167. *Bombycilla cedrorum* (cedar waxwing)
168. *Lanius excubitor* (northern shrike)
169. *Sturnus vulgaris* (common starling)
170. *Acridotheres cristatellus* (crested myna)
171. *Vireo huttoni* (Hutton's vireo)
172. *V. solitarius* (solitary vireo)
173. *V. gilvus* (warbling vireo)
174. *Vermivora celata* (orange-crowned warbler)
175. *Dendroica petechia* (yellow warbler)
176. *D. coronata* (yellow-rumped warbler)
177. *D. nigrescens* (black-throated grey warbler)
178. *D. townsendi* (Townsend's warbler)
179. *Oporornis tolmiei* (MacGillivray's warbler)
180. *Geothylpis trichas* (common yellowthroat)
181. *Wilsonia pusilla* (Wilson's warbler)
182. *Passer domesticus* (house sparrow)
183. *Sturnella neglecta* (western meadowlark)
184. *Agelaius phoeniceus* (red-winged blackbird)
185. *Euphagus cyanocephalus* (Brewer's blackbird)
186. *Molothrus ater* (brown-headed cowbird)
187. *Piranga ludoviciana* (western tanager)
188. *Pheucticus melanocephalus* (black-headed grosbeak)
189. *Hesperiphona vespertina* (evening grosbeak)
190. *Carpodacus purpureus* (purple finch)

Appendix 9.1 (cont'd).

191. *C. mexicanus* (house finch)
192. *Spinus pinus* (pine siskin)
193. *S. tristis* (American goldfinch)
194. *Loxia curvirostra* (red crossbill)
195. *Pipilo erythrophthalmus* (rufous-sided towhee)
196. *Passerculus sandwichensis* (Savannah sparrow)
197. *Junco hyemalis* (dark-eyed junco)
198. *Spizella passerina* (chipping sparrow)
199. *Zonotrichia leucophrys* (white-crowned sparrow)
200. *Z. atricapilla* (golden-crowned sparrow)
201. *Passerella iliaca* (fox sparrow)
202. *Melospiza lincolnii* (Lincoln's sparrow)
203. *M. melodia* (song sparrow)
204. *Calcarius lapponicus* (lapland longspur)
205. *Plectrophenax nivalis* (snow bunting)

(ii) MAMMALS *

Order Insectivora (shrews)
Family Soricidae
Sorex obscurus (dusky shrew)
S. vagrans (vagrant shrew)
Order Chiroptera (bats)
Family Vespertilionidae
Eptesicus fuscus (big brown bat)
Myotis californicus (Californian bat)
M. evotis (long-eared bat)
M. keenii (Keen's bat)
M. lucifugus (little brown bat)
M. yumanensis (Yuma bat)
Plecotus townsendii (Townsend's big-eared bat)
Order Rodentia
Family Sciuridae (squirrels, chipmunks, marmots)
Marmota vancouverensis (Vancouver marmot)

* order and nomenclature based on Banfield, A.W.F. 1974. The mammals of Canada, University of Toronto Press, Toronto, 438 p.

Appendix 9.1 (cont'd).

Tamiasciurrus hudsonicus (American red squirrel)

Family Castoridae (beavers)

Castor canadensis (American beaver)

Family Muridae (rats, mice and voles)

Microtus townsendii (Townsend's vole)

Mus musculus (house mouse)

Ondatra zibethicus (muskrat)

Peromyscus maniculatus (deer mouse or white-footed mouse)

Rattus norvegicus (Norway rat)

R. rattus (black rat)

Order Cetacea (whales and dolphins)

Family Delphinidae (dolphins and porpoises)

Lagenorhynchus obliquidens (Pacific white-sided dolphin)

Orcinus orca (killer whale)

Phocoena phocoena (harbour porpoise)

Family Balaenopteridae (rorquals)

Balaenoptera acutorostrata (pike or Minke whale)

Megaptera novaeangliae (humpback whale)

Order Carnivora

Family Ursidae (bears)

Ursus americanus (black bear)

Family Procyonidae (raccoons)

Procyon lotor (racoon)

Family Mustelidae (weasels and allies)

Martes americana (American marten)

Mustela erminea (ermine)

M. vison (American mink)

Lontra canadensis (river otter)

Family Felidae (cat-like flesh-eaters)

Felis concolor (cougar)

Order Pinnipedia (seals, sea-lions, and walrus)

Family Otariidae (eared seals)

Eumetopias jubata (northern sea-lion)

Appendix 9.1 (cont'd).

Family Phocidae (true seals)

Phoca vitulina richardi (harbour seal)

Order Artiodactyla (cloven-hoofed mammals)

Family Cervidae (deer)

Odocoileus hemionus columbianus (mule deer)

Cervus elaphus roosevelti (wapiti or American elk)

(iii) AMPHIBIANS AND RETILES *

Ambystoma gracile (northwestern salamander)
A. macrodactylum (long-toed salamander)
Aneides ferreus (clouded salamander)
Bufo boreas (northwestern toad)
Chrysemys marginata belli (Bell's painted turtle)
C. picta (painted turtle)
Ensatina eschscholtzi (red salamander)
Gerrhonotus coeruleus (northern alligator lizard)
Hyla regilla (Pacific tree toad)
Plethodon vehiculum (red-backed salamander)
Rana aurora (red-legged frog)
R. pretiosa (western spotted frog)
Taricha granulosa (Pacific coast newt)
Thamnophis elegans (coast garter snake)
T. ordinoides (Puget garter snake)
T. sirtalis (northwestern garter snake)

* from B.C. Provincial Museum, Victoria, B.C., unpublished data, order alphabetical.

Appendix 10.1. Estimated participation in recreational boating by Nanaimo-Gabriola Island residents in 1973 (Mos and Harrison, 1974).

No. of households	13,123
No. of households owning one or more boats	3,778
Percent of households owning one or more boats	28.8
No. of primary boats	3,778
No. of secondary boats	817
Total No. of boats	4,595
Percent primary boat type:	
sail	7.5
outboard	52.5
inboard-outboard	30.0
rowboat, canoe and other	10.0
Average value of primary boats	$2,790
No. of days of saltwater use by primary boats	82,965
No. of person-days of saltwater use by primary boats	223,176
Average proportion of primary boat use in saltwater (percent)	86.9
Percent primary boat activity:	
fishing	84.6
cruising	12.8
other	2.6
Average No. of days spent on boat outings	21.9
Average No. of persons on board	2.7
Average No. of salmon taken on board primary boat	12.9

Appendix 10.2. Maps, charts and aerial photographs of the Nanaimo Region.

TOPOGRAPHIC MAPS

	Sheet No.	Scale
Alberni, B.C. (Third Status Edition, 1972)	92F	1:250,000
Alberni, B.C. (Edition 3 ASE Series A 502)	92F	1:250,000
Nanaimo, B.C.	92G/4 (east half)	1:50,000
Nanaimo, B.C.	92G/4 (west half)	1:50,000
Nanaimo, B.C.	92F/1 (east half)	1:50,000
Nanaimo, B.C.	92F/1 (west half)	1:50,000

Available from: Canada Map Office, 615 Booth St., Ottawa, Ontario, or, Surveys and Mapping Branch, British Columbia Lands Service, Victoria, British Columbia.

MISCELLANEOUS MAPS (Environmental Land Use)

Forest cover Series	Map 49°-123°-NW N°3	1 inch = 20 chains
Esquimalt and Nanaimo	Map 49°-123°-SW N°3	" "
Railway Land Grant	Map 49°-124° N°1	1 inch = 40 chains
(1947 - 1948)	Map 49°-124° N°2	" "

Available from: Forest Inventory Division, British Columbia Forest Service, Victoria, B.C.

The Biogeoclimatic subzones of Vancouver Island and adjacent mainland based on climax vegetation (third approximation). 1 inch = 6 miles

Available from: MacMillan Bloedel Limited Forestry Division, Nanaimo, B.C.

Appendix 10.2 (cont'd).

		Scale
Nanaimo coalfield (Buckham, A.F., 1947)	Prelim. 47	1:63,360
Surficial geology, Nanaimo, B.C. (Halstead, E.C., 1963)	Prelim. 27	1:63,360
Geology of Nanaimo Group, Vancouver Island and Gulf Islands (Muller, J.E., 1970)	Figure 11 Paper 69-25	1:250,000
Vancouver Island, Mineral Inventory Maps (December, 1971) B.C. Dept. Mines and Petroleum Resources	Same sheet numbers as National Topographic maps.	1:250,000
Soil map of Vancouver Island Duncan-Nanaimo Sheet	Report No. 6 B.C. Soil Survey, 1959.	1:63,360

Available from: Geological Survey of Canada, Department of Energy, Mines and Resources, Ottawa, or 100 West Pender, Vancouver, B.C.

HYDROGRAPHIC CHARTS	Chart No.	Scale
Vancouver Island	3001	1:525,000
Gulf Islands - Porlier Pass to Departure Bay	3310 (sheet 4)	1:40,000
Approaches to Nanaimo Harbour	3456	1:18,000
Plans in Stuart Channel, Dodd and False Narrows	3471	1:18,000
Plans in the Strait of Georgia, Departure Bay	3558	1:18,300
Sand Heads to Ballenas Islands	3577	1:77,300
Nanaimo Harbour	3581	1:6,100

Available from: Canadian Hydrographic Service, Ocean and Aquatic Sciences, Department of the Environment, Ottawa, or local agents.

Appendix 10.2 (cont'd).

AERIAL PHOTOGRAPHS

	Flight line	Date	Scale
Nanaimo Harbour and adjacent areas	BC 7754	July 22, 1975	20 chain (1 in = ¼ mi.)
	BC 5047	1962	40 chain
	BC 5057	1962	(1 in = ½ mi.)
	BC 5628	Sept. 13, 1974	80 chain
			(1 in = 1 mi.)
Mosaic of Nanaimo and Gabriola Island	B.C. Photo No. PM 65	Aug, 1972	1 in = 4,000 ft.
Nanaimo River (Pacific Survey Corp. Ltd.)	67159B-67192B	Mar. 22, 1973	1 in = 400 ft.

Information regarding Federal Government photographs and prices may be obtained from: National Air Photo Library. Department of Energy, Mines and Resources, Ottawa, Ontario.

The Surveys and Mapping Branch maintains a library of air photographs taken by the Provincial Government. Prints are available for reference and sale at Map and Air Photo Sales, Department of Lands, Forests and Water Resources, 553 Superior, Victoria, B.C.

Appendix 10.2 (cont'd).

Canada Land Inventory Land Capability Maps	Sheet No.	Scale
Agriculture	92G/4 (east & west halfs)	1:50,000
Recreation	" "	"
Waterfowl	" "	"
Ungulates	92 G/SW	1:126,270
	92 F/SE	"

Available from: Map Librarian, Resources Analysis Unit, ELUC Secretariat, Parliament Buildings, Victoria, B.C.

Departmental Reference Maps (Foreshore leases, timber leases, survey lots and sections)	R 92G/4	1 inch = 1/2 mile
	R 92F/1	" "

Available from: Surveys and Mapping Branch, British Columbia Lands Service, Victoria, B.C.

	Scale
Generalized land use Strait of Georgia - Puget Sound Basin	1:500,000
Water use Strait of Georgia - Puget Sound Basin	1:500,000

Available from: Lands Directorate, Environmental Management Services, Environment Canada, Ottawa.

Appendix 10.2 (cont'd).

Georgia Strait Urban Region Map ELD-4 (Land use pattern, population density, Transport movements - Vancouver and Vancouver Island, Nanaimo to Victoria).

Available from: Canada Map Office, Department of Energy, Mines and Resources, Ottawa, or Information Canada Bookstores.

Enumeration Boundaries (Nanaimo area - 1971 census)

National topographic map series
92G/4 east half, and
92F/1 east half

Available from: British Columbia Department of Municipal Affairs, Victoria, B.C.

Locations and classes of parks in the Nanaimo Regional District Provincial Parks on Vancouver Island.

Available from: British Columbia Department of Recreation and Conservation.

Plan of the city of Nanaimo, showing revised city limits, 1975. Scale 1 inch = 2,000 feet.

Available from: Engineering Department, City of Nanaimo, Nanaimo, B.C.

GEOLOGICAL MAPS

	GSC Map No.	Scale
Coal fields, Nanaimo, Comox (Richardson, J., 1871)	87	1 in = 10 mi.
Economic geology, Nanaimo coal area (Clapp, C.H., 1911)	54A (1912)	1 in = 1.5 mi.
Economic geology, Nanaimo sheet (Clapp, C.H., 1911)	160A (1916)	1:62,500

Appendix 10.3. List of foreshore leases in the Nanaimo River estuary and area (see map Figure 10.4) (B.C. Dept. Rec. & Cons., Unpubl. data).

Nanaimo Harbour Commission controlled Leases:

Lot 275 — Leased to MacMillan Bloedel until 1974. File #0191543.

Lot 240 — Leased to H.R. MacMillan Export Company File. #0175752.

Lot 260 — Leased to Eureka Sawmills Ltd. File #0191907.

Lot 263 — Leased to MacMillan Bloedel File #0195215, Addition to Lot 263. Application to lease by MacMillan Bloedel and Powell River Ltd. Survey complete. File #0195215.

Lot 321 — File #0195215.

Lot 292 — Leased to Mayo Lumber Co. File #0218629.

Lot 65 — File #0218629.

Lot 83 — Application to lease by G.W. Dorman Pulp Chip Company. Survey complete. File #0291386

Lot 350 — File #0120824.

Lot 313 — File #0234726.

Lot 356 — File #0235333.

Lot 264 — Blk. D File #0216458.
Blk. B Department of Public Works File #0152281.

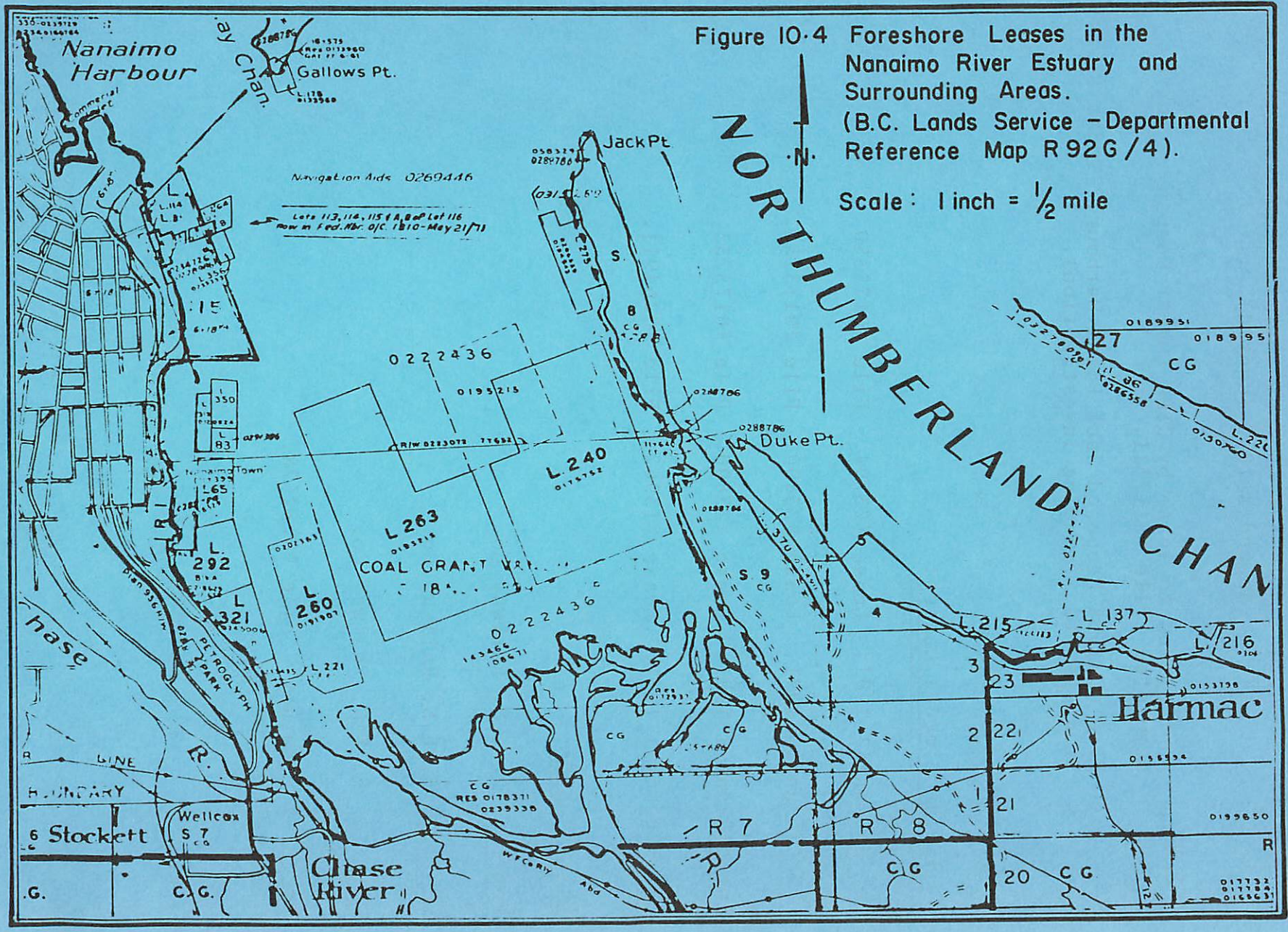


Figure 10·4 Foreshore Leases in the Nanaimo River Estuary and Surrounding Areas. (B.C. Lands Service – Departmental Reference Map R 92 G/4).

Scale: 1 inch = ½ mile

Appendix 10.3 (cont'd).

Lot 89 Application to lease by CIPA Lumber Company. Survey complete. File #0117311.

File #031528 Proposed Jack Point Harbour. Tudor Forest Products Ltd. (pending investigation).

MacMillan Bloedel Leases:

Lot 215 until 1991. Lease #23794. File #0175350

Lot 216 until 1991. Lease #23890. File #0175753.

Lot 217 until 1991. Lease #23890. File #0175753.

Lot 370 until 1971. Lease #13962. File #0264911.

Private Lots

Lot 115 E. & N. Railway Co.

Lot 116 E. & N. Railway Co.

Lot 114 E. & N. Railway Co.

Parcel A - Burney. File #0152578.

Appendix 11.1. Water Pollution Sources in the Nanaimo Area

(Compiled from B.C. Pollution Control Branch permit listings)

PCB ID Number	Discharger	Location of Discharge	cu. m/day (IGD)	Present Effluent Quality	Comments
PE-0096-01	Hooker Chemicals Ltd.	Northumberland Channel, 1.6 km north of Harmac mill	9,181 (2,020,000)	surface water chlorine conc. less than 0.1 mg/l anytime near the outfall	expired June, 1969
PE-00338-01	Greater Nanaimo Sewerage and Drainage District	1500 m north of Five Finger Island	27,300 (6,000,000)	BOD - 130 mg/l max TSS - 122 mg/l max Chlorine Residue - 0.1 - 1.0 mg/l pH - 6.5 - 7.5	Wastes treated in primary sedimentation tank, aeration lagoon, 1 hour chlorine contact chamber. Offshore submarine discharge.
PE-02093	Canadian Liquid Air Ltd. - Air Liquide Canada Ltee.	0.8 km west of Hwy #1, 5 km north of city centre	19.1 (4200) 9.55 yr. av. (2100) yr. av.		

Appendix 11.1 (cont'd).

PCB ID Number	Discharger	Location of Discharge	cu. m/day (IGD)	Present Effluent Quality	Comments
PE-02111-01	Liquid Carbonic Canada Ltd./ Ltee.	0.8 km west of Hyw #1, 5 km north of city centre	4.55 (1000)		
PE-02386-01	Hub City Paving Ltd.	3.2 km west of Hwy #1 on Nanaimo Lakes Rd.	262 (57, 600)	TSS - 20.0 mg/l	Asphalt plant. Treatment via settling pond.
PE--02419-01	Ocean Construction Supplies Ltd.	Departure Bay, next to B.C. Ferries terminal	18.2 (4000)		Redi-mix concrete plant. Treatment via settling pond.
PE-03209-01	MacMillan Bloedel Ltd.	Northumberland Channel	2.3 (500)	domestic sewage	Treatment via septic tank. Discharged via submarine diffuser

Appendix 11.1 (cont'd).

PCB ID Number	Discharger	Location of Discharger	cu. m/day (IGD)	Present Effluent Quality	Comments
PE-03209-02	MacMillan Bloedel Ltd.	Northumberland Channel	2.3 (500)	domestic sewage	Treatment via septic tank. Discharged via submarine diffuser.
PE-03971-01	Alpine Mobile Parks Ltd.	1.6 km north of Long Lake, west of Hwy #1		domestic sewage	Groundwater disposal.
PE-04348-01 (presently being processed)	Lafarge Canada Ltd.	0.8 km west of Hwy #1 on Haslam Rd.	654 max (144,000)		Surface runoff from coal slack waste pile excavations. Treatment via three settling ponds. Operations to be shut down during periods of moderate to high runoff.

Appendix 11.2. Landfill Operations in the Nanaimo Area

(Compiled from B.C. Pollution Control Branch permit listings)

PCB ID Number	Discharger	Location of Landfill	Volume	Waste Characteristics	Comments
PR-01609-01	Pacific Logging Company Ltd.	west of Hwy #1, 1.6 km west of Hub City Paving on Nanaimo Lakes Road.	506 cu.m/day (666 cu.yd/day)	hog fuel and log yard debris	Refuse from sawmills in Nanaimo and Ladysmith.
PR-01660-01	G.W. Dorman Pulp Chip Co. Ltd.	just east of Hwy #1 at South Wellington	1045 cu.m/week (1375 cu.yd/week)	bark and wood waste	Refuse from a lumber and pulp chip operation in Nanaimo.
PR-01714-01	Regional District of Nanaimo	near the junction of Cedar and Fielding roads, 0.8 km east of Hwy #1	608 cu.m/day (800 cu.yd/day)	domestic and commercial refuse	Refuse from the City of Nanaimo and surrounding area.
PR-03246-01	Mayo Lumber Company Ltd.	west of Hwy #1 at intersection of White Rapids and Extension roads	114 cu.m/week (150 cu.yd/week)	bark, wood, hog fuel	Yard waste from sawmill in Nanaimo.

Appendix 13.1. Some Statistical Data Available from Government Agencies.

British Columbia Department of Agriculture, Parliament Buildings, Victoria, B.C.

- Climate of British Columbia. Tables of temperature, precipitation and sunshine, 1973. (Based on data compiled by Environment Canada.)
- Climate of British Columbia. Tables of temperature and precipitation. Climatic normals 1941-1970, extremes of record.

British Columbia Department of Environment, Pollution Control Branch, Victoria, B.C.

- PCB effluent, emission and landfill permit listings and pertinent information including PCB and permittee monitoring data where available (computer printouts).

British Columbia Department of Recreation and Tourism, Fish and Wildlife Branch, Victoria, B.C.

- Steelhead harvest analysis (annual).
- Hunter sample. Wildlife management harvest statistics (annual).

Environment Canada, Atmospheric Environment, 4905 Dufferin Street, Downsview, Ontario.

- British Columbia, Temperature and Precipitation, 1941-1970.
- Monthly record meteorological observations in Canada.
- Canadian Normals Vol. III, wind 1955-1972.

Environment Canada, Fisheries and Marine Service, Fisheries Operations, Pacific Region, 1090 West Pender, Vancouver, B.C.

- Salmon escapement estimates to coastal rivers and streams.
- British Columbia catch statistics (commercial fishing).

Appendix 13.1 (cont'd).

- Salmon sport fishing catch statistics for British Columbia tidal waters.

Environment Canada, Fisheries and Marine Service Fisheries Management, Fisheries Research Board of Canada.

- Manuscript report series (data records).

Environment Canada, Inland Waters Directorate, Ottawa.

- Surface water data, reference index Canada, 1972 (Water Survey of Canada).

- Historical streamflow summary, British Columbia, to 1973 (Water Resources Branch).

- Sediment data for Canadian Rivers, 1969 (Water Survey of Canada).

- Water quality data, British Columbia, 1961-1971 (Water Quality Branch).

Statistics Canada, User Inquiry Service, Census Field, Ottawa, or Statistics Canada Information, 16 E. Hastings, Vancouver, B.C.

- Statistics Canada Catalogue 11-204 E (up-dated to June 30, 1974).

  Part I - Publications.

  Part II - Data Files and Unpublished Information.

- 1971 Census Catalogue 11-506-Population, Agriculture, Housing, Employment.

- 1971 Census of Canada, Population Census divisions and subdivisions (western provinces), Catalogue 92-707.

- 1971 Census of Canada, Special Bulletin-Geography, Land areas and densities of statistical units, Catalogue 98-701 (SG-1).

- 1971 Census of Canada-Agriculture, British Columbia, Catalogue 96-711.

- 1973 Shipping Report Part II. International seaborne shipping (by port) Catalogue 54-203.

15. GLOSSARY

GLOSSARY OF SELECTED TERMS

accretion: an increase or build-up of land by the gradual or imperceptible action of natural forces.

advection: refers to the horizontal or vertical flow of sea water as a current.

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.

algal mat: layer of algae covering sediments usually found in the lower to intermediate tidal zone.

allochthonous: originating elsewhere; not native to a place.

alluvial soils: pertaining to alluvium, a general term for all detrital deposits resulting from the operations of modern rivers, thus including the sediments laid down in river beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries.

amphipod: one of an order of crustacea, mostly marine, characterized by having the first and, perhaps, the second thoracic segment fused with the head; the abdomen is not well differentiated from the thorax, and the legs are modified for various functions; the body is laterally compressed.

anadromous: a form of fish life cycle in which maturity is attained in salt water, and the adults enter fresh water to spawn.

anemograph: a self-recording anemometer which gives a continuous trace of the speed and also the direction of the surface wind.

anemometer: an instrument by which the speed and often also the direction of the wind is measured.

angler-day: a day on which a fisherman participates in a sport fishery for any reasonable length of time.

anoxic: anaerobic, without oxygen.

aquaculture: cultivation of aquatic plants and animals for human use or consumption.

aquatic: growing or living in, or frequenting, water; occurring, or situated in, or on, water. Analogous to "terrestrial" for the case of land.

aquifer: a layer of rock which holds water and allows water to percolate through it.

artesian well: a type of well which normally gives a continuous flow, the water being forced upwards by subterranean hydrostatic pressure.

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. The metric unit of atmospheric pressure adopted by Canada is the kilopascal (1 kPa equals 3.386 in. of mercury).

autotroph: green plants, some protozoa, etc., capable of making organic matter from carbon dioxide,fertilizers and water, in the presence of chlorophyll, using sunlight as an energy source.

avian: of relating to, or derived from birds.

bacteria: microscopic organisms living, either singly or in colonies, in soil, water or the bodies of plants and animals (including man).

bathymetry: the art or science of measurement of the depths of oceans, seas, or lakes. Sometimes used synonymously with "bottom topography".

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 at the bottom of a water body.

benthos: organisms living in or at the bottom 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).

bioaccumulation: the concentration of a substance or substances by living organisms.

bioassay: a determination of the concentration, or dose, of a given material necessary to affect a test organism under stated conditions; or, the use of living organisms as an index to determine environmental conditions.

biochemical oxygen demand (BOD): a measure of the amount of oxygen used by micro-organisms to consume biodegradable organics in waste water. The 5-day BOD test is widely used to measure the organic strength of waste water in terms of dissolved oxygen that would be consumed if the waste water were discharged into a natural body of water.

biochronology: geologic time scale based on fossils.

biogeoclimatic zone: a regional ecosystem characterized by a zonal or mesic (moist) vegetation and soil which are a product of the macroclimate in which they occur.

biomass: the total weight of living organisms per unit volume of water or per unit area.

biota: the living organisms of an ecosystem as distinct from the abiotic or non-living component of an ecosystem.

bivalve: one of a class of molluscs; soft unsegmented animals most of which are protected by a shell containing calcium in some form. They are either permanently attached to a material (e.g., sediment or wood) or burrow into it. The class includes clams, mussels and oysters.

bloom: an unusually large number of organisms per unit volume of water, usually algae, made up of one or a few species.

blueback: Strait of Georgia coho salmon in the beginning of their third year characterized by a deep blue colour on the back and bright red flesh.

brackish: describes water having a salinity less than about 17 $^{o}/_{oo}$ and more than 0.5 $^{o}/_{oo}$ (parts per thousand).

bulrush: any of a number of annual or perennial sedges that bear solitary or much-clustered spikelets containing perfect flowers with an external envelope of (six) bristles.

caustic soda: an alkali, same as sodium hydroxide (NaOH), usually in the impure industrial form.

chironomid: any of a family of tiny flies that are two-winged and lack piercing mouthparts.

clastic: consisting of fragments of rocks that have been moved individually from their places or origin.

climax community: a final, self-perpetuating community of plants and animals that develops in a particular climate and soil; it will persist as long as the same conditions prevail.

cloud cover: the percentage or fraction of sky covered by cloud, e.g. 2/10, scattered cloud; 10/10, overcast.

coastal zone: the coastal waters and adjacent shorelands influenced by each other, including transitional and intertidal areas, salt marshes, wetlands, and beaches. The coastal zone extends seaward to the outer limit of the territorial sea, and extends inland from the shoreline to the extent necessary to control land uses which may have a direct and significant impact on the coastal waters.

coliform: designating of, or like the aerobic bacillus normally found in the colon; a coliform count is designated by the most probable number (MPN) of bacteria derived statistically from a series of cultures of different dilution. It is often used as an indicator of fecal contamination of water supplies.

comminute: to reduce to small, fine particles.

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.

complex: an area of two or more soil series which are so intimately mixed as to render their separation impractical at the scale of mapping.

condition factor: a measure of the physical condition of shellfish, as represented by dry weight of meat in relation to shell size.

conglomerate: rounded waterworn fragments of rocks or pebbles, cemented together by another mineral substance.

copepod: any of a large class of usually small marine and freshwater crustaceans. Most species range between about 0.5 to 10 millimetres in length. They often form an important source of food for fish in temperate and sub-polar waters.

crustacean: any of a large class of mostly aquatic creatures having an outer skeleton ("exoskeleton") composed of calcium carbonate, chitin, or some form of carbohydrate; it includes shrimps, crabs, wood lice, water fleas, and barnacles.

cuesta: an unsymmetrical ridge with one slope long and gentle and the other slope steep or precipitous.

dabbling ducks: ducks that obtain their food by submerging only the head, while the body remains floating on the water surface.

decapod: crustaceans having ten legs such as lobsters, crabs and shrimps or any cephalopod having ten arms, as a squid.

delta: an alluvial deposit at the mouth of a river emptying into a lake or sea.

detritus: dead organic matter, both plant and animal in origin. Fragments of matter that have been removed - by disintegration, weathering or other processes - from the surface of rocks; a deposit of any or all forms of detritus (adjective: detrital).

diatom: one of a class of microscopic phytoplankton organisms, characterized by thin shells of silica. Diatoms are one of the most abundant groups of organisms in the sea, and are a primary food source for marine animals.

diffusion: the spreading, scattering or transfer of matter under the influence of a change in its concentration with distance; the movement is from the stronger to the weaker concentration.

diurnal: daily; recurring once a day, having a period or cycle of approximately one tidal day.

diving ducks: ducks which obtain their food by diving below the water surface.

drainage area: the region that drains all the rainwater and snow that falls on it apart from that removed by evaporation, into a river or a stream, which then carries the water to a sea or a lake; its boundary is defined by the ridge beyond which water flows in the opposite direction - away from the region.

driftpole observations: observations of water currents made by following the movements of a weighted pole suspended vertically in the water.

drogue: a current-measuring assembly consisting of a weighted cross-piece, parachute, or similar device and an attached surface buoy. The drogue can be placed at any desired depth and current speed and direction determined by tracking and timing of the surface buoy.

ebb tide: outgoing or falling tide.

echinoderm: a phylum of invertebrates, all of which are marine and dwell on the bottom; comprised of the starfish, brittlestars, sea urchins, sand dollars, sea cucumbers and sea lillies.

ecology: the branch of science dealing with the interrelationships of organisms and their environments; the totality or pattern of relations between organisms and the their environments.

ecosystem: the complex of a community (biotic) and its environment (abiotic), functioning as an ecological unit in nature.

eddy: a circular movement of water usually formed where currents pass obstructions, between two adjacent counter-flowing currents, or along the edge of a permanent current.

eelgrass: a submerged vascular marine plant that has very long narrow leaves, produces seeds and generally grows on a sand or mud substrate, in the lower intertidal and upper subtidal zones.

effluent: waste material (such as sewage or liquid industrial refuse) discharged into the environment, especially when considered as a pollutant.

emission: in pollution work, usually refers to gaseous or vaporized wastes, as opposed to liquid wastes which are called effluents.

entrainment: the transfer of fluid from one water mass to another; occurs if the masses are in motion relative to one another, and results from mixing due to frictional effects at the interface between the masses.

environment: the totality of climatic, soil and biotic factors that act upon an organism or an ecological community and ultimately determine its form and survival.

escapement: the number of fish that escape, or are permitted to pass unharmed; often used in the sense of being left free to proceed to spawning grounds.

estuary: a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage.

euphausiid: one of an order of shrimplike, planktonic crustaceans, widely distributed in oceanic and coastal waters.

eustatic: pertaining to simultaneous, world-wide changes in sea-level.

eutrophic: referring to a water body rich in plant nutrient minerals and organisms but often deficient in oxygen in midsummer.

evaporation: the physical process by which a liquid is transformed to a gas, or in general, the amount of water evaporated.

fault: a fracture or a fracture zone along which there has been displacement of the sides relative to one another parallel to the fracture.

fauna: animal life of a specific region or time (microfauna - organisms that pass through 100 micron mesh; meiofauna - organisms that pass through a 500 micron mesh but are retained by a 100 micron mesh; macrofauna - organisms retained by a 500 micron mesh).

fetch: in wave forecasting, the continous stretch of water over which the wind blows in essentially a constant direction.

fingerling: a small finger-sized fish or a young fish up to the end of the first year.

flood plain: the area of land, adjacent to a river channel, subjected to flooding, when floodwater levels reach a predetermined height.

flood tide: rising or incoming tide.

flora: plant life of a specific region or time.

food chain: a series of organisms in a community in which each uses the next lower member in the sequence as a food source and is in turn consumed by animals on the next level above.

food web: the totality of, and interrelationships between, all the food chains characterizing a community.

forb: a broadleafed, flowering, non-grassy plant which does not possess a persistent woody stem above ground (plural: forbs).

fluvial: of or pertaining to, rivers; produced by river action, as a fluvial plain.

freshet: a sudden increase or rise in river flow or level because of melting snow and/or heavy rain.

fry: the young fish of a year.

game birds: wild birds hunted for sport or food; usually refers to members of the grouse family, and to ducks and geese.

grilse: immature sea-going chinook or coho salmon.

habitat: the place where an organism, or a population, lives.

harmonic constants: the amplitude and epoch of a constant recurring motion such as tides; used in prediction of local tide height and timing relative to reference datum.

headwaters: the streams and creeks that are the sources of a river or other water body.

heterotroph: all animals and fungi, most bacteria and a few flowering plants, requiring organic food substances to produce their own organic material.

hinterland: the land or district behind that bordering on a coast or river.

humidity: a measure of the water vapour present in the air; may be given in terms of relative humidity, or the absolute humidity.

hydrograph: a graph showing changes in water flow over a period of time.

hydrography: the study, description, and mapping of oceans, lakes, and rivers, especially with reference to their navigational and commercial uses.

infauna: benthic organisms which live buried in, or beneath, the surface of the sediment.

invertebrate: an animal not having a backbone.

isopod: any of an order of crustaceans, mostly aquatic, with a flat, oval body and seven pairs of walking legs of similar size and form, each pair attached to a segment of the thorax.

intertidal zone: that area of shore bounded by the levels of high and low tide.

jacks: precocious male chinook salmon returing to spawn in their second or third year.

juvenile: not having attained maturity in all respects.

kokanee: a sockeye salmon (*Oncorhynchus nerka*) which does not migrate to the sea, but spends its entire life in fresh water.

leach: to subject to the action of percolating liquid (such as water) in order to separate the soluble components; to dissolve out by the action of a percolating liquid.

littoral: the benthic zone between high-water and low-water marks; related to, situated or growing on, or near a shore.

loam: a soil composed of a mixture of clay, silt, sand, and organic matter.

macrophyte: a large plant; used to describe algal species large enough to be readily apparent to the naked eye.

maritime climate: a regional climate that is under the predominant influence of the sea, and that is characterized by small diurnal and annual ranges of temperature.

marsh: a tract of soft, wet land, characterized by growth of plants such as sedges and grasses; a saltmarsh is subject to overflow by salt water, as by tidal action.

mercaptan: a foul-smelling, sulfur-containing substance, characterized by the monovalent radical-SH.

migratory: passing, usually periodically, from one region or climate to another for purposes of feeding, breeding, etc.

mixed tide: type of tide in which a mixture of semi-diurnal and diurnal waves produces large inequalities in heights and/or durations of successive high and/or low waters.

modified maritime climate: a maritime climate that has attained a degree of continentality owing, for example, to occasional intrusions of cold arctic air.

morphology: the observation of the form of lands; or the study of the form and structure of organisms.

nutrient: a substance necessary to maintain life and promote growth.

oceanography: the science that deals with the oceans, and includes the delimitation of their extent and depth, the physics, chemistry and biology of their waters and the exploitation of their resources; can be divided into branches according to basic interest, e.g. chemical oceanography (chemistry).

paleontology: the science that deals with the life of the past geological ages. It is based on the study of the fossil remains of organisms.

pathogen: parasite which causes disease.

permeability: the ease with which gases and liquids penetrate or pass through a rock or soil.

periphyton: a more or less dense coating on submerged or intertidal surfaces chiefly consisting of filamentous algae and diatoms.

phytoplankton: plant life, mostly microscopic, found floating or drifting in the oceans or large bodies of fresh water; forms the base of most aquatic food chains as the main primary producers.

plankton: plant and animal life, mostly microscopic, drifting or floating freely in the water column of oceans and bodies of fresh water.

podzolic soils: highly bleached soils low in iron and lime, formed under moist and cool climatic conditions.

polychaete: any of a class of mostly marine, segmented worms; usually having a pair of fleshy leg-like appendages covered with setae, on most segments, and usually having a well developed, distinct head.

population dynamics: the study of the behaviour of populations, based on quantitative assessment of stock, recruitment, mortality and other factors.

primary productivity: the rate at which energy from light is absorbed and utilized with carbon dioxide in the production of organic matter in photosynthesis.

raptorial bird: a bird of prey, usually having a strong hooked beak and sharp talons (e.g., eagles, hawks, owls, vultures).

relative humidity: the ratio of the actual amount of water vapour in a given volume of air to the amount which would be present if the air were saturated at the same temperature, usually expressed as a percentage.

riparian: of, adjacent to, or living on, the bank of a river or other water body.

run-off: the portion of rainfall which ultimately reaches the streams; it consists of the water which flows off the surface, instead of sinking into the ground, together with some of the water which originally sank into the ground and joins it later in the streams.

salinity: a measure of the quantity of dissolved salts in sea water. It is formally defined as the total amount of dissolved solids in sea water - in parts per thousand ($^{o}/_{oo}$) by weight - when all the carbonate has been converted to oxide, the bromide and iodide replaced by chloride, and all organic mater is completely oxidized.

salmonid: any fish of the family Salmonidae (e.g. salmon or trout).

saprophyte: an organism which obtains organic matter in solution from dead and decaying tissues of plants or animals.

sedge: any of a family of grass-like plants often found on wet ground or in water, usually having triangular solid stems, three rows of narrow, pointed leaves, and minute flowers borne on spikelets.

sedimentary rock: rocks formed by the accumulation of sediment in water or from air, usually having a characteristic layered structure known as bedding or stratification.

shell-hash: a sediment layer composed of loosely-cemented sand, silt, clay and shell fragments or fossil debris generally larger than 2 mm.

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.).

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.

smolt: life-stage of a salmonid, older than a fry, that is leaving fresh water and entering salt water.

spat: the newly settled young of a bivalve mollusc, such as that of an oyster.

spawn (verb): to produce or deposit eggs - usually used in reference to aquatic animals such as fish, or crustaceans; the eggs themselves. (noun): the eggs of the above.

specific gravity: ratio of the weight or mass of a given substance to that of an equal volume of another substance (water for liquids and solids, air or hydrogen for gases) used as a standard.

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

sublittoral: the benthic zone extending from low tide level to the edge of the continental shelf or some comparable depth of water.

subtidal: below the lowest low tide.

surficial geology: characteristic of, pertaining to, formed on, situated at, or occurring on the earth's surface; especially, consisting of unconsolidated residual alluvial, or glacial deposits lying on the bedrock.

suspended solids: substances, the particles of which are dispersed through a fluid but not dissolved in it, and which will separate out on standing.

temperature inversion: an increase of temperature with height above the earth's surface, being the reverse of the normal condition in which the temperature decreases with height.

thermocline: a vertical temperature gradient in some layer of a body of water, that is appreciably greater than the gradients above and below it.

tidal flat: a gently sloping, marshy, muddy, sandy or sometimes pebbly area which is covered and uncovered by the rise and fall of the tide.

tidal flushing: replacement of some or all of the water mass of a semi-enclosed water body, such as an estuary, bay or inlet by outside water caused by the action of the tides.

topography: the surface features of an area including its relief, usually represented by means of contours and physical features such as forests, rivers and lakes.

toxic: of, relating to, or caused by a toxin or poison - which through chemical action, kills, injures, or impairs an organism.

trawl: to fish by dragging a large bag-like net along the bottom of a fishing bank.

troll: to fish with a moving line, sometimes with a revolving lure, trailed behind a moving boat.

turbidity: the measure of the content of suspended and/or dissolved material in a body of water that inhibits light penetration; indicates the corresponding decrease in clarity.

vapour pressure: the pressure exerted in the atmosphere by a substance through its vaporization, and usually measured in millimetres of mercury; in meteorology this term is used almost exclusively to denote the partial pressure of the molecules of water vapour in the atmosphere.

vernal: relating to, or appearing, or occurring in, the spring.

visibility: the distance of visual perception, usually through the atmosphere, measured in kilometres; in meterology, defined as the horizontal distance at which a prominent dark object can be seen and identified against the sky at horizon (daytime) or at which a known light source of moderate intensity can be seen and identified (nighttime).

waterfowl: birds that live on, or near, water, especially swimming game birds like geese and ducks.

watershed: the elevated boundary line separating the headstreams which are tributary to different river systems or basins.

water quality: the totality of physical, biological, chemical and aesthetic characteristics of water; the applicability - based on these characteristics - of water for various uses.

wind rose: a diagram illustrating the proportion of winds which blow from each of the main points of the compass at a certain place, averaged over a considerable period.

zooplankton: animal life, usually microscopic, found floating or drifting in the water column of oceans or bodies of fresh water; form the bulk of the primary consumer link above the phytoplankton in aquatic food chains.

16. BIBLIOGRAPHY

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