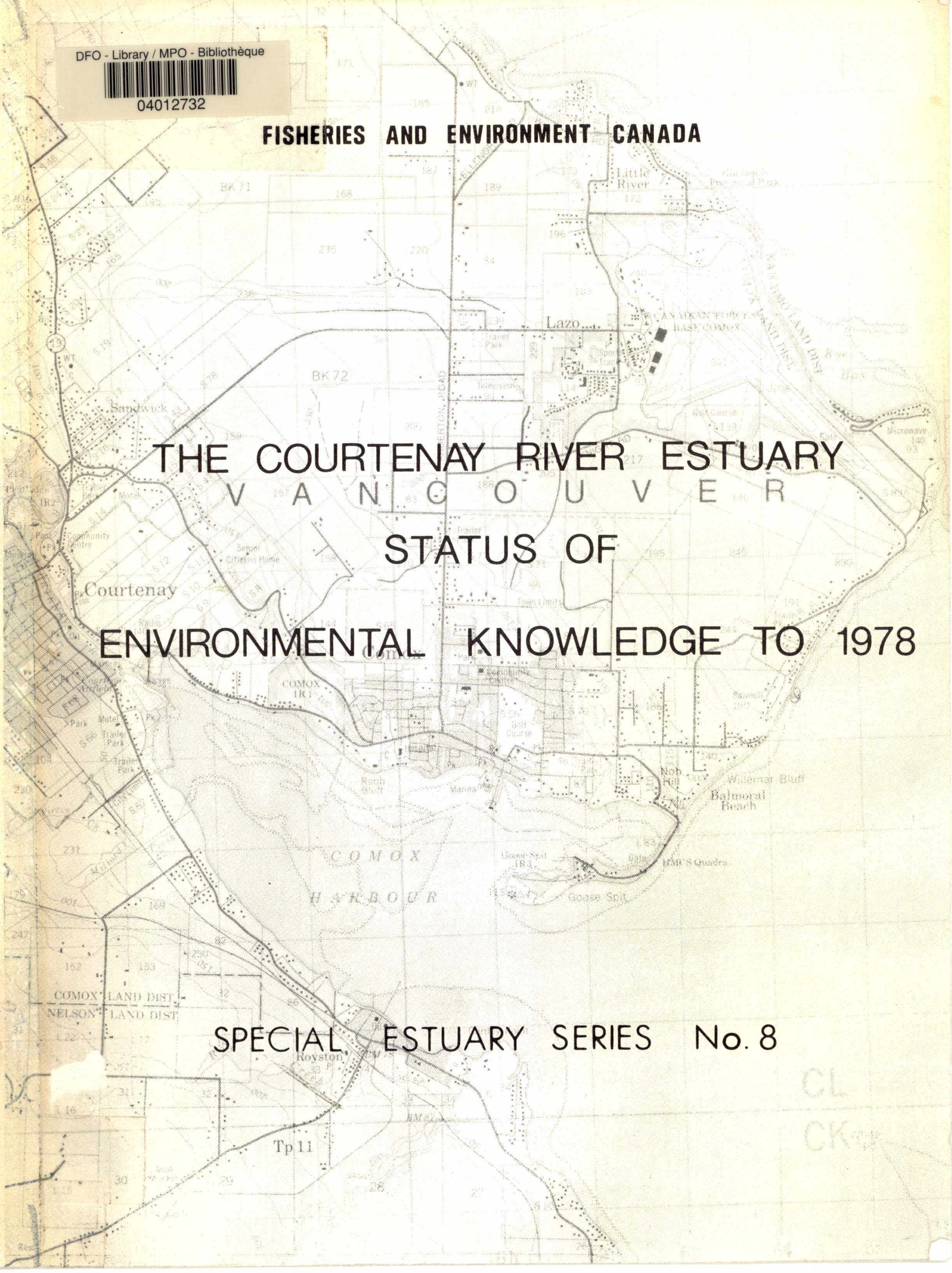
FISHERIES AND ENVIRONMENT CANADA



THE COURTENAY RIVER ESTUARY

STATUS OF

ENVIRONMENTAL KNOWLEDGE TO 1978

SPECIAL ESTUARY SERIES No. 8

FISHERIES AND ENVIRONMENT CANADA

THE COURTENAY RIVER ESTUARY STATUS OF ENVIRONMENTAL KNOWLEDGE TO 1978

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

BY
SAHLAA MORRIS, ADELLE J. LEANEY,
LEONARD M. BELL and JAMES M. THOMPSON

Under the Direction of Dr. M. Waldichuk
Department of Fisheries and the Environment
Resource Services Branch
4160 Marine Drive,
West Vancouver, B.C., V7V 1N6

SPECIAL ESTUARY SERIES No. 8

MARCH 15, 1979

Courtenay River Estuary - July 18, 1975

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF APPENDICES (cont'd)

LIST OF FIGURES

LIST OF FIGURES (cont'd).

LIST OF TABLES

LIST OF TABLES (cont'd).

ABBREVIATIONS AND SYMBOLS

asl	above sea level
ac.	acre(s)
A.R.D.A.	Agricultural and Rural Development Act
et al.	and others
AESL	Associated Engineering Services Ltd.
Atmos. Environ. Serv. (AES)	Atmospheric Environment Service
ave.	average
BOD	biochemical oxygen demand
fbm	board feet
B.C.	British Columbia
BP	Before Present (geologic time scale)
C.L.I.	Canada Land Inventory
CPR	Canadian Pacific Railway
cm	centimetre(s)
cm/s	centimetres per second
cont'd.	continued
m^3 (cu.m)	cubic metre(s)
m^3/s	cubic metres per second
cu. yd.	cubic yard(s)
dm^3	cubic decimetre(s)
^{o}	degree(s)
^oC	degrees Celsius (centigrade)
^oF	degrees Fahrenheit
σ_τ	density (sigma-t)
DND	Department of National Defense
E	east
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)
ft.	foot (feet)
e.g.	for example

ABBREVIATIONS AND SYMBOLS (cont'd).

gal.(g)	gallon(s)
g	gram(s)
gpd	gallons per day
GSC	Geological Survey of Canada
>	greater than
ha	hectare(s)
Hz	hertz
HMS	Her Majesty's Ship
hp	horse power
h. (hr.)	hour(s)
Igpd	Imperial gallons per day
in.	inch(s)
Ibid.	in the same place
kg	kilogram(s)
km	kilometre(s)
km/h	kilometres per hour
kn	knot(s)
<	less than
l	litre(s)
MS	manuscript
MPN	most probable number
m	metre(s)
μg	microgram(s)
μm	micrometre(s)
mi.	mile(s)
m.p.h.	miles per hour
meq/l	milliequivalents per litre
mg	milligram(s)
mg/l	milligrams per litre
ml	millilitre(s)
mm	millimetre(s)
m	million
MMfbm	million board feet
n.mi.	nautical mile(s)
N.T.S.	National Topographic System

ABBREVIATIONS AND SYMBOLS (cont'd).

N	north
No. (#)	number
oz.	ounce
PBS	Pacific Biological Station
PEI	Pacific Environment Institute
p.	page or pages
ppm	parts per million
$^{o}/oo$	parts per thousand
%	percent
pers. comm.	personal communication (with)
PCB	Pollution Control Branch
lb.	pound or pounds
Reg. Dist.	Regional District
rept.	report
sat.	saturated
ser.	series
S	south
spec.	special
spp.	species
s	seconds
cm^2	square centimetres
sq. ft.	square feet
m^2	square metre(s)
sq. mi.	square mile(s)
STD (std.)	standard
temp.	temperature
i.e.	that is
Mfbm	thousand board feet
TOC	total organic carbon
TSS	Total suspended solids
UBC	University of British Columbia
U. Vic	University of Victoria
VSS	volatile suspended solids
vol.	volume

ABBREVIATIONS AND SYMBOLS (cont'd).

W	west
yd.	yard
yr.	year

PREFACE

The territory chosen for the Courtenay River estuary study area has been somewhat arbitrarily defined to cover the coastal stretch from Oyster Bay in the north to Deep Bay at the southern end of Baynes Sound, in the south. This includes some of the coastal waters important for fisheries and wildlife which would not be covered by more confining limits for the estuary.

The Puntledge-Courtenay river system has been of considerable interest to developers and conservation agencies alike for many years. The Puntledge and Tsolum rivers merge to form the Courtenay River only a few kilometres from its mouth in the vicinity of the town of Courtenay. The Courtenay River drains into Comox Harbour, which is connected with Baynes Sound, on the northwest side of the Strait of Georgia. Because of various hydroelectric developments on the Puntledge River affecting the salmon fisheries, there have been numerous attempts at mitigation to replenish and enhance salmon stocks artifically for many years. The provincial government once had a hatchery on the Puntledge River system. There has been a long history of research on the Puntledge River salmon stocks by biologists of the Pacific Biological Station in Nanaimo, and more recently, the federal government is developing a major hatchery on the Puntledge River for coho and chinook salmon, as part of its Salmonid Enhancement Program. Streams tributary to Baynes Sound, such as Nile and Chef Creeks, have been studied by Nanaimo Biological Station scientists in connection with stream ecology of coho salmon. Another tributary, Rosewall Creek, is used for various freshwater rearing and environmental and genetic manipulation experiments. Salmon from the artificial spawning channels of the Big Qualicum River facility and other systems, spend part of their early life in Baynes Sound.

Besides salmon, the marine waters in the vicinity of Comox and Courtenay offer an assortment of other species for the commercial fisheries. In the Comox and Lazo Bight area are extensive concentrations of shrimps that have been harvested for many years. From Denman Island to north of Cape Lazo, an area characterized by a sandy bottom, there has also been a productive fishery for English (lemon) sole in the past.

One of the major cultivated oyster areas in the province is located in Baynes Sound. Although restrictions have been imposed in some sectors because of sewage pollution, a large number of oyster leases are still farmed, and shucked oysters are shipped to many points in the province. Clam digging is carried on recreationally as well as commercially in some areas, in season. The sandy bank to the north of Denman Island has one of the best butter clam beds on the coast. This population has been extensively studied by shellfish biologists at the Pacific Biological Station. Now, there is growing exploitation of the geoduck clam population seaward of Willemar Bluff between Cape Lazo and Point Holmes.

The Courtenay-Puntledge river system and Comox Harbour provide a recreational outlet for the populations of both Courtenay and Comox, as well as for residents of some of the outlying communities, e.g. Cumberland and Union Bay. There is a modest amount of tourism seasonally.

Recreational and cultural activities include outdoor sport, such as physical education, and the indoor pursuits of competitive sports, music, drama and other arts. Sports fishermen enthusiastically seek coho and chinook salmon in both marine and estuarine waters, and steelhead and cutthroat trout in the rivers. The Puntledge-Courtenay river system, Comox Harbour and the shoreline beyond are rich in living resources and provide many opportunities for nature lovers. Naturalist groups organize educational - recreational outings to examine and study life on the seashore and count birds.

The Courtenay-Comox area, with a combined population of about 25,000, is perhaps first and foremost a residential area, with services for agriculture, logging and tourism. From this point of view, a major impact arises from the presence of people, their accommodation with residences and services, and the disposal of their wastes. The Canadian Forces Base in Comox, a major employer in the area, contributes mainly domestic sewage and refuse, rather than "industrial" pollutants to the environment. The 1974 staff report of the Regional District of Comox-Strathcona (formerly the Regional District of Comox Valley), entitled "Population Growth and Distribution" reviewed some of the problems of anticipated population increase.

The Courtenay River passes through the urban environment of the town of Courtenay, and its inner estuary occupies most of Comox Harbour, which is bordered by the town of Comox to the east and Courtenay to the west. Sewage was discharged raw into the Courtenay River and into Comox Harbour for many years. Oysters contained high coliform counts, and bathing areas were occasionally closed to swimming. By the late 1950's, Comox undertook to improve its sewage collection and disposal facilities in a way that would be least environmentally damaging, but within economic means for the municipality. After investigations by personnel from the Pacific Biological Station, the Upper Vancouver Island Health Unit and the consulting engineers, it was decided to release raw sewage through an outfall discharging at 22 m (12 fathoms) in the northern end of Baynes Sound, outside of Comox Harbour. Part of the objective of this scheme was to restore bacteriological quality of oyster areas in Comox Harbour and to allow safer use, from the health standpoint, of the beaches for bathing along Goose Spit and the northeastern side of Comox Harbour.

The town of Courtenay developed a plan for improving its sewerage and sewage disposal facilities, shortly after the new sewage disposal system of Comox was in place. This consisted of a lagoon on the northwest side of Comox Harbour to treat the sewage of Courtenay and of some of the adjacent suburban subdivisions, followed by discharge of lagoon effluent into the north end of Comox Harbour. While both the new Comox and Courtenay sewage treatment and disposal systems provided some general improvement in sanitary facilities for these communities, the water within Comox Harbour continued to show substantially higher coliform counts than acceptable for safe oyster culture. Consequently, oyster leases that had been banned or restricted for oyster harvesting because of sewage pollution continued essentially under the same status.

Comox Valley, which backs up the Courtenay River estuary, is largely agricultural. From the point of view of impact on the river and estuary, the effect of agriculture is mainly the introduction by runoff of nutrients from fertilizers, pesticides from agricultural pest control and silt from the ploughed soil. There has been relatively little industrial development in Courtenay - Comox and adjacent territory. With the closing of the coal mines in the Cumberland area, the industrial mainstay of these communities is forestry. Logging in nearby forests and lumber manufacture in local sawmills provide a substantial proportion of the employment for local residents. Log booming in coastal waters contributes to one of the major marine ecological impacts of the forest industries. In line with the industrial focus on forest products, there was even preliminary study in the early 1960's on the feasibility of a pulp mill in Union Bay on Baynes Sound.

The Regional District of Comox-Strathcona has prepared an Offical Regional Plan, which takes into account not only projected residential and industrial growth, but also transportation and recreational facilities, as well as conservation areas. An excellent document, "Report on Land Use and Resources within the Region 1975", has been compiled by the Planning Department of the Regional District of Comox-Strathcona.

This is the eighth report in the Special Estuary Series of Fisheries and Environment Canada in the Pacific Region. It is hoped that the report covers all available relevant environmental information for the Courtenay River estuary, one of the eighteen estuaries along the British Columbia coast designated as being critical from the point of view of preservation of renewable resources in the face of threats of development. Environmental information for eight estuaries has been summarized in the seven previous reports: (1) Fraser, (2) Squamish, (3) Skeena, (4) Cowichan and Chemainus, (5) Nanaimo, (6) Kitimat, and (7) Campbell. Nine estuaries of those originally identified remain to be examined in this series: the Indian, Homathko, Wannock, and Bella Coola on the British Columbia mainland coast; and the Somass, Quatse, Salmon, Gold, and Nimpkish on Vancouver Island. The next report in the series will review the Somass River estuary as a priority system because of activities already underway there, and the possibility of instituting environmental improvement. Changing priorities may dictate deletion of some of the remaining estuaries from the series of reports.

The reports in this series are intended to bring together a wide range of environmental material on the selected estuaries, to summarize it, to pinpoint the sources of existing and upcoming information and to identify the gaps in knowledge. The audience for which these reports are written consists of government agencies, the academic community, consulting firms and interested lay persons. Our goal is to have the reports available in as many libraries as possible at least in the Pacific Region, so that they can receive maximum use by interested persons and institutions.

It is a pleasure to acknowledge the continued financial and moral support in this project from Regional Directors and Directors-General of Fisheries and Environment Canada in the Pacific Region. Members of the Estuary Working Group are to be commended for their efforts in reviewing the first draft of this report and for offering constructive criticisms. The contractors, Messrs. L.M. Bell and J.M. Thompson, continued to take an active interest in completing sections of this report even after they had departed to undertake other activities. We are grateful to them for their valued input, and to Adelle Leaney and Sahlaa Morris, the present contractors, who saw this report to its completion.

Every effort has been made to correctly interpret findings of investigators cited in this series, by consultations with experts and appropriate reviews. We apologize to authors of cited works for any misinterpretations that may have filtered through the review process. *Readers are urged to examine the original literature on specific topics in which they may have a special interest.*

M. Waldichuk

Preface Table (i)

*Members of the Estuary Working Group, Fisheries and Environment Canada, Regional Board Pacific Region

Dr. C.D. McAllister (Chairman)
Resource Services Branch
Pacific Biological Station
Nanaimo, B.C. Phone: 666-8362

Dr. M. Waldichuk
Resources Services Branch
Pacific Environment Institute
West Vancouver, B.C. 926-2614

Mr. T. Bird
Resource Services Branch
1090 West Pender Street
Vancouver, B.C. 666-3166

Mr. W. Schouwenburg
Resource Services Branch
1090 West Pender Street
Vancouver, B.C. 666-3856

Mr. Ralph Wills
Ocean & Aquatic Sciences
Institute of Ocean Sciences
P.O. Box 6000
Sidney, B.C. 656-8349

Dr. D.S. Lacate
Lands Directorate, Pacific Region
Environmental Management Service
1001 West Pender Street
Vancouver, B.C. 666-3161

Mr. M. Romaine
Lands Directorate, Pacific Region
Environmental Management Service
1001 West Pender Street
Vancouver, B.C. 666-6751

Dr. J.L. Luternauer
Geological Survey of Canada
Department of Energy, Mines and Resources
Institute of Ocean Sciences
P.O. Box 6000,
Sidney, B.C. 656-8424

Mr. W.L. Kreuder
Inland Waters Directorate
Environmental Management Service
502 - 1001 West Pender Street
Vancouver, B.C. 666-3715

Mr. J. Millen
Ecological Protection Group
Environmental Protection Service
Kapilano 100 - Park Royal
West Vancouver, B.C. 666-6711

Mr. D.G. Schaefer
Scientific Services
Atmospheric Environment Service
739 West Hastings Street
Vancouver, B.C. 666-1433

Mr. D. Trethewey (Secretary)
Canadian Wildlife Service
Environmental Management Service
P.O. Box 340
Delta, B.C. 112-946-8546

Mr. L. Retfalvi
Canadian Wildlife Service
Environmental Management Service
P.O. Box 340
Delta, B.C. 112-946-8546

Mr. Bruce Pendergast
Fish and Wildlife Branch
Ministry of Environment
Parliament Buildings
Victoria, B.C. 387-3473

Mr. D. Tillapaugh
Marine Resources Branch
Ministry of Environment
Parliament Buildings
Victoria, B.C. 387-1537

**All members are from the Canada Department of Fisheries and the Environment, except the representative of the Geological Survey of Canada and the provincial representatives, who are from the British Columbia Ministry of Environment.*

Acknowledgements

The authors would like to thank the staff of the Regional District of Comox-Strathcona, C.F.B. Comox and the Municipal Districts of Courtenay and Comox for furnishing documents and data referred to herein.

We are also grateful for the participation, interest and co-operation of all federal and provincial agencies, private industries, consultants, and other individuals who contributed valuable time and information to the preparation of this report.

Our appreciation is extended to the members of the Estuary Working Group for reviewing the draft manuscript and for providing constructive criticism. We thank them for their continuing support.

We are indebted to Dr. M. Waldichuk for writing the Oceanography section, for his direction throughout the organization of this report and for his ongoing interest in the estuary series.

Finally, we would like to thank Miss Colleen Yuen, Mrs. Rose Dawson and Miss Carol Price for typing the manuscript.

SUMMARY

The Courtenay River estuary and adjacent lands have been attractive for settlement since earliest times when native people inhabited the area. The Comox tribe of Salish Indians were the first known inhabitants of the Comox Valley. After intermarriage between the Pentlatch tribe of Kwakiutl Indians from the north, they became known as the Comox Band. These Indians now live on two reserves, one at the intersection of the Puntledge and Tsolum rivers, the other on the northeast side of Comox Harbour.

The explorations of Captain George Vancouver resulted in the first contacts of Europeans with the area. The first hydrographic survey of the waters approaching the Courtenay River estuary was made by Captain Vancouver in 1792. Between 1846 and 1849, a more detailed survey was conducted by Captain Courtenay.

Farming was the initial occupation of the first white settlers who arrived in 1862. Soon afterwards, a lumber industry was established, with the estuary providing an ideal location for log dumping and storage.

Prior to 1960, geological investigations in the study area were confined to explorations in the Cretaceous Formations where coal deposits were first discovered. Viable deposits were found within the Comox Formation in the Cumberland and Tsable River areas. The first mine was opened in 1888 near the present day village of Cumberland, and the last, near Tsable River, was closed in 1966. The best production years were from 1904 to 1921. In 1911, a record yield of 442,827 tonnes (488,125 short tons) of coal was mined.

Under the Comox Formation are the Nanaimo Basin sediments (soft shale, sandstone and conglomerates), which in-

clude marine and non-marine beds. Basement volcanic (basalt) rocks of the Karmutsen Formation predominate in the Beaufort Range near Comox Lake. Surficial deposits found in the study area include two post-glacial deposits and the Vashon Drift till, associated with the last period of regional glaciation of southwestern British Columbia. The two post-glacial deposits are the Salish sediments, related to the present sea, river and lake levels, and the Capilano sediments of marine lacustrine and fluvial origin, related to former (higher) sea, river and lake levels.

Soils in the study area consist of the loamy sands of the Bowser-Dashwood series, not suitable for agriculture, and the fine silty loams of the Chemainus series which are well drained, highly fertile and particularly attractive for agriculture. The latter soils are found along the banks of the Tsolum River and on the Courtenay River delta.

The Comox Harbour area is characterized by long, cool, relatively wet summers and short, mild, wet winters. Winds are predominantly southeast during the winter and northwest during the summer. The southeast winds are stronger, partly because they have the unobstructed stretch of the Strait of Georgia over which to develop.

Precipitation is greatest during November, December and January, with the maximum monthly mean occurring in December (212 mm, 8.33 in.). While there is no distinct dry summer season, the mean monthly precipitation for July is only 28 mm (1.12 in.) Mean daily temperatures range from 2.1^{o} C (35.7^{o}F) in January to 17.4^{o}C (63.2^{o}F) in July. An estimated 1,650 hours of sunshine are recorded annually in the Comox Harbour area.

Courtenay River, formed from the merging of the Puntledge and Tsolum rivers, drains 841.8 sq. km (325 sq. mi) and provides the main source of freshwater inflow to Comox Harbour.

Trent River and Roy, Willemar and Brooklyn creeks also contribute freshwater to the harbour. North of Comox Harbour, Black Creek and Oyster River empty into the Strait of Georgia, while many small streams flow into Baynes Sound, south of the harbour.

The mean annual discharge of the Courtenay River, a combination of flows from the Puntledge and Tsolum rivers, is 53.7 m^3/s (1,899 cfs). The flow of the Puntledge River, below Comox Lake, is regulated by the B.C. Hydro storage dam. Flooding is minimized by controlling the water levels in Comox Lake. B.C. Hydro diverts a minimum of 2.83 m^3/s (100 cfs) via the fish hatchery, downstream from the diversion dam, to aid migrating fish.

Frequent flooding of the Oyster River has resulted in major properly losses. The streambanks have subsequently been reinforced and dykes built to prevent further erosion.

The Courtenay River estuary (Comox Harbour) and Baynes Sound, exhibit the typical two-layered estuarine system of the British Columbia coast. A thin layer of brackish water overlies the deeper sea water to a maximum depth of approximately 5 m (16.4 ft.). In the winter, this layer may be only 2-3 m (6.6 - 9.8 ft.) deep near the river mouths. Salinity is comparatively low in the deeper waters (26 - 27 $^{o}/_{oo}$). In the surface layer, it may drop off to zero near the Courtenay River mouth, but generally runs between 15 and 20 $^{o}/_{oo}$ in the northern part of Baynes Sound. Summer water temperatures are relatively high, occasionally reaching 20^{o}C (68^{o}F). The temperature may be considerably less at the surface than in the deeper water during the cold winter months. Dissolved oxygen is usually quite high at all depths during the winter, ranging from 8 to 9 mg/1 below 2 m (6.6 ft.) and reaching about 12.5 mg/1 in the surface water. During the summer months, it may decline to 50% or less of saturation in deeper waters.

Currents at all depths in the Comox Harbour - Baynes

Sound area show a distinct tidal component. Surface currents may exceed 50 cm/s (1 kn.), while subsurface currents are considerably weaker. There are indications of currents at 4.6 m (15 ft.) and 9.1 m (30 ft.) occasionally reaching speeds of 50 cm/s (1 kn.). In general, currents appear to be vigorous in all parts of the study area, particularly over Comox Bar and adjacent to Goose Spit, where they have contributed to the littoral transport of sand and the formation of this spit.

Tides are generally mixed and diurnal with marked inequalities in both the height and duration of the rise and fall of successive low and high waters. The flood tide is primarily influenced by the tidal waves that come through the Strait of Georgia from the south, although there may be some effect in the northern part of the study area from the tide flooding southward through Discovery Passage. Comox is a secondary port for tidal prediction with respect to Point Atkinson, the reference port.

Wave action is most extreme from the east to southeast with the exposure to winds blowing across Comox Bar from the Strait of Georgia. Winds from this direction may create waves up to an estimated 1.5 m (5 ft.) in height during the winter months. Northwest winds do not develop sizeable waves because of the short fetch from that direction. The ecological impact of seas from the southeast, mainly impinges on the beaches west of Cape Lazo, on the south side of Goose Spit, and on the delta front of the Courtenay River estuary directly westward of Goose Spit.

Both Comox Harbour and Baynes Sound are considered to be relatively actively flushed at all times of the year. Surface waters are replaced much more quickly than those in the deep zone, which can be exchanged only through the deeper entrance channel from the south. There is some indication that the net surface flow of water through Baynes Sound is from north to south, and that this would have some influence on the

dispersion of any pollutants introduced into the system in the surface layer, eventually transporting it through the connecting channel between the southern end of Denman Island and Mapleguard Point on Vancouver Island.

Beach crabs (*Hemigrapsus nudus*), barnacles (*Balanus balanus*), mussels (*Mytilus edilus*), limpets (*Acmaea* spp.), rock whelks (*Thais lamellosa*) and oysters (*Crassostrea gigas* and *Ostrea lurida*) were the most abundant species of epifauna found in Comox Harbour. Polychaetes, ghost shrimp (*Callianassa californicus*) and pelecypods were the most common infauna. The zooplankton in the harbour have not been studied, although large numbers of bivalve and decapod larvae have been seen. Invertebrates noted in the Oyster River area include bivalves, gastropods and decapods.

In Baynes Sound, beds of Pacific oysters (*Crassostrea gigas*), native west coast oysters (*Ostrea lurida*) and shrimp (*Pandalus* spp.) have been surveyed. Oysters, shrimp, clams, (*Saxidomus*, *Protothaca* and *Siliqua* spp.), geoducks (*Panope generosa*), crabs and abalone (*Haliotus* spp.) are harvested in the sound. This area is the most productive oyster growing region in British Columbia, yielding approximately 104,690 kg (230,798 lb.) of oysters in 1977 and providing shellfish fishermen with about $83,000. While the shrimp fishery was declining until 1976, 1977 statistics show that the wholesale value of the shrimp and prawn catch was double that in 1976. Abundant geoduck populations in the study area have potential for increased commercial exploitation.

Chum, coho, chinook, pink and sockeye sa mon (*Oncorhynchus keta*, *O. kisutch*, *O. tshawytscha*, *O. gorbuscha*, *O. nerka*), as well as cutthroat and steelhead trout (*Salmo clarki clarki* and *S. gairdneri*), occur in the rivers and streams draining the study area. All seven species were observed in the Courtenay - Puntledge River system, while only migratory trout,

though logging continues in the headwaters of the Puntledge and Oyster rivers. The trees are mainly second growth. Near Comox Harbour, most of the terrestrial vegetation has been removed to make way for urban and industrial development.

Communities of emergent vascular vegetation in Comox Harbour and the Oyster River estuary have been identified and mapped. The sedge (*Carex lyngbyei*) was found along the northern shore of Comox Harbour and at the mouths of Courtenay River and Millard - Piercy Creek. These sedge beds account for a large portion of the primary productivity in the harbour.

In Comox Harbour, *Fucus distichus* and *Enteromorpha* spp. were found in the intertidal zone, while green algae (mostly *Ulva* spp.) were fairly abundant in the nearshore waters. In the low intertidal zone, extensive beds of eelgrass (*Zostera marina*) and one species of brown algae were seen. Concentrations of the marine alga, *Iridaea cordata* were found off Kye Bay, north of the estuary, while eelgrass beds were found scattered throughout the study area.

Phytoplankton concentrations in Comox Harbour were greatest in late spring and primary productivity was estimated to be 465gC. m^{-2} yr^{-1}.

As many as 10,000 waterbirds have been seen utilizing Comox Harbour in one day. These birds concentrated at the mouths of Millard - Piercy Creek and the Courtenay River, near Dyke Slough and behind Goose Spit. The most common groups of birds seen were diving ducks, dabbling ducks, gulls and shorebirds. As many as 260 trumpeter swans (*Olor buccinator*) a day were seen feeding in the marshes near the mouth of Millard - Piercy Creek. At the Oyster River estuary, large flocks of diving ducks and gulls were observed. Black brant (*Branta bernicla*) were also common in the Oyster River estuary during spring migrations.

Mammals thought to frequent Comox Harbour and the Oyster River area include raccoons *(Procyon lotor)*, American marten (*Martes americana*), American mink (*Mustela visor*), beaver (*Castor canadensis*), river otter (*Lontra canadensis*), mule deer (*Odocoileus hemionus*), and American black bear (*Ursus americanus*). As the muskrat (*Ondatra zibethicus*) only utilizes the marsh areas, it would not be expected in the Oyster River estuary where marshes are absent.

Deer populations are thought to range from 25 to 40 deer per sq. mi. (259 ha) near the estuary to 5 to 15 deer per sq. mi. (259 ha) in the mountains and recently logged areas. Only a few elk are thought to inhabit the Oyster River and Black Creek areas, as logging has reduced much of their habitat.

Residential and industrial development associated with the Courtenay - Oyster River study area is confined to the eastern plain bordering the Strait of Georgia and Baynes Sound. Development is essentially east - west oriented. The Official Regional Plan, adopted in 1977, encouraged future growth in previously established population centres.

Most of the Courtenay River watershed, covered by marketable timber stands, is owned or leased by forest companies, the major operators being Crown Zellerbach and Weldwood of Canada Limited. The forest industry contributes substantially to the local economy of the Courtenay - Comox area.

The hydro-electric facilities on the Puntledge River were enlarged by the B.C. Hydro and Power Authority between 1953 and 1958. The powerhouse, located 1.6 km (1 mi.) upstream of Courtenay, generates about 27,000 kilowatts of power.

Rivers, lakes and undeveloped lands of the Courtenay River area are used extensively for fishing, hiking, camping and other outdoor activities. The many provincial parks in the study area also provide facilities for outdoor recreation. The large number of recreational outlets is a reflection of the high quality of the environment.

The Comox Valley and Courtenay River flood plain are the major agricultural districts in the area. According to the 1976 census of Statistics Canada, 172 farms were located within the study area. The principal source of agricultural revenue is dairying.

Water quality studies (chemical and bacteriological) were carried out in the Courtenay River watershed and estuary. In the watershed areas, water quality is generally good.

The quality of the water in Comox Harbour is a function of the quality of water in the tributary rivers and the pollutants discharging directly into the harbour. Most of the parameters of water quality measured in 1974, showed no unusual values. High concentrations of fecal coliforms are found in the harbour, particularly near the mouth of the Courtenay River.

Past logging practices have generated most of the pollution in the Courtenay River watershed. Large amounts of debris have accumulated in and around Comox and Willemar lakes from sorting logs in the water. Clear cutting has resulted in extremes of flow. High flows have caused the destruction of large numbers of salmon eggs in the Oyster River.

Peak flows have also led to severe streambank erosion in the Oyster and Browns rivers. The resulting cementation or displacement of gravel is thought to have reduced salmon spawning areas. Logging, coupled with the diversion of water for irrigation, has resulted in some low flows in the Tsolum River during the summer, making upstream migration difficult for salmon.

In the estuary, sewage and log storage are the

major sources of pollution. The Courtenay and Cumberland sewage treatment lagoons, and the seepage of sewage from septic tanks and other minor sources has resulted in the introduction of fecal coliforms into the harbour, closing the area to shellfish harvesting. Surveys of the old Royston booming grounds and the log storage areas in 1974, showed a decline in the abundance and diversity of benthic fauna. Other minor sources of pollution in the harbour include: periodic dredging of the log de-watering area releasing hydrogen sulfide; oil spills by boats; and the discharge of effluents from storm drains.

Developments in the estuary and watershed area have also placed stress on natural biological communities. The expansion of the facilities at the hydro-electric dam on the Puntledge River caused declines in the number of salmon utilizing the Puntledge River to such an extent that it was considered necessary to build a hatchery to restock the river. In the estuary, some tidal marsh areas have been eliminated by some foreshore industries.

Proposals have been made to include measures in the development of plans to aid the preservation and restoration of the estuarine ecosystem. One such proposal is to collect sewage from Courtenay - Comox and from the Canadian Forces Base Comox and to discharge it through a deep outfall away from the estuary, so the area could be reopened for shellfish harvesting.

1. INTRODUCTION

1 (i) GENERAL

The Courtenay River estuary (includes Comox Harbour, latitude 49°41'N, longitude 124°59'W) and the Oyster River estuary (latitude 49°52'N, longitude 125°07'W) are located about 140 and 155 miles northwest of Victoria, respectively.

For the purpose of this report, the boundaries of the study area are as follows: the northern limit is delineated by the watershed of the Oyster River estuary (latitude 49°55'N, longitude 125°20'W); the southern limit is marked by Lymn Creek which flows into Deep Bay (latitude 49°27'N, longitude 124°49'W); the head-waters of the Puntledge and Browns rivers to the north and the Beaufort Mountain range to the south define the western limit. Hornby and Denman islands are also included in the study area (Figure 1.1).

Courtenay River, and its two major tributaries, the Puntledge and Tsolum rivers, have a combined total average flow of 57.3 cms (1,899 cfs). This system is the major source of freshwater flowing into Comox Harbour. The flow of the Puntledge has been regulated since 1913 when a dam was constructed on the northeast end of Comox Lake, 12.8 km (8 mi.) from the mouth of the Courtenay River. Additionally, much smaller streams flowing into Comox Harbour include the Trent River and Roy, Millard and Brooklyn creeks.

Comox Harbour, located at the northern end of Baynes Sound, is generally protected from open Strait of Georgia waters by Denman Island and to a lesser extent, Goose Spit. The entire harbour is said to be freshwater dominated. As no studies have been carried out to determine the extent to which fresh-water from any of the rivers flows into Comox Harbour, the

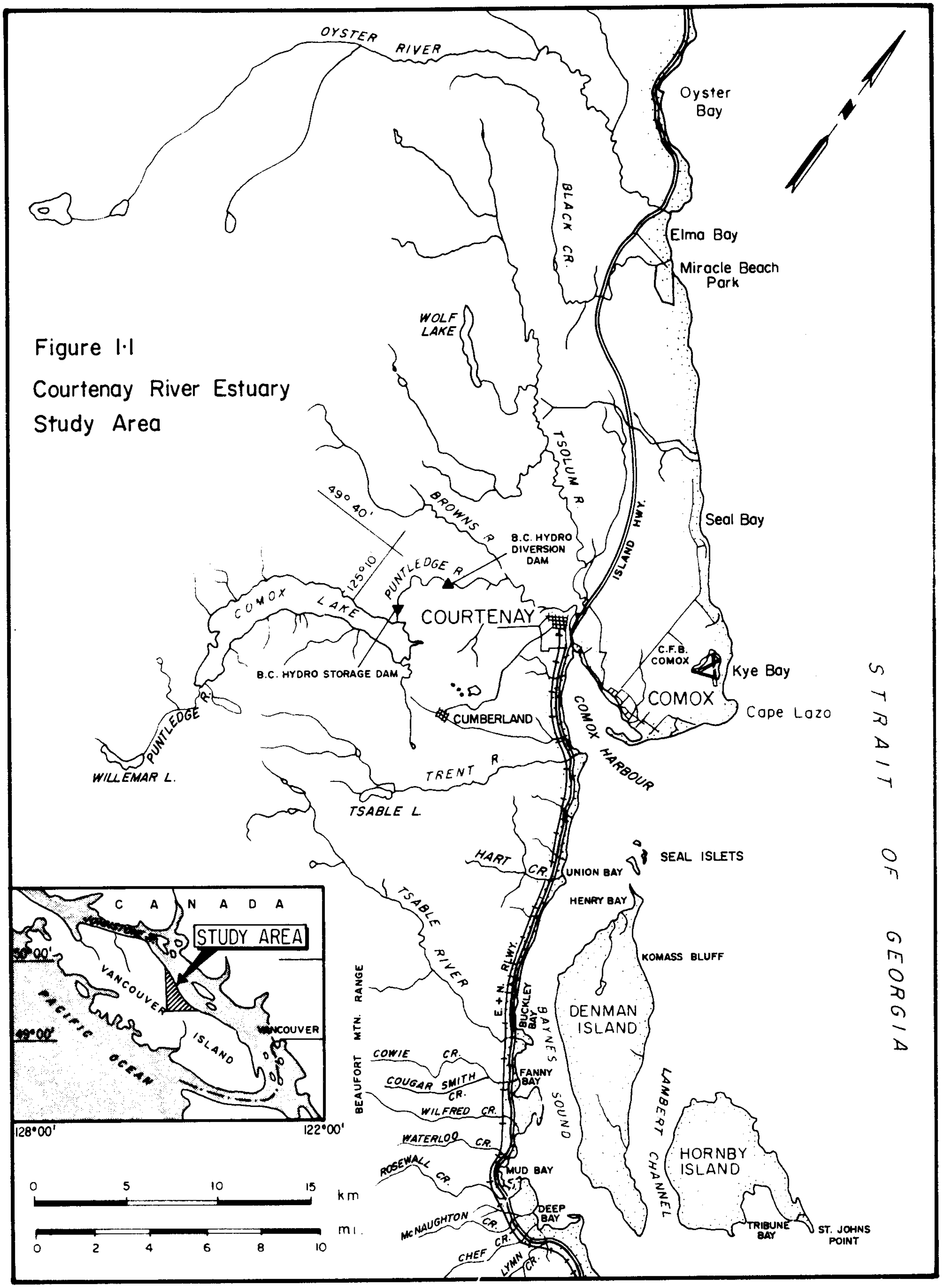


Figure 1·1
Courtenay River Estuary
Study Area

Courtenay River estuary and Comox Harbour are considered to be equivalent and so are used interchangeably throughout the report. Comox Harbour is classed as a positive estuary where the salinity in the harbour is lower than the adjacent sea resulting in a net seaward flow of freshwater. The large amount of freshwater draining into the harbour has produced a two-layer estuarine system, where a layer of brackish water (freshwater and saltwater) overlies a layer of salt water.

The boundaries of the city of Courtenay, the fourth largest city on Vancouver Island, encompasses an area of 620.8 ha (1,533 ac.). Approximately 7,500 people now live within these boundaries. Once a primarily agricultural and logging centre, Courtenay is now supported by the service industry, serving the Canadian Forces Base (CFB) Comox which provides direct or indirect employment for about one-third of the city's population, the forest industry and fishing. Farming occurs in the Tsolum River area and north of the Courtenay River delta.

Development is scattered along the shore of Comox Harbour. Log storage areas are located at Royston, Fields Sawmill, and near Goose Spit. Three wharves have been built in the harbour for the unloading of petroleum products and five marinas were built to cater to recreational boaters (Figure 1.2).

B.C. Land Management Branch is attempting to rationalize industrial growth in the estuary. Some of the present industries may be encouraged to move elsewhere. Log dumping did occur at Royston but has been phased out.

1 (ii) HISTORICAL PERSPECTIVE

Information on the history of Comox Valley is taken primarily from Stubbs (1975) and the Regional District Comox Strathcona (1975).

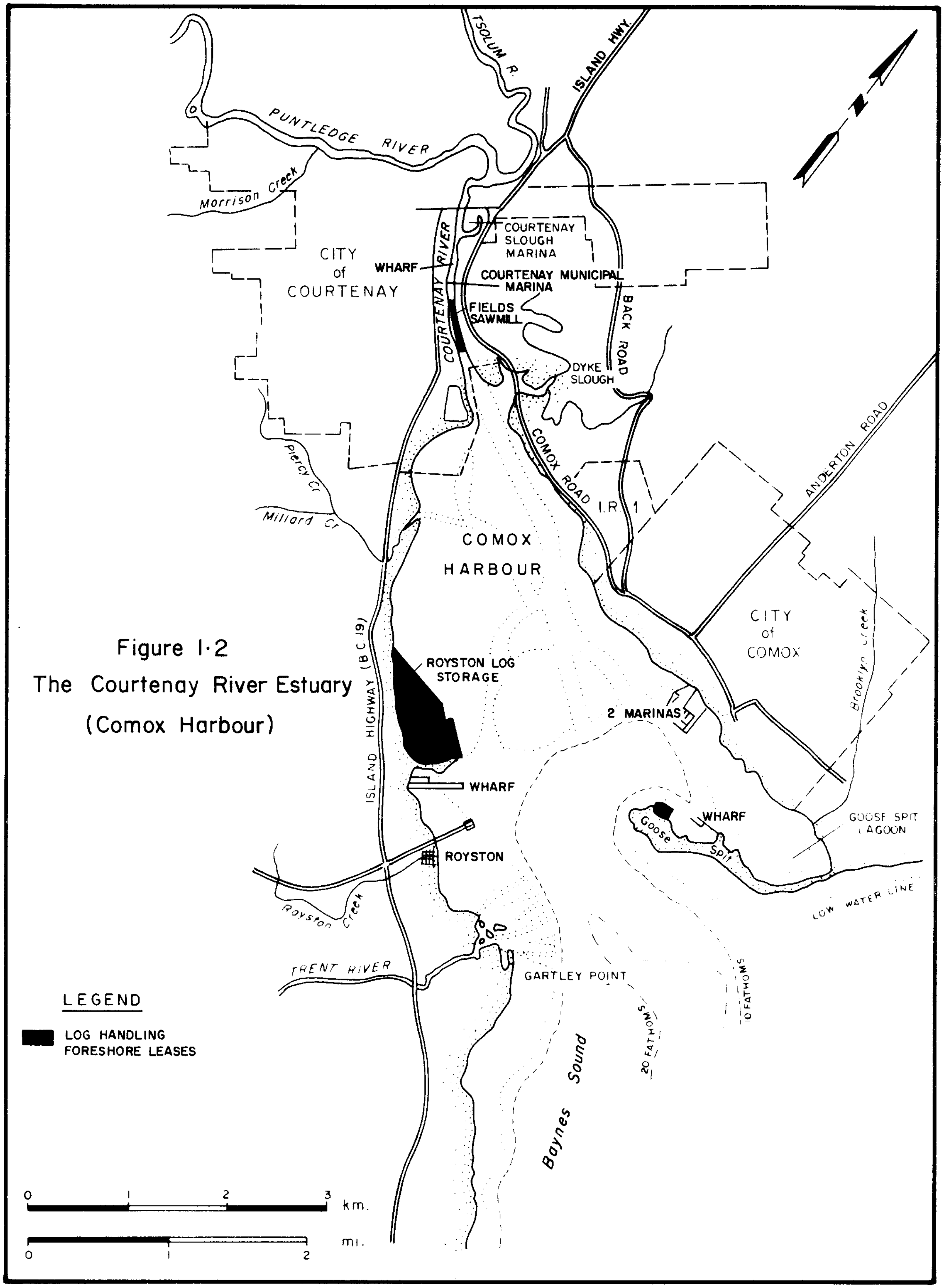


Figure 1·2
The Courtenay River Estuary
(Comox Harbour)

5. Introduction

The first settlers on the east coast of Vancouver Island, in the Courtenay area were Indians of the Salish nation known as the Comox tribe and later, before 1860, the Indians of the Kwakiutl nation known as the Pentlatch (Puntledge) tribe (Harding, 1958). The Comox tribe lived in a village on the east side of the mouth of the Courtenay River, where they lived off fish caught in Comox Harbour. Comox, meaning "plenty" or "abundance" was given to the Salish Indians by the Euclataw tribe to the north.

The Pentlach tribe settled between the Puntledge and Tsolum rivers and on Denman Island after they were driven south by the Euclataw Indians. Raids by the Alberni and Alert Bay Indians so severly reduced the numbers of Pentlatch Indians that their culture was eventually lost through intermarriage with the Comox Indians. Today these Indians, known as the Comox Band, live on reserves just west of Comox and at the junction of the Puntledge and Tsolum rivers.

The first survey of Comox Harbour was done by Captain Vancouver in HMS *Discovery*. A more indepth survey was completed by Captain Courtenay of the British Admiralty between 1846 and 1849.

The first white settlers came to Comox Valley in 1862 where they began growing vegetables. The first cattle were brought into the area in 1863 (Stubbs, 1975). The following year logs, seeds and more cattle were shipped to the valley. Agriculture later became the predominant occupation of the new settlers who established farms along the Tsolum River.

A market for produce developed when miners flocked into Cumberland in 1899 to mine newly discovered coal deposits (Stubbs, 1975). In 1901, the Comox Valley Co-operative Creamery was built to package milk and make butter. A meat and produce co-operative was also constructed to meet growing demands. Both the completion of the Island Highway in 1910 and the Esquimalt to Nanaimo (E and N) railway, extended to Courtenay in 1914, stimulated production by expanding the market area to include southern Vancouver Island. Agriculture still continues at a modest level.

Coal mining began in the study area when the Baynes Sound Company first began mining near Tsable River between 1865 and 1876 (Regional District of Comox-Strathcona, 1975). A drop in the coal market forced the company to close. The Union Colliery Company, that bought the Baynes Sound Company, opened a mine in 1889. By 1900, five more mines were active. With the development of these mines, up to 10,000 miners had settled in Cumberland. The Union Colliery Company was purchased in 1910 and became known as Canadian Colliery Limited.

Prior to the completion of the E and N Railway to Courtenay, all coal was transported by an "eleven mine railway" from Cumberland to the offloading wharves at Union Bay (Apps, 1958). Some of the coal was then processed into coke tons, much of which was shipped to the Crofton and Ladysmith smelters.

Between 1888 and the closure of the Tsable River mine in 1966, 18,597,600 tonnes (20.5 million short tons) of coal were removed from Cumberland. This represented 30% of the coal mined on Vancouver Island (Regional District of Comox-Strathcona, 1975). The most productive years occurred between 1902 and 1924. In 1911, the peak year for coal production, 572,327 tonnes (488,725 short tons) were mined. Number 4 mine, at the east end of Comox Lake was the richest, producing a total of 10,866,400 tonnes (12 million short tons) of coal.

With the increasing utilization of oil, the market for coal declined, and further exploration for coal deposits in the area ceased. Some potential for other minerals like copper, however, exist in the upper reaches of the Courtenay River drainage basin.

With the influx of settlers to the Courtenay area, the demand for lumber increased. In 1872, the first sawmill was constructed between present day First and Fourth steets (Haas, 1958). Another sawmill was built in 1883 - 1884 to supply miners in the Cumberland area with lumber. The timber was supplied from the first logging camp which was established in 1880 near the confluence of Dove Creek and Tsolum River.

Other logging camps were built shortly afterwards. By 1882, one camp was operating at the mouth of the Trent River and another at Union Bay (Regional District of Comox-Strathcona, 1975). A total of five logging camps were operating by 1883, including those at Mud Bay and Williams Beach. The logs from the mills were transported by water. Some of the forest products destined for other ports were moved by the S.S. Beaver, a coastal paddle wheeler.

By 1904, new sawmills in the study area were producing lumber for the expanding coal mining communities in the area. The lumber was transported by the first logging railroad north of Nanaimo, built in the Courtenay vicinity. In 1906, the Chemainus Logging Company, later known as the Comox Logging and Railway Company, began logging in the Headquarters Creek area. The company constructed the town of Headquarters in 1911. A railway built from Headquarters to Royston moved 1 MM fbm of lumber to the Canadian Collieries track where these forest products were unloaded at Union Bay for shipment by sea to markets abroad.

Logging operations were expanded to include the Tsolum River, from Courtenay to Wolf Lake, up the Puntledge to Comox Lake and an inland camp at Oyster River (Regional District of Comox-Strathcona, 1975). Eventually, all logging camps were phased out of the valley. As moving lumber by truck became more economical than shipping it by rail, Comox Logging and Railway Company sold their locomotives and had removed all their tracks by 1953. The Comox Logging and Railway Company was sold to Crown Zellerbach in 1954.

Both logging and sawmilling are major mainstays of the city of Courtenay today. Logs are now transported on trucks or in rafts by tugs.

To provide an alternate route to marine shipping the first section of the E and N Railway was completed to Nanaimo in 1886 (Stubbs, 1975). The Canadian Pacific Railway bought the E and N Railway in 1906. The line was extended to Courtenay in 1914 to service this part of Vancouver Island. In the near furture, the railway may be closed because alternate means of transport are more efficient.

2. GEOLOGY AND SOILS

2 (i) GENERAL GEOLOGIC HISTORY

The Cretaceous rocks of Vancouver Island attracted attention more than a century ago. The discovery in 1849 of British Columbia's first mineral resource, coal, brought into prominence the formation in which it was found, and scientific studies of the Cretaceous formations began.

In 1857 Newberry established the Cretaceous age of the coal bearing strata on the basis of its plant fossils. Paleontological studies were carried out for the Geological Survey of Canada as early as 1874 by Whiteaves (1879, 1895).

The earliest geological explorations in the vicinity of the Courtenay estuary were made by Richardson (1872, 1873, 1878). His investigations were confined to the coal-bearing formations of the east coast of Vancouver Island, and he named the narrow strip of upper Cretaceous rocks, between Campbell River and Bowser, the Comox Basin after Comox Harbour (now the city of Courtenay), at that time the nearest settlement to the coal deposits.

A reconnaissance geological survey of the northern part of Vancouver Island was carried out in 1885 for the Geological and Natural History Survey of Canada by Dawson (1887), whose report includes a description of the coastal geological formations between Comox Harbour and Oyster Bay.

This early research provided much general information for the geologists and paleontologists who carried out more detailed explorations of the coal bearing strata between Comox and Campbell River. Clapp (1912), whose work has become established as a standard reference on the Nanaimo Group, established and named the succession of formations in the Nanaimo area. McKenzie (1922) continued Clapp's work and investigated the coal measures in the Cumberland area.

Usher (1949, 1952) and McGugan (1962, 1964) made detailed studies of the marine fossils associated with the Upper Cretaceous rocks of the region. Bell (1957) described the non-marine fossil plants of the Nanaimo Group. Their work was followed by the most definitive of all the studies on the geology of the Upper Cretaceous Nanaimo Group, namely that of Muller and Jeletzky (1970).

2 (ii) BEDROCK GEOLOGY

East-central Vancouver Island, including the study area, consists of basins of soft shale, sandstone and conglomerate lying on a basement of basic volcanic rocks, sedimentary rocks and bodies of granitoid plutonic rocks.

The basin sediments, collectively named the Nanaimo Group, underlie most of the coastal lowland and in particular the Comox Basin. These Mesozoic sediments are of Late Cretaceous age (Appendix 2.1) and include both marine and non-marine beds. Their structure and mode of deposition has been described by Buckham (1947).

Basement rocks comprised of Karmutsen Formation volcanics (basalt), overlying Upper Triassic sediments (argillite and limestone), are exposed in the Beaufort Range in an area extending from the eastern end of Comox Lake to its western extremity, and to the headwaters of the Tsable River in the south and the Oyster River in the north.

The geology of the Comox Lake Area has been mapped by the Geological Survey of Canada at a scale of one inch to two miles by J.E. Muller (1965). This map includes an excellent set of descriptive notes and a short bibliography. An "Open File" map of the geology of Vancouver Island at a scale of one inch to four miles (Muller, 1977) includes the Courtenay-Comox region, as well as a comprehensive table of the rock formations of Vancouver Island.

For a detailed study of the geology of the Upper Cretaceous Nanaimo Group, including a discussion of the stratigraphy, biochronology, paleogeography and structure, the reader is referred to Muller and Jeletzky (1970).

2 (iii) SURFICIAL GEOLOGY

The surficial geology of the coastal lowland of eastern Vancouver Island has been mapped and described in detail by Fyles (1963). A map of the study area (GSC Map 32-1960) at a scale of one inch to one mile is available. The mapped area includes Denman Island and the Tsable River, Comox Lake, Comox Harbour and lower Tsolum River areas. The surficial geology of upper Tsolum River and the Oyster River area is shown on the Oyster River map sheet (GSC Map 49-1959).

Thick unconsolidated deposits in the coastal lowland record two periods of glaciation with an intervening period of nonglacial activity. Part of the "standard" succession proposed by Fyles (1963) as the basis for the stratigraphic subdivision of the surficial deposits of the study area, is shown in Table 2.1.

The origin and nature of these deposits have been described in detail by Fyles (1963). In the Comox-Courtenay

Table 2.1 Stratigraphic subdivisions of surficial deposits found in the study area (based on Fyles, 1963)

Stratigraphic Unit	Composition	Max. Thickness Metres (Feet)
Salish Sediments (Postglacial deposits)	gravel, sand, silt, clay and peat related to present sea, river and lake levels	24 (80)
Capilano Sediments (Postglacial deposits)	gravel, sand, silt and clay of marine lacustrine and fluvial origin, related to former (higher) sea, river and lake levels	
Vashon Drift (Glacial deposits associated with the last period of regional glaciation of southwestern B. C.)	till, glaciofluvial deposits of gravel and sand containing lenses of till	30 (100)
Pre-Vashon stratified sediments (nonglacial and proglacial strata)	white sand, horizontally stratified, with local beds of gravel	75 (250)
	silt and fine gravel	8 (25)
	clayey silt containing stones and marine shells	24 (80)

area, his "standard" succession is well exposed along Komas Bluff on the northeast side of Denman Island.

In the Comox area, the stratified deposits of sand and gravel above and below the Vashon till contain extensive aquifers, which are tapped by large-capacity wells to supply much of the water needs of the area.

The marine sediments of the Courtenay River estuary and adjacent waters were first investigated by Waldichuk (1953) and Cockbain (1962, 1963a, 1963b) while they were studying the bottom characteristics and distribution of sediments in the Strait of Georgia. The distribution and composition of the sediments of the Cape Lazo Gully (a depression extending from Cape Lazo to the northern end of Denman Island) have been studied in relation to the fishery resources of the area. Sheldon and Warren (unpublished) studied the relationship of the bottom sediments to local shrimp (*Pandalus jordani*) distribution, while Levings (1967) analyzed catches of black-belly eelpout (*Lycodopsis pacifica*) in relation to the modal grain diameter of sediments in the Cape Lazo Gully.

During 1974, marine sediment samples were collected by the Geological Survey of Canada in the vicinity of Comox Harbour and Denman Island, as part of a study of the Quaternary geology of the northern Strait of Georgia. A report by Clague (1975b) presents the results of the analyses of the sediments for particle size and organic and total carbon, and suggests some environmental and sedimentological implications of the analyses.

Discussing the effect of local current patterns and bathymetry, Clague points out that in some places in the northern Strait of Georgia, currents prevent the deposition of silt and clay down to depths of about 230 metres. However, silty clay and clayey silt are the dominant bottom sediments at water depths less than 50 metres southeast of Courtenay in an area separated from the Strait of Georgia by Denman Island and the shallow Comox Bar, which is mantled by sand and gravel.

The Comox Bar is submerged only a few metres at low tide, and may be the remnant of an eroded ridge of Pleistocene sediments that connected the Comox headland to Denman Island about 9,000 years ago (Mathews, Fyles and Nasmith, 1970).

Clague (1975b), also noted that in Comox Harbour, as well as in the vicinity of Powell River, some of the sediments have unusually high organic carbon content (up to 8 percent). Possible sources of the carbon suggested for the Comox-Courtenay area, include sewage, terrestrial vegetation marine organisms and relic carbon from coal mining in the area (discontinued in 1966).

Subsequently, Clague (1976) analyzed the sedimentary environments of the inner and outer estuaries of the Courtenay pattern of sediment distribution, between latitudes $49^{o}36'N$ and $49^{o}42'N$, and longitudes 124^{o} 46'W and 124^{o} 56'W. This area includes three major bathymetric elements described by Clague as follows:

" a shallow, flat-topped sill (Comox Bar) trending northwest-southeast between Vancouver Island and Denman Island, a trough (the inner trough) to the west of the sill with a maximum depth of 50 metres, and a trough (the outer trough) immediately east of the sill with a maximum depth of 100 metres."

The active delta of the Courtenay River estuary extends from Courtenay to about 1 km west of Goose Spit, a low-lying tongue of sand and gravel extending southwest from a headland near Willemar Bluff into the inner trough. Tidal flats of the delta are separated from the floor of the inner trough by a depositional front sloping up to 6 degrees.

Discussing sediment distribution and dispersal patterns, the author (Clague, 1976) again points out the close relationship of sediment distribution to bathymetry. The coarse sediments (sand and gravel) found in the shallower waters, probably originated from exposures of unconsolidated sediments in nearby coastal bluffs (Fyles, 1960, 1963; Clague, 1975a). The coarse sediments occurring on Comox Bar are believed to be lag deposits from Pleistocene sediments that once formed a continuous subaerial ridge between Vancouver Island and Denman Island.

Muds and sandy muds mantle the inner and outer troughs; seismic profiles (Clague, 1976) indicate that post-glacial sediments are up to 50 metres thick in the outer trough. The effects of the fresh water outflow from the Courtenay River and local currents on the distribution of sediments found in the inner and outer troughs were discussed by Clague (1976). His conclusions were based on oceanographical data collected by Waldichuk, Meikle and Markert, (1968), which include salinity and temperature measurements in the inner trough, and the direction and magnitude of currents at various water depths south of Goose Spit.

Clague (1976) also reported that trace metal concentrations in the sediments of the Courtenay-Comox area are generally comparable to those of other estuarine sediments in southwestern British Columbia, including those of the Fraser River delta. One interesting anomaly is the high concentration of lead in some Comox samples for which there is no known source. Similar concentrations have been found in the sediments of the Nanaimo River delta, and it is possible that they may be related in some way to the coal mining industry, active in the area until 1966, or possibly to residual lead from the shotgun pellets used by sportsmen during the duck hunting season.

Hay and Secter (1978) discussed the unique features of the Oyster River delta, in the northern sector of the study area and described studies undertaken to assess the feasibility and impact of a proposed 520 m (1700 ft.) navigation channel for small craft across the delta. Aerial photos taken in 1946, 1957, 1964, 1972 and 1975 showed some remarkable changes in the delta during this period. Evidence was presented also to show that the mouth of the river had been in at least one location south of the present mouth prior to 1946, and that a spit existed south of the present spit.

2. (iv) ECONOMIC GEOLOGY

The geology, history and potential of the Vancouver Island coalfields have been described in detail by James (1969) and Muller and Atchison (1971). A bibliography of the Nanaimo and Comox coalfields was prepared by Bickford (1975). Coal seams in the Comox Basin are confined to the Comox Format-ion of sandstone and shales, believed to have been deposited in a lagoonal environment, Muller and Atchison, (1971) (Table 2.2).

While coal seams have been found in drillholes in the Comox Formation from Oyster River in the north to Cowie Creek in the south (Fanny Bay), coal has only been mined economically in the Cumberland and Tsable River areas. Mining in the Comox coalfield commenced in 1888 with the opening of the Union Colliery, and ended in 1966 when the Tsable River Mine was finally closed. The best production years in the Comox field were from 1904 to 1921. A record was attained for the year of 1911, when 572,327 tonnes (488,725 short tons) of coal were produced. Of the total production from the Comox field, the Cumberland area produced some eighteen million tons and the Tsable River area two million (James, 1969). With increasing energy demands and newer extraction methods, the feasibility of resuming coal mining in the area is being considered (EPEC Consulting Western Ltd., 1975).

Table 2.2 Five sedimentary cycles of the Nanaimo Group rocks of Vancouver Island (Muller and Atchison, 1971)

Position In Cycle	Lithologies Present	Environmental Interpretation	Formations Represented
1	Fanglomerate Greywacke	Fluvial and Coastal deposits	Benson Member
2	Conglomerate Grit Sandstone	Deltaic and Shoreline deposits	Geoffrey De Courcy Extension Gabriola
3	Sandstone Shale Coal (plant fossils)	Shore bar and lagoonal deposits	Protection Wellington Member Comox
4	Siltstone Shale Sandstone (minor) (many thick-shelled fossils)	Nearshore marine deposits	Spray Northumberland
5	Thin-bedded siltstone shale turbidite sequence (many fossils, mainly ammonites)	Offshore marine deposits	Cedar District Haslam

Large deposits of sand and gravel, suitable for concrete aggregate and road building, are readily available in the study area east of Comox Lake between the Trent River and Browns River, and in the vicinity of Comox Airfield and Cape Lazo (Figure 2.1). Glaciofluvial deposits of the Vashon Strade of the Fraser Glaciation (Armstrong, Crandell, Easterbrook and Noble, 1965) have been mapped in the Courtenay area by Fyles (1960). Between Cumberland and Bevan, deposits of Vashon Drift underlie about 1,440 hectares (3,600 acres), and while the average depth of the deposits is not known, some pits show as much as 27 metres (90 feet) of sand and gravel. Leaming (1968) estimated the amount of sand and gravel contained in the Vashon deposits in this area to be 140 million cubic metres (180 million cubic yards), based on an average depth of 9 metres (30 feet).

In addition to the glaciofluvial deposits of Vashon Drift, Leaming (1968) described three main areas of terraced fluvial deposits of Capilano sediments located along the Tsable, Trent, Brown and Puntledge rivers. These deposits are estimated to contain 122 million cubic metres (162 million cubic yards) of sand and gravel. Marine deposits along the coast containing mostly silt, clay and sand have also provided a local source of sand and gravel in the Comox area. Several pits were opened to provide materials for runway construction at the Comox Airfield.

At the northern limit of the study area, extensive deposits of sand and gravel have been found along the Oyster River (Figure 2.2). The following is a description of two of the largest deposits (Leaming, 1968).

"The most extensive and continuous deposit of sand and gravel is the terraced fluvial gravels along the Oyster River. Gravel from an area of 320 hectares (800 acres) on the

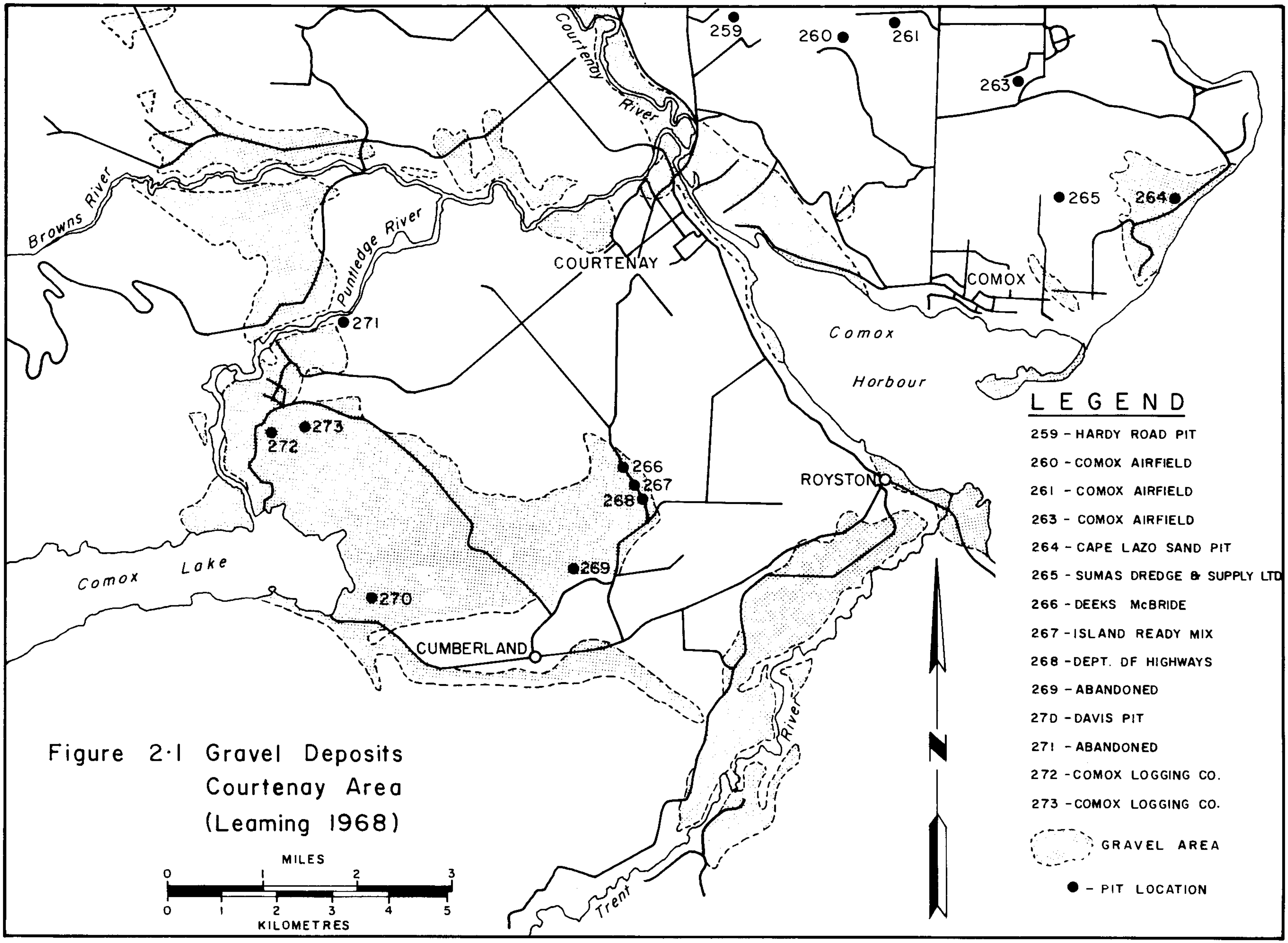


Figure 2·1 Gravel Deposits Courtenay Area (Leaming 1968)

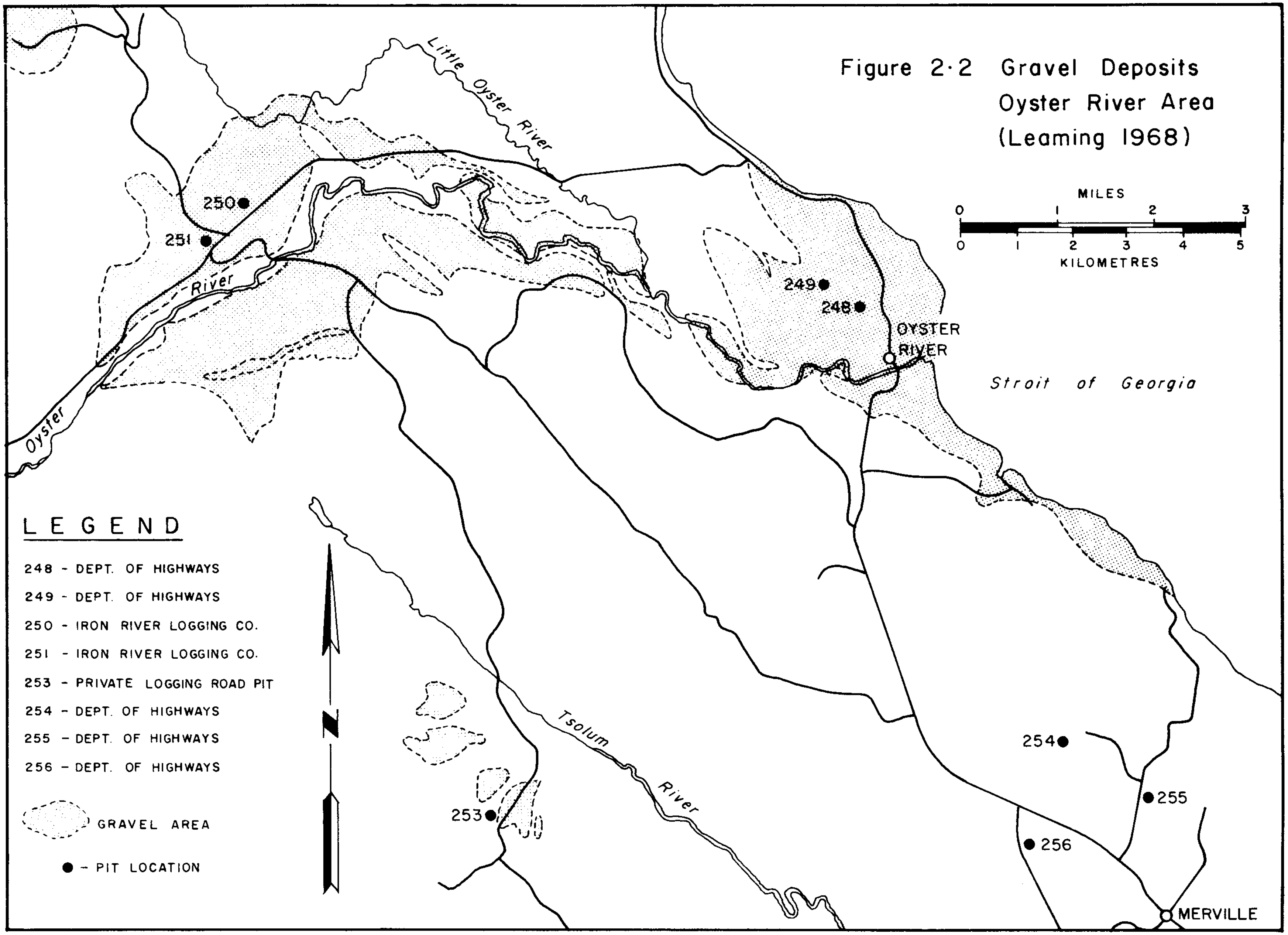


Figure 2·2 Gravel Deposits Oyster River Area (Leaming 1968) north side of Oyster River, west of Highway 19, has been used for highway construction. The full depth of the deposit has not been reached in any pit; the highest working face is 6 metres (20 feet) in a pit on the east side of the deposit. Using this as an average depth, the deposit would contain about 12 million cubic metres (16 million cubic yards).

Flanking Oyster River upstream from a point about 5 km (3 miles) from the mouth, an area of about 1,554 hectares (6 square miles), is underlain by fluvial deposits of Capilano gravel in the form of delta terraces and channel fillings. Only two pits have been opened in this deposit, in one of which a face 18.5 metres (60 feet) high exposed north-dipping deltaic beds of fine to medium gravel. The deposit is estimated to contain at least 150 million cubic metres (200 million cubic yards) of sand and gravel".

2 (v) SOILS

For a detailed description of the soils in the Courtenay-Comox area, the reader is referred to Report No. 6 of the British Columbia soil survey of southeast Vancouver Island (Day, Farstad and Laird, 1959).

This survey was carried out by the Research Branch, Canada Department of Agriculture in co-operation with the University of British Columbia and the British Columbia Department of Agriculture, and includes a detailed map sheet of the Courtenay to Campbell River area, at a scale of one inch to one mile. It is presently the most comprehensive reference available on soils in the study area, and with a compendium of soils of Vancouver Island compiled by the Research Division, British Columbia Forest Service (Keser and St. Pierre, 1973a), forms the basis for the following summary.

On the east coast, between Comox and Oyster River, the predominant soils are the loamy sands of the Bowser-Dashwood Series. Generally not suited for agriculture, only a small percentage of these soils is cultivated for hay and pasture.

Fine silty loams of the Chemainus Series comprise the alluvial soils found along the banks of the Tsolum River and on the Courtenay River delta. These well drained soils are generally highly fertile and productive and are very desirable for agriculture. Potato growing and dairy farming are the main agricultural uses of land in the study area.

Qualicum soils, comprised mainly of gravelly, loamy sands are found in several areas north of Comox and east of Highway 19, and in an area bounded by Cumberland to the south, Comox Lake to the west and the Puntledge River to the north. These soils are submarginal for agriculture, but where cultivated, are used mainly for the production of crops such as strawberries and vegetables, for the early market.

3. CLIMATOLOGY

3 (i) GENERAL

The climate of the Courtenay River estuary is characterized by long, cool, relatively wet summers and short, mild and wet winters. The estuary lies in a transition zone between the cooler, wetter estuaries to the north and the warmer, drier estuaries to the south (Kendrew and Kerr, 1955). The relatively low temperatures limit the heat available for growing crops (B.C. Department of Agriculture, 1972). It is estimated that the total annual growing degree-days, as expressed by the amount and duration of temperature above the daily average of 5.6°C (42°F), is between 3,000 and 3,500 h. The estuary, classed as $1b_3$ is also expected to have about 150 frost free days. During the winter, the temperature of the coldest month never goes below -23.3°C (-9.9°F) and the snow cover is discontinuous.

Based on the Koppen classification system, the estuary exhibits a marine west coast climate (Cfb) having the following characteristics: (1) the mean daily temperature of the coldest month ranges between 18°C (64.4°F) and 0°C (32.0°F); (2) the mean daily temperature of the warmest month is below 22°C (71.6°F); and (3) there is no distinct dry season, the driest month of summer receiving more than 30.5 mm (1.2 in.) of precipitation (Trewartha, 1943).

The mountains of Vancouver Island and the mainland channel winds up and down the Strait of Georgia in a southeast and northwest direction. Strong southeast winds blow from the Strait of Georgia into Comox Harbour during the winter months, while predominately northeast winds blow through the Comox Valley in the summer months, As the Strait of Georgia begins to narrow to form Johnstone Strait, southeast winds start to ascend, thereby augmenting precipitation in the area. At Comox Airport, the maximum mean monthly precipitation is 212 mm (8.33 in.) in December and the minimum mean monthly precipitation is 28 mm (1.12 in.) in July (Canada Dept. of Environ., 1975b).

The influence of the Pacific Ocean ensures that the harbour experiences mild winters and cool summers. The mean daily temperatures in January and July are 2.1°C (35.7°F) and 17.3°C (63.2°F), respectively. With an extreme maximum of 34.4°C (94°F), and an extreme minimum of -21.1°C (-6°F). The annual frost-free periods extends over 180 days between April 24 and October 22 (Hemmerick and Kendall, 1972). An estimated annual average of 1,650 h. of sunshine are thought to occur in the Comox Harbour area.

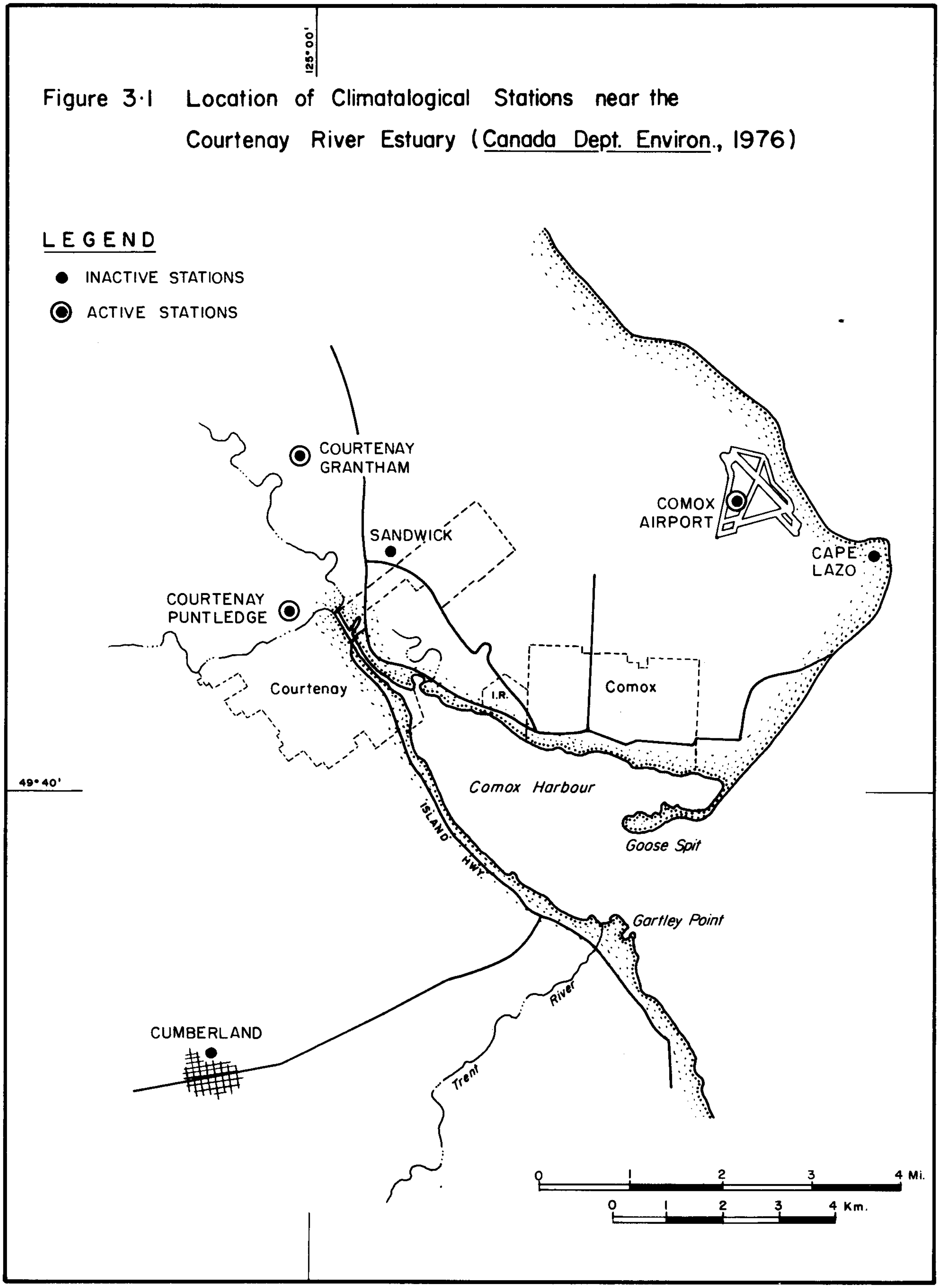
Near Union Bay, the climate changes to cool summer Mediterranean (Csb) due to somewhat drier summers while a Humid Continental Cool Summer (Dfb) climate exists in the surrounding mountainous regions. The criteria for these two climates is found in Trewartha (1943).

3 (ii) CLIMATOLOGICAL STATIONS

Although there are no meteorological stations recording data by Comox Harbour, six stations are located within a six mile radius of the harbour (Figure 3.1). Three of these are no longer operational. Cumberland first began recording precipitation in 1893. From 1922 to 1977, precipitation and temperature were noted at the Cumberland station. Sandwick registered precipitation between 1914 and 1943 while Cape Lazo recorded precipitation between 1935 and 1962.

Both the Courtenay Grantham and the Courtenay Puntledge stations measure precipitation while Comox Airport

Figure 3·1 Location of Climatalogical Stations near the Courtenay River Estuary (Canada Dept. Environ., 1976)



records rainfall, temperature, wind speed and direction, air and vapour pressure, cloud cover and visibility.

The Canada Dept. Environ. (1973) noted that the climate of the Courtenay River estuary is best represented by data collected at Comox Airport. Data have been summarized in Table 3.1.

A list of all the climatological stations in the study area is given in Table 3.2. Publications summarizing meteorological data from these stations are found in Table 3.3.

3 (iii) TEMPERATURE

Temperatures in the study area are primarily influenced by the Pacific Ocean. The distinguishing features of an ocean-dominated climate are mild winters, cool summers, long transitional seasons and small ranges in temperature.

The thirty-year (1941 - 1970) mean daily temperatures, recorded at Comox Airport, showed a difference of only 15.2°C (27.5°F) between the mean daily minimum temperatures reported for January (2.1°C, 35.7°F) and July (17.3°C, 63.2°F). The mean daily minimum temperature was -0.8°C (30.5°F) for January, while the maximum was 22.8°C (73.0°F) for July.

Altitude and sea breezes also modify temperatures (Kendrew and Kerr, 1955). While no significant differences can be found, the mean daily minimum temperatures for Cumberland (159 m, 523 ft. asl) were consistently lower than those at Comox Airport (22 m, 75 ft. asl) (Canada Dept. Environ., 1971b). Between 1941 and 1970, the mean daily minimum temperatures for Comox Airport were 1.9°C (35.5°F) in January and 11.9°C (53.5°F) in July, while for Cumberland they were -2.7°C (27.1°F) in January and 9.8°C (49.6°F) in July.

Table 3.1 Summary of the mean climatic characteristics at the Courtenay River Estuary (1941-1970) (Canada Dept. Environ. - Atmospheric Environment Service, 1975b).

COMOX AIRPORT		
Precipitation (mm, inches)		
Mean annual total precipitation	1206.5mm	47.50 in.
Mean annual rainfall	1101.0mm	43.35 in.
Mean annual snowfall	106.2cm	41.80 in.
Temperature (°C, °F)		
Mean Temperature - Annual	9.3° C	48.8°F
Mean Temperature - January	2.1° C	35.7°F
Mean Temperature - July	17.3° C	63.2°F
Extreme maximum temperature	34.4° C	94.0°F
Extreme minimum temperature	-21.1° C	-6.0°F
Annual Number of Days with measurable:		
Precipitation	160 days	
Rainfall	14 days	
Snowfall	152 days	
Wind		
Prevailing wind direction by hours	southeast	
Prevailing wind direction by miles	southeast	
Mean annual wind speed	11.9km/h	7.4 mph
Annual Number of Days with:		
Frost	77 days	
Thunder	3.1 days	
Frost Free Period		
April 24 - October 22	180 days	
Average Annual Hours of Sunshine	1,650 h (approximate)	
Cloud Cover		
Mean annual cloud cover	6.6 tenths	
Month with least cloud cover - July	4.8 tenths	
Month with greatest cloud cover - December	8.1 tenths	
Fog - Defined by a visibility of less than 5/8 of a mile		
Annual number of days with fog	17.8 days	
Month with greatest average - October	4.6 days	
Month(s) with least average - April-July	0.2 days	

Table 3.2 Available meteorological data from climatological stations serving the study area, (Canada Dept. Environ., 1976).

---

1. Oyster River: 49°52'N, 125°08'W, elevation unknown.

Temperature and Precipitation:	May 1949-Jul. 1955

2. Oyster River UBC Experimental Farm: 49°53'N, 125°08'W, 11 m (36 ft.) asl

Precipitation	Apr. 1967-May 1967
Temperature and Precipitation	June 1967-continuing

3. Cape Lazo: 49°42'N, 124°52'W, 38 m (125 ft.) asl

Temperature and Precipitation	Nov. 1935-Sept. 1940
	Feb. 1941-Dec. 1942
	Jul. 1943-Aug. 1962
Hourly weather reports	Jan. 1955-Aug. 1962

4. Comox Airport: 49°43'N, 125°54'W, 24 m (75 ft.) asl

Temperature and Precipitation	July 1944-continuing
Hourly weather reports (pressure, humidity, cloud cover, visibility, wind, etc.)	Jan. 1944-continuing
Wind Mileage (recorder)	Sept. 1944-Sept. 1959
Rate of Rainfall	May 1962-continuing

5. Courtenay Grantham: 49°45'N, 125°01'W, 35 m (110 ft.) asl

Precipitation	Jan. 1960-Oct. 1972

Location changed to: 49°46'N, 125°00'W, 81 m asl

Precipitation	Nov. 1972-continuing

6. Courtenay: 49°41'N, 125°02'W, 24 m (80 ft.) asl

Precipitation	Jul. 1921-Jul. 1925
	Jan. 1930-Mar. 1964
Rate of Rainfall	Apr. 1964-continuing

Note: 1970 name changed to Courtenay Puntledge.

Table 3.2 (cont'd.)

7. Sandwick: 49°45'N, 125°03'W, 46 m (150 ft.) asl

Precipitation	Oct. 1914-Jul. 1943

8. Cumberland: 49°37'N, 125°02'W, 159m (523 ft.) asl

Precipitation	Nov. 1893-Dec. 1900
Temperature and Precipitation	May 1922-Oct. 1959
	Jan. 1960-Feb. 1970
	Apr. 1971-Nov. 1976
	Apr. 1977-May 1977

9. Denman Island: 49°31'N, 124°49'W, 35 m (115 ft.) asl

Precipitation	Sept. 1906-May 1909
	Apr. 1910-Nov. 1955
Temperature and Precipitation	Jan. 1960-Dec. 1965

10. Hornby Island: 49°30'N, 124°39'W, 12 m (39 ft.) asl

Precipitation	intermittent 1907-1911
	Feb. 1911-Oct. 1937
	intermittent 1939-1940

Location changed to: 49°32'N, 124°36'W, 6 m (18 ft) asl

Precipitation	Apr. 1964-May 1964
Temperature and Precipitation	May 1967-Sept. 1970

11. Mud Bay FRB: 49°28'N, 124°47'W, 11 m (36 ft) asl

Temperature and Precipitation	April 1971-continuing

Table 3.3 Courtenay - Comox area climatological stations and reference sources.

DATA	PUBLICATION	SOURCE
Temperature and Precipitation	British Columbia means for the period 1941 - 1970 and extremes up to 1970	Can. Dept. Environ., 1971 Atmos. Environ. Serv.
	Climatic normals 1941 - 1970 Extremes of record	B.C. Dept. of Agric., 1971 (compiled from Atmos. Env. Serv., data)
Temperature, Sunshine and Precipitation	Summary of monthly and annual means	B.C. Dept. of Agric. (Published annually) (compiled from Atmos. Env. Serv., data)
Temperature, Wind and Precipitation	Canadian Normals Vol.1 Temperature (1941-1970) Vol.2 Precipitation (1941-1970) Vol.3 Wind (1955-1972)	Can. Dept. Environ., Atmos. Env. Serv. (Downsview, Ontario)
Frost-Free Periods	Frost Data 1941-1970	Can. Dept. Environ., Atmos. Env. Serv. (Downsview, Ontario)
Sunshine	Daily Bright Sunshine 1941-1970	Can. Dept. Environ., Atmos. Env. Serv. (Downsview, Ontario)
Temperature, Wind, Precipitation, Vapour Pressure, Atmospheric Pressure, Cloud Cover, Visibility and Sunshine	Monthly record of meteorological observations in Canada includes daily observations and monthly summaries	Can. Dept. Environ., Atmos. Env. Serv. (Downsview, Ontario)

Strong daily sea breezes keep summer temperatures cool and winter temperatures moderate along the coast. A comparison of the mean daily temperatures recorded at Comox Airport and Cumberland between 1941 and 1970 shows a greater range between the maximum and minimum temperatures at Cumberland, which is located farther inland (Canada Dept. Environ., 1971b).

As Comox Harbour is located on the coastline, it probably experiences lesser extremes in temperature than Comox Airport.

3 (iv) WINDS

Winds in the Courtenay River estuary, as in the adjacent Strait of Georgia, are strongly influenced by the semi-Aleutian low-pressure cell (mean centre, about 30^{o}N, 145^{o}W). In the winter, the anti-clockwise circulation around the low pressure cell dominates the coastal wind regime, while in the summer the direction is reversed as the high pressure system builds northward. The mountains on Vancouver Island and the mainland act as barriers, forcing coastal winds to orient along the Strait of Georgia in a southeasterly - northwesterly direction. Based on hourly records of wind direction and speed from Comox Airport, southeast winds occur 23% of the time (Figure 3.2). Between October and April, 25 to 29% of the wind originates from the southeast (Figure 3.3).

Southwest winds are strongest for several reasons: (1) the pressure gradients which often precede the passage of storms from the Pacific are greatest during the winter; (2) the long unobstructed fetch over the Strait of Georgia; and (3) lack of protection from Goose Spit as it is low lying and without vegetation (Waldichuk, MS,1962). During the winter months, the monthly mean wind speed ranges between 11.7 km/h (7.3 mph) in February and 13.8 km/h (8.6 mph) in December. The maximum hourly speed reported was 93.3 km/h (58 mph) (Canada

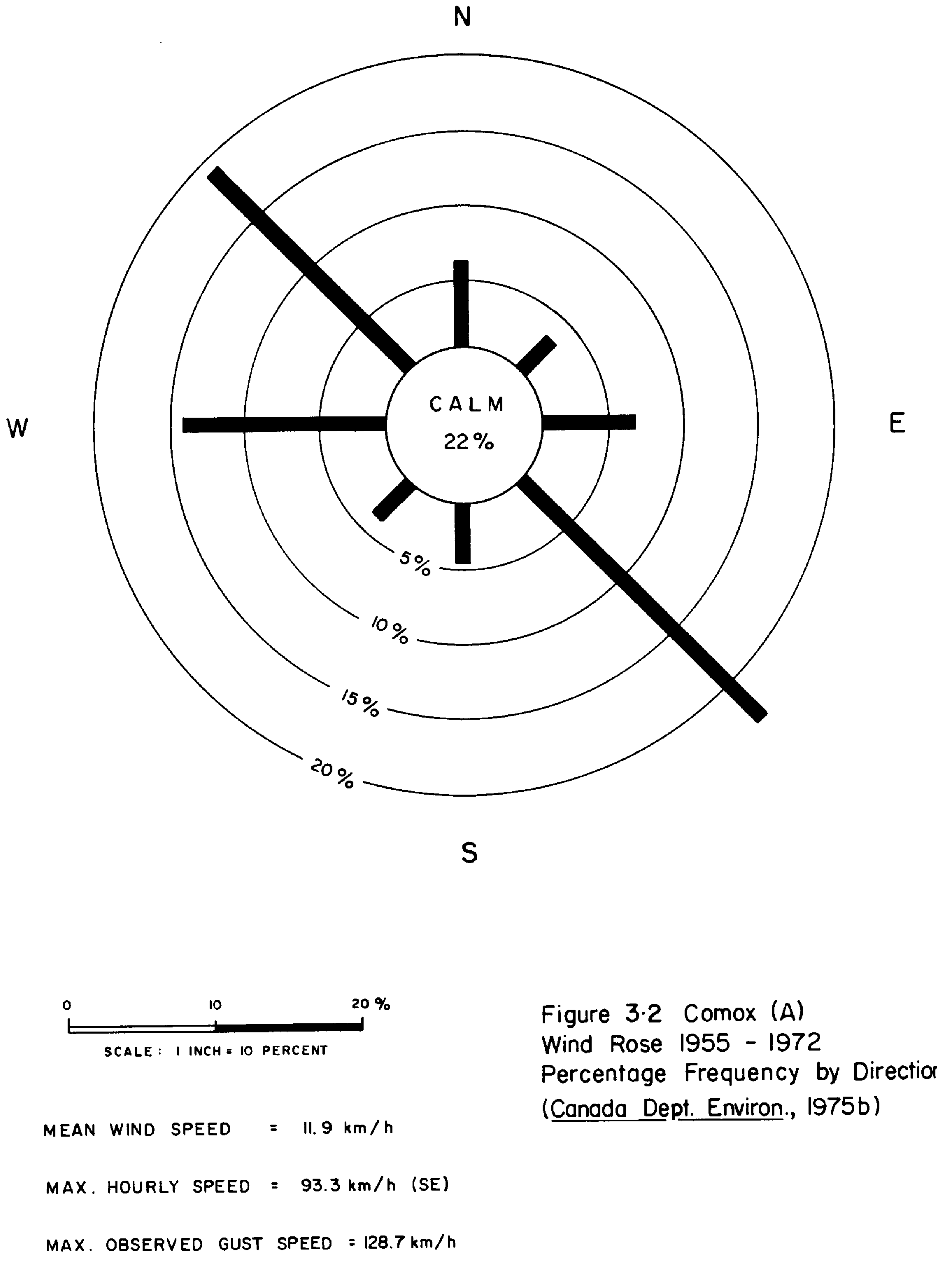


Figure 3·2 Comox (A)
Wind Rose 1955 - 1972
Percentage Frequency by Direction
(Canada Dept. Environ., 1975b)

	J	F	M	A	M	J	J	A	S	O	N	D
N	1	4	6	7	11	9	12	11	9	5	2	1
NE	0	2	4	4	6	5	5	5	4	2	1	0
E	5	6	7	8	9	9	7	6	5	6	6	5
SE	25	25	27	25	16	20	14	15	18	28	26	29
S	6	6	6	7	4	4	3	2	4	5	6	7
SW	4	3	3	3	4	3	2	2	2	2	4	5
W	19	13	13	11	12	10	10	12	13	12	15	19
NW	12	13	13	17	23	26	34	27	20	13	11	11
CALM	28	28	21	18	15	14	13	20	25	27	29	23
MEAN SPEED (km/h)	12.1	11.8	13.4	12.9	11.4	11.8	11.4	9.8	9.8	11.9	12.1	13.8

Figure 3·3 Comox (A) – Percentage Frequency Wind Direction (and Calms) and Mean Wind Speed by months for period 1955 – 1972. (Canada Dept. Environ., 1975b)

Dept. Environ., 1975b).

Throughout each year about 19% of the winds originate from the northwest. These winds occur most frequently (25% of the time) between May and September (Figures 3.2 , 3.3).

Vancouver Island coastal mountains act to decrease the speed of northwest winds in Comox Harbour (Waldichuk, MS, 1962). These winds are not substantially different during any season. Daily speeds vary between 12.1 km/h (7.5 mph) in August to 15.0 km/h (9.3 mph) in April.

3 (v) PRECIPITATION

Precipitation is influenced by wind direction and topography. Where the Strait of Georgia narrows in Johnstone Strait, moisture bearing southeast winds, predominant in the late fall to early spring, converge and ascend. Augmented by the condensation of water vapour produced by lifting, precipitation is greater in the northeast than in the southeast areas of eastern Vancouver Island.

The maximum mean monthly precipitation for the thirty-year period, 1941 - 1970, at Comox was 211.6 mm (8.33 in.) in December, while the minimum was 28.4 mm (1.12 in.) in July. The greatest amount of precipitation in 24 hours was 113.0 mm (4.45 in.) in December.

On the average, precipitation occurs on 160 days during a year. Between October and January, precipitation occurs an average of 19 days each month. Between May and August, an average of only 8 days each month receive precipitation (Canada Dept. Environ., 1971b).

Precipitation was also found to be heavier though no more frequent, closer to the Vancouver Island mountain range

(Nikleva and Emslie, pers. comm., 1978). The southeast winds from the Strait of Georgia, forced to rise over the Beaufort Range, condense producing more precipitation at higher elevations (Ferguson *et al.*, 1974). A comparison of the total precipitation for Cumberland, at 159 m (423 ft.) asl and for Comox Airport at 24 m (75 ft.) asl. shows that both rainfall and snowfall are greater at Cumberland (Canada Dept. Environ., 1971b).

3 (vi) OTHER CLIMATOLOGICAL VARIABLES

Variables like atmospheric pressure, vapour pressure, cloud cover and visibility are noted at Comox Airport.

The numbers of frost-free days per year were recorded at Cape Lazo, Comox Airport and Cumberland between 1941 and 1970. The data show that an average of 214 frost-free days were recorded between April 5 and November 7 at Cape Lazo, 180 days between April 24 and October 22 at Comox Airport and 148 days between May 16 and October 12 at Cumberland (Hemmerick and Kendall, 1971).

No records are available for sunshine. The Canada Dept. Environ., (1973) estimated that 1,650 h of sunlight occur annually at the Courtenay River estuary.

3 (vii) AIR POLLUTION POTENTIAL

The information below was supplied by Emslie (pers. comm. 1978).

The horizontal and vertical dispersal of pollutants is influenced by wind speed and direction, frequency of calms, the frequency of gound-based inversions and precipitation. Winds in the estuary are primarily from the southeast or northwest. During the summer in particular, these winds are modified by a sea breeze-land breeze diurnal cycle where east-southeast winds blow throughout the daylight hours and north-west winds blow overnight.

Calms are most frequent from sunset to several hours after sunrise, particularly in the autumn. During spring and summer days, calms are infrequent.

With adjacent ridges of high ground and the relatively cold water of the Strait of Georgia close by, Courtenay is an area where overnight and early morning surface-based inversions are frequent. Occurrences during the day are fairly uniform throughout the year, resulting from over-running warmer air in the fall and winter and the cooling of the surface air layer by the sea in spring and summer. The following table shows a percentage frequency during the four seasons of ground-based inversions in the late afternoon and early morning.

	Winter	Spring	Summer	Fall
P.M.	35	25	80	40
A.M.	70	75	88	80

In summary, there is effective horizontal and vertical dispersion of pollutants emitted during the day. Calm winds and a deep inversion could trap night-time emissions producing significant local concentrations of atmospheric pollutants.

Airborne pollutants are reduced by rainout particularly in the fall and winter. Approximately 1,270 mm (50 in.) of rain falls on about 50%, of the days adding these pollutants to the aquatic environment.

4. HYDROLOGY

4 (i) GENERAL

The Courtenay and Oyster river systems are the largest in the study area. The Courtenay River is formed by the union of the Puntledge and the Tsolum rivers which merge one and one half miles upstream from Comox Harbour (Figure 4.1). The Puntledge River drains an area of 582.8 sq. km (225 sq. mi.) while 258.2 sq. km (99.7 sq. mi.), are drained by the Tsolum River, resulting in a combined area of 841.8 sq. km (325 sq. mi.) contributing to the Courtenay River.

The Puntledge River is about 48 km (29.8 mi.) in length and originates from Puntledge Lake (1,560 m, 5,117 ft. asl), on the eastern slope of Forbidden Plateau. The river flows for about 12.9 km (8 mi.) in an easterly direction through Forbush (49 ha, 121.9 ac.) and Willemar (89 ha, 219.9 ac.) lakes before emptying into Comox Lake. The Cruikshank River and Boston and Perseverance creeks also feed the lake: The Puntledge River re-emerges from the northeastern corner of Comox Lake and flows northwest for about 8 km (5 mi.) before being joined by its largest tributary, the Browns River. The Puntledge River then flows for approximately 4.8 km (3 mi.) before merging with the Tsolum River.

The Tsolum River emerges from marshland near Blue Grouse Lake (457.2 m, 1,500 ft. asl) northwest of Courtenay. It flows for a total of 27.3 km (17 mi.). *En route*, the Tsolum River is joined by Murex, Headquarters and Dove creeks before combining with the Puntledge River.

Other small rivers flowing into Comox Harbour include the Trent River and Roy, Millard and Brooklyn creeks.

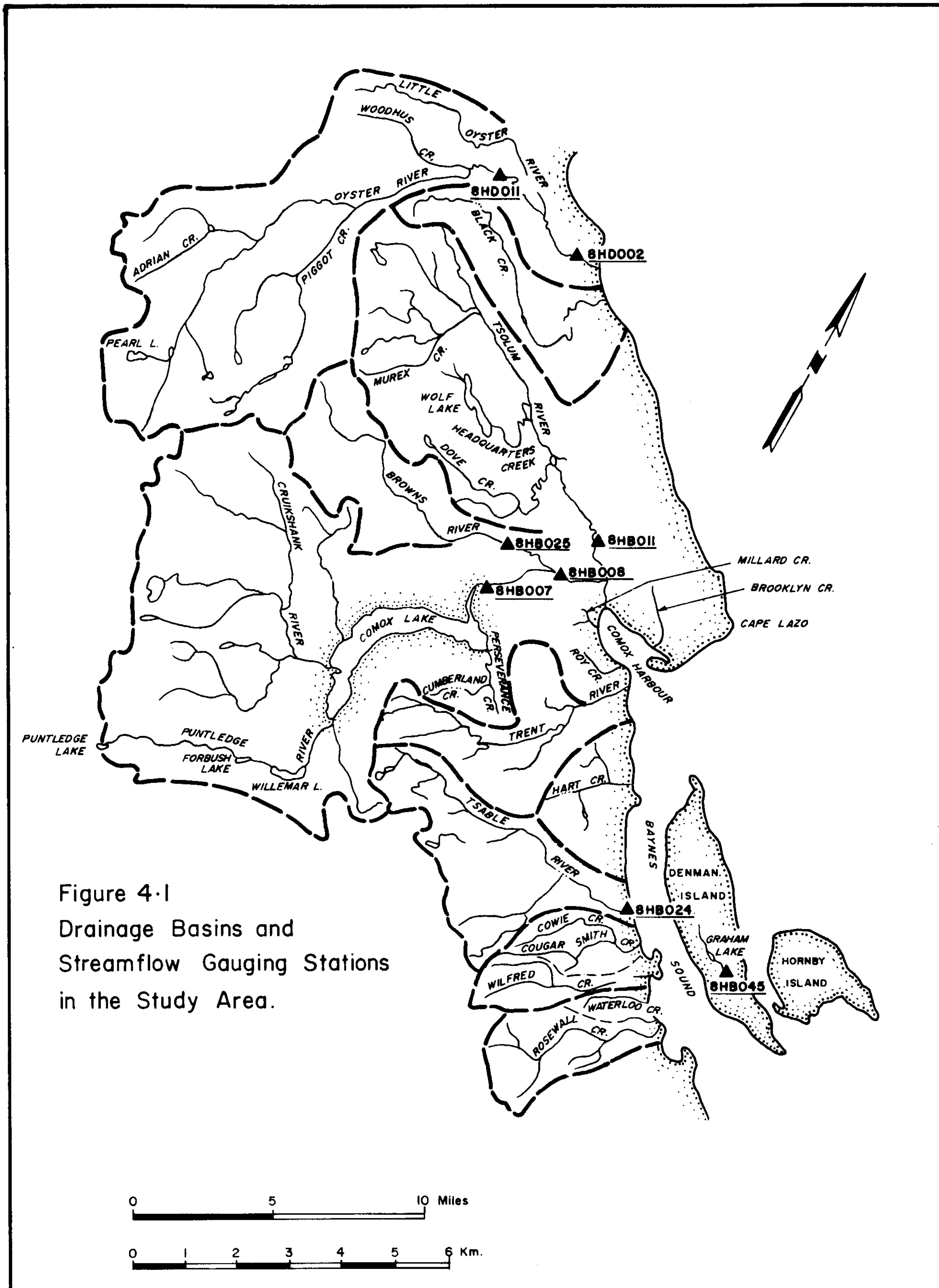


Figure 4·1
Drainage Basins and
Streamflow Gauging Stations
in the Study Area.

The Trent River originates in the Beaufort Range. The other streams emerge from the gently sloping land surrounding the harbour at elevations ranging between 45.7 (150 ft.) and 76.3 m (250 ft.).

The Oyster River, draining an area of 362.6 sq. km (140 sq. mi.), originates from Pearl Lake, in the Forbidden Plateau west of Courtenay. It flows northeast for 27.3 km (17 mi.) where it is joined by Piggot and Adrian creeks. Oyster River then flows for about 16 km (10 mi.) where it is fed by both Woodhus Creek and the Little Oyster River before emptying into the Strait of Georgia.

Other minor rivers in the study area include Black Creek, which flows into the Strait of Georgia, and the small rivers south of Comox Harbour, which originate in the Beaufort Range and empty into Baynes Sound. The largest of these, the Tsable River, has a drainage area of 112.7 sq. km (43.5 sq. mi.) and flows into Union Bay.

4 (ii) STREAMFLOW GAUGE STATIONS

Continuous streamflow data for rivers flowing into Comox Harbour and for Oyster River have been collected by the Water Survey of Canada (Canada Dept. Environ., 1974). Station 08HB011 on the Tsolum River near Courtenay has been operating continuously since 1964, while station 08HD011 on the Oyster River near Woodhus began recording in 1973. A station on the Trent River, near Royston, has recorded flow rates since 1971.

In the past, flow measurements were taken between about 1960 to 1972 from a station on the Browns River at Courtenay. A station on the Puntledge River near Cumberland, operated between 1914 and 1953. Data were also recorded at a station near the mouth of the Oyster River between 1914 and 1917. For additional information on these and other gauge stations in the study area, see Appendix 4.1.

4 (iii) RIVER FLOWS

Both lake storage and precipitation in the head waters influence the discharge of naturally-flowing rivers. Lake storage modifies both runoff and peak flows. Runoff is reduced by evaporation and seepage from the lakes while flows are higher in summer and lower in winter in rivers with lakes in the upper watershed.

Flows are also dependent on the slope of the terrain and the amount of streambank vegetation. Higher-than-normal flows, during heavy precipitation and lower-than-normal flows, during dry periods, occur in rivers draining steep sloping, sparsely-vegetated or logged-off areas (AESL, 1975).

The Oyster, Browns and Puntledge rivers, whose head-waters are located in Forbidden Plateau, receive an average precipitation of 2,540 - 3,180 mm (100 - 150 in.) per year (AESL, 1975). Only 1,524 - 2,540 mm (60 - 100 in.) per year fall on the Tsolum River watershed, as it originates at lower elevations.

The mean annual flow of the Courtenay River, the sum of the mean annual flows of the Puntledge and Tsolum rivers measured intermittently between 1914 and 1975, is 53.7 m^3/s (1,899 cfs) (Canada Dept. Environ., 1974).

The flow of the Puntledge River has been controlled by a hydro-electric dam since 1913. Water is diverted for the generation of hydro-electric power and for migrating fish. Under Water Licence Number 1919, a maximum of 28.3 m^3/s (1,000 cfs) can be diverted from the river to the power plant. The minimum amount of water that can be used by the hydraulic turbine in the plant is 19.1 m^3/s (675 cfs) (Marzocco, pers.

comm., 1978). The federal Fisheries and Marine Service has requested that an absolute minimum flow of 2.8 cms (100 cfs) be maintained below the diversion dam to facilitate upstream migration.

A summary of record-flow data for the Puntledge, Tsolum and Oyster rivers is seen in Table 4.1.

Hydrographs of the mean daily discharges for the Tsolum and Puntledge rivers between 1968 and 1977 and for the Oyster River, between 1973 and 1977, are seen in Figure 4.2. Peak river flows on the Tsolum and Puntledge rivers generally occurred between mid-October and mid-January and between mid-April and mid-July, following the snowmelt and subsequent spring runoff. Peak flows of the Oyster River occurred during November and December only.

4 (iv) FLOODS AND FLOOD CONTROL

Data on the maximum instantaneous discharge, the maximum daily discharge and the total annual discharge for the Puntledge, Tsolum and Oyster rivers, and plots of the probability of flooding by the Puntledge and Tsolum rivers is contained in the report entitled "The Magnitude of Floods in British Columbia" (Canada Dept. Environ., 1972b).

Flood probability curves for the Tsolum and Puntledge rivers (Figures 4.3 and 4.4) are based on the maximum daily mean flows recorded at stations 08HB006 on the Puntledge River and station 08HB011 on the Tsolum River.

No curves depicting the probability of a flood are available for the Oyster River at Woodhus, as the station has only been operational since 1973. Floods were observed in 1962, 1963, 1968 - 1970 and 1975 by Wright (unpublished).

Table 4.1

Flow records for the Puntledge (station 08HB006), Tsolum (station 08HB011) and Oyster (station 08HD011) rivers (Kreuder, pers. comm., 1979).

	PUNTLEDGE m^3/s (cfs)	date	TSOLUM m^3/s (cfs)	date	OYSTER m^3/s (cfs)	date
Mean annual discharge	42.6 (1,507.0)		11.7 (392.0)		15.1 (534.0)	
Max. daily flow	333.9 (11,800.0)	Nov.5/75	191.5 (6,770.0)	Jan.15/73	257.0 (9,180.0)	Nov.13/75
Min. daily flow	4.8 (170.0)	Oct.15/16	0.3 (1.1)	Aug.4/65	1.1 (39.5)	Nov. 4/74
Largest mean annual flow	50.6 (1,950.0)	1919	15.2 (545.0)	1968	16.9 (604.0)	1975
Smallest mean annual flow	29.7 (1,060.0)	1970	7.3 (262.0)	1970	11.3 (403.0)	1976
Max. mean monthly flow	138.8 (4,960.0)	Nov./75	43.9 (1,810.0)	Dec./66	55.1 (1,970.0)	Nov./75
Min. mean monthly flow	281.0 (526.0)	Mar./55	0.2 (7.2)	Aug./77	2.3 (80.2)	Aug./77

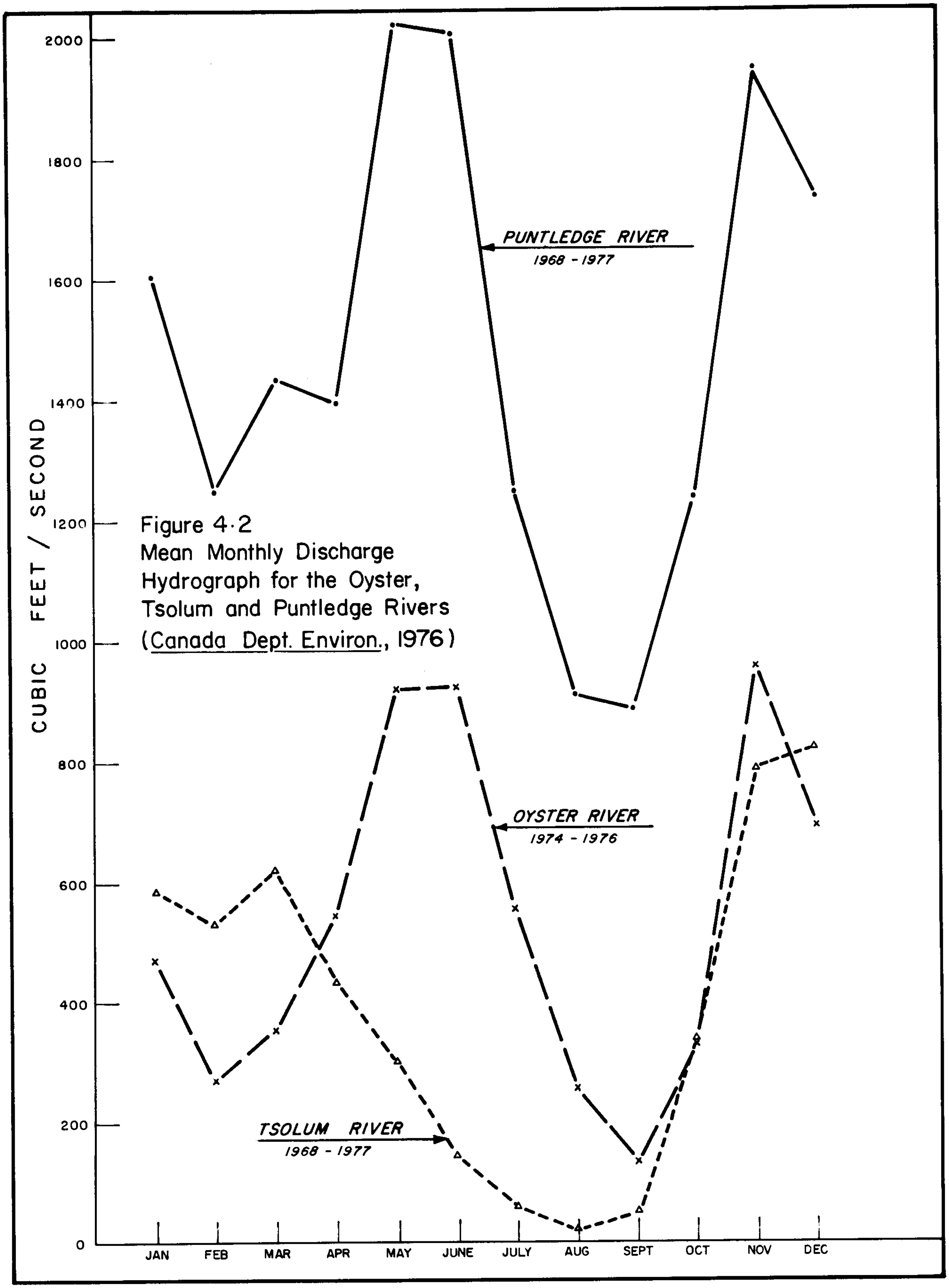


Figure 4·2
Mean Monthly Discharge Hydrograph for the Oyster, Tsolum and Puntledge Rivers
(Canada Dept. Environ., 1976)

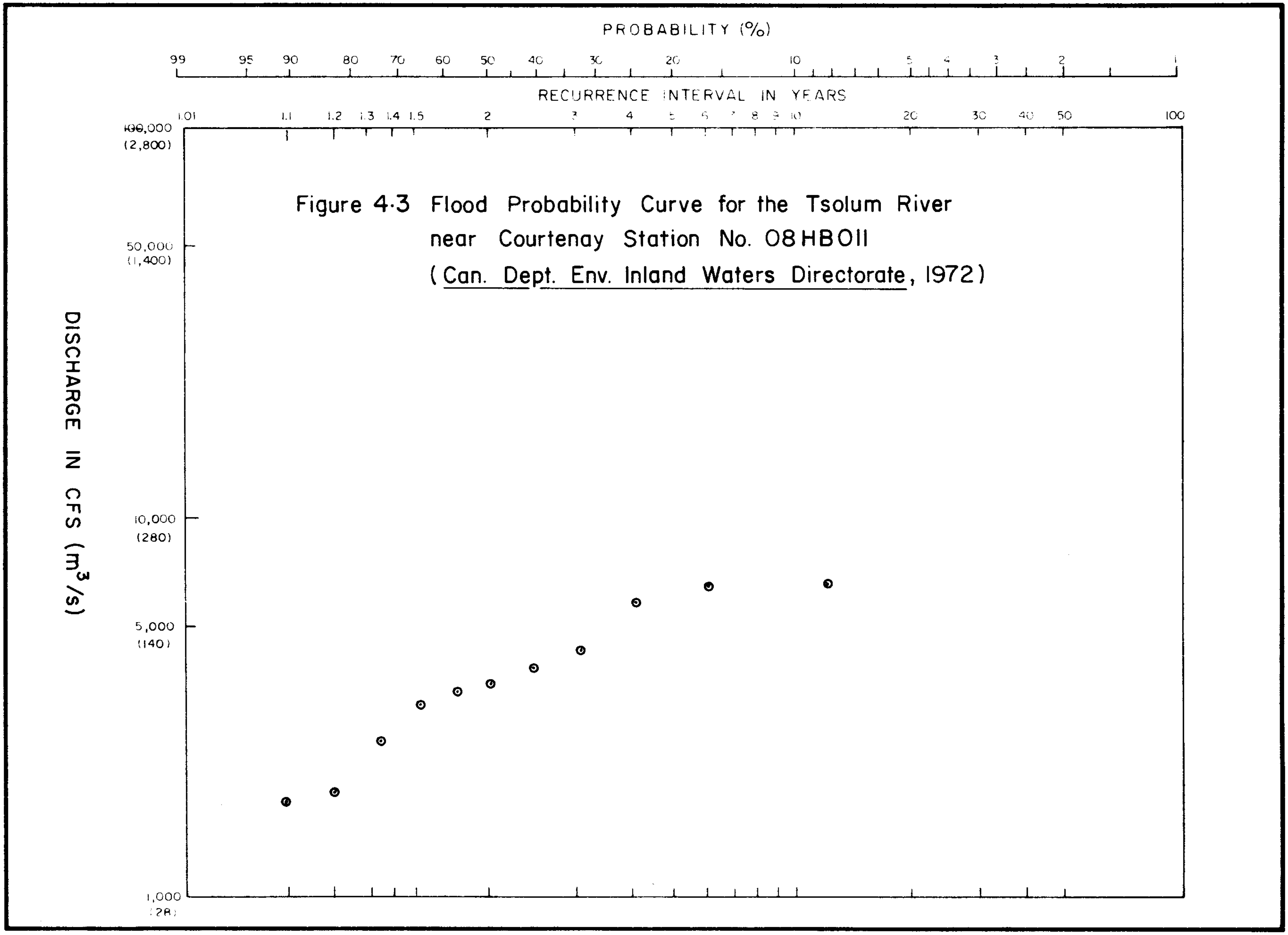


Figure 4·3 Flood Probability Curve for the Tsolum River near Courtenay Station No. 08HB011 (Can. Dept. Env. Inland Waters Directorate, 1972)

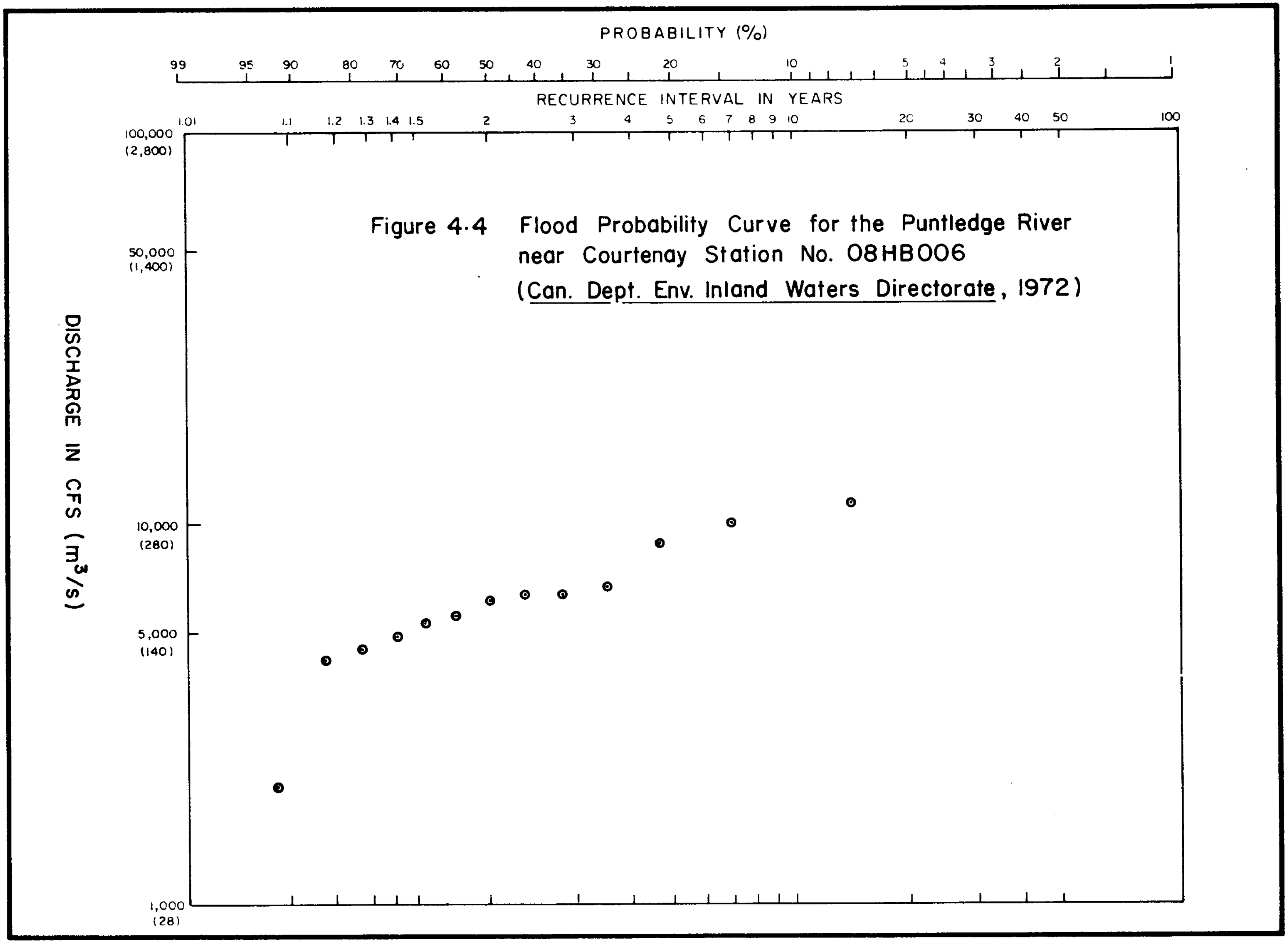


Figure 4.4 Flood Probability Curve for the Puntledge River near Courtenay Station No. 08HB006 (Can. Dept. Env. Inland Waters Directorate, 1972)

Procedures for flood control on the Puntledge River have been outlined by B.C. Hydro and Power Authority in their Operation Order No. 412 manual (1977). To determine the rate at which the Comox Lake water level will rise, the amount and texture of the snowpack in the watershed of the upper Puntledge and Cruikshank rivers are surveyed (Marzocco, pers. comm., 1978). During flood conditions, water is discharged from the impounding dam as outlined in Table 4.2. The discharge of water from the sluice gates is initially timed to avoid flood flows from the Browns and Tsolum rivers and high tides. Water released at the impounding dam takes one and three quarter hours to reach Courtenay.

Table 4.2 Volume of Water Discharged at Specific Levels of Comox Lake to Control Flooding (B.C. Hydro and Power Authority, 1977)

COMOX LAKE LEVEL (m, ft.) Oct. 1 - Mar. 1	Mar. 1 - Oct. 31	VOLUME OF WATER (m^3/s, cfs)
134.4m (441.0 ft.)	135.5 m (444.0 ft.)	begin spillage unless conditions warrant advanced spillage
134.4 - 135.5 m (441.0 - 444.0 ft.)	135.3 - 136.2 m (444.0 - 447.0 ft.)	169.8 m^3/s 6,000 cfs
135.3 - 136.2 m (444.0 - 447.0 ft.)	136.2 - 136.9 m (447.0 - 449.0 ft.)	198.1 - 283.0 m^3/s (7,000 - 10,000 cfs), depending on tide
136.2 m+ (447.0 ft.+)	136.9 m+ (449.0 ft.+)	28.3 m^3/s (1,000 cfs+) spilled in two hour intervals until controlled flooding occurs or the lake level declines.

+means plus

To determine when high and low tides will occur, the regional tide tables, produced annually by the Canadian Hydrographic Service, are consulted (see Oceanography Section).

During high tides, the flux of water results in an increase in the level of the Tsolum River as far as Maple Pool, near the intersection of the Island Highway and Ryan Road, and in the Puntledge River, as far as Condensory Bridge.

Following a flood in the Tsolum River in 1968, the river was surveyed and suggestions were made by the Water Investigations Branch for the stabilization of the river banks to protect against a flood of 283 m^3/s (10,000 cfs) (Robertson, unpublished). The proposals were not acted upon and more land was lost in a flood in 1974. Farmers with property bordering on the Tsolum River are now requesting bank stabilization and dyking again (Fuller, pers, comm., 1978).

Severe erosion of the Oyster River banks during the flood in 1975 prompted a survey of the river by the Water Investigations Branch. In March, 1976, 213 lineal metres (700 ft.) of river bank were stabilized on the lower part of the river (Brown, 1976). Rip rap bank protection totalling 1,324 lineal metres (4,345 lineal ft.) was constructed for three more sections of the stream. An additional 247 lineal metres (900 ft.) of dyke was built to prevent flooding over Glenmore Road. At the request of the B.C. Fish and Wildlife Branch, artificial pools were created and big boulders added to slow down river flow in order to aid migrating fish (Bond, pers. comm., 1978).

4 (v) POWER DEVELOPMENT AND FLOW DIVERSIONS

In 1913, Canadian Collieries (Dunsmuir) Limited constructed a storage and diversion dam on the Puntledge River to utilize the water for mining.

B.C. Hydro and Power Authority purchased the complex in 1953, and modified the discharge capacity at the impounding dam and the effective storage of Comox Lake. The sill elevation and maximum flood level are now 128.9 m (423 ft.) and 136.6 m (448 ft.), respectively. The normal maximum range of the level of Comox Lake is 129.2 - 135.3 m (424 - 444 ft.) (AESL, 1975). At the normal maximum elevation of 135.3 m (444 ft.), the discharge capacity is 226.4 m^3/s (8,000 cfs). The discharge at maximum flood elevation, 136.6 m (448 ft.) is 339.6 m^3/s (12,500 cfs) (Acres, 1973).

Comox Lake, the natural reservoir behind the dam is 14.5 km (9 mi.) long and covers an area of 197.8 ha (488.8 ac.). At its maximum depth, the lake is 128.9 m (428 ft.) deep (Canada Dept. Fish., 1958).

B.C. Hydro and Power Authority also constructed a wider and deeper intake approach channel and a new penstock at the diversion dam so that a maximum of 28.3 m^3/s (1,000 cfs) could be diverted from the Puntledge River to a newly constructed powerhouse (Acres, 1973).

The flow of Headquarters Creek is controlled by a dam built near its outlet from Wolf Lake. In 1964, the Canada Department of Fisheries constructed a control outlet gate which allows a maximum draw-down of 3 m (10 ft.) (AESL, 1976). The level of Wolf Lake was raised between 2.4 and 2.7 m (8 - 9 ft.). The lake is now 4.8 km (3 mi.) long, 152.4 - 457.2 m (500 - 1,500 ft.) wide and covers an area of 1.62 sq. km (400 ac.). Usable storage of about 394 x 10^4 cu. m. (32,000 acre-feet) is released at a rate of 0.7 m^3/s (25 cfs) in an effort to protect fisheries resources.

As farmers are diverting more water to their farms than is permitted under their water licences (DeMong, pers. comm., 1978; Tsolum River Stream Obstruction File, Fisheries and Marine Service, Vancouver, B.C.), the flow of the Tsolum River is often too low for salmonids. In a report prepared for Fisheries and Marine Service, of Environment Canada, AESL (1976) proposed that the Wolf Lake dam be enlarged to give over-year storage and even out flow. Bams (memo to W. Crouter, 1973) calculated that 0.8 - 0.9 m^3/s (30 - 35 cfs) should be supplied by the dam. To maintain sufficient flow during July, 4.25 m of lake storage per m^3/s (0.39 ft./cfs) would be required.

Other diversions occur on the rivers in the study area. These are summarized in Table 4.3.

4 (vi) PUNTLEDGE RIVER DISCHARGE CONTROL FACTORS

To allow migrating fish to swim up the Puntledge River, the B.C. Hydro and Power Authority and the federal Fisheries and Marine Service of the Department of Fisheries and Environment agreed in 1974, to divert water through the Puntledge River hatchery, where it would empty back into the Puntledge River, downstream from the diversion dam. The minimum flow diverted between the diversion dam and the Browns River in flow is 2.83 m^3/s (200 cfs) from October 31 to June 1. Between June 1 and October 31, B.C. Hydro diverts an additional flow of 4.86 m^3/s (200 cfs) for a total of 8.5 m^3/s (300 cfs). This flow is thought to be sufficient to ensure a minimum year-round flow of 15.6 m^3/s (550 cfs) downstream of the Browns River (MacKinnon, pers. comm., 1978)

Negotiations are currently underway between B.C. Hydro and Power Authority and the federal Fisheries and Marine Service to divert water to the proposed new hatchery on the Puntledge River.

Table 4.3 Major Diversions of Rivers in the Study Area (AESL, 1975).

River	Purpose	Amount of Water being diverted
Oyster River	2 - irrigation 1 - resort 1 - domestic proposed water supply to Campbell River	$0.17\ m^3/s$ (6 cfs) 13,636.8 cu.m/day (3M gal./day)
Black Creek	5 - irrigation 5 - domestic diversion to increase water to Campbell River (proposed)	197,357 cu.m/yr (160 acre-ft./yr) 38.6 cu.m/day (8,5000 gal./day)
Browns River	Regional District water supply to Courtenay and Comox (stand-by supply)	789,427 cu.m/yr (640 acre-ft./yr) 4545.6 cu.m/day) (1M gal./day)
Trent River	28.3 ha irrigation (70 acre irrigation)	
Perseverance and Cumberland Creeks	Domestic supply for Cumberland/Royston	
Hart Creek	Water for Union Bay diverted by pipe	
Cowie/Cougar-Smith Creek	Fanny Bay Water-Works District	159.1 cu.m/day (35,000 gal./day)
Wilfred Creek	Ships Peninsula Sub-division	454.5 cu.m/day (100,000 gal./day) (proposed)
Graham Lake	Domestic supply	154.6 cu.m/day (31,000 gal./day)

5. OCEANOGRAPHY

5 (i) INTRODUCTION

There has always been some interest in the waters of the Courtenay River estuary, particularly as they affect Comox Harbour and Baynes Sound, which contribute substantially to commercial fisheries, as well as providing outlets for recreational fishing, boating and other water sports. However, as true for virtually all the estuaries of British Columbia, there has been little oceanographic work done on the Courtenay River estuary *per se*. Oceanographic surveys have been conducted in such adjoining waters as Comox Harbour (Waldichuk, MS, 1962, 1974), Baynes Sound (Waldie, 1951; Waldichuk, *et al.*, 1968) and the Cape Lazo area (Anderson, 1975). The review in this section will deal primarily with findings from the latter studies, which should provide a basis for understanding the general behaviour of the waters at least outside the inner estuary.

The Courtenay River estuary area is particularly rich in aquatic living resources, and most of the environmental studies have been conducted in order to gain a better understanding of the ecology so that the resources could be protected against man-made impacts. Such commercial bottom species as the English (lemon) sole, *Parophrys vetulus*, and smooth pink shrimp, *Pandalus jordani*, prefer the sandy bottoms available in this part of the Strait of Georgia, and have been particularly abundant in the vicinity of the Comox Bar and in the Lazo Bight area generally. Salmon and trout, of course, migrate into and out of the various streams tributary to the Comox Harbour-Baynes Sound area. The Pacific oyster, *Crassostrea gigas*, has found the warm brackish surface waters of Comox Harbour and Baynes Sound suitable for its growth, although reproduction of this species is rather irregular in these waters. Some of British Columbia's most productive oyster leases are on the

Vancouver Island shores of Baynes Sound because of the richness of the food supply. The sandy bar north of Denman Island surrounding Sandy Island and Seal Islets has been found to be highly productive in clams.

The geological and oceanographic characteristics of the Baynes Sound-Comox Harbour area (Clague, 1976) and of the northwestern part of the Strait of Georgia (Waldichuk, 1953, 1957) have contributed to the many sandy beaches along the shoreline as well as to the various bars that have formed by erosion, littoral drift and deposition of sand. These sandy areas have provided desirable habitats for various species of flatfish and crustaceans. The relationship of the characteristics of sedimentary materials to the presence of shrimp populations have been studied by Sheldon and Warren (MS, unpublished).

Sand bars also affect navigation. Comox Bar, for example, makes the northern entrance to Baynes Sound accessible only to smaller vessels with shallow draught. The main access to larger vessels is through the passage between Boyle Point on the southern end of Denman Island and Mapleguard Point on Vancouver Island. East of the town of Comox is Goose Spit, a curved extension of shoreline from Cape Lazo consisting mainly of an accumulation of sand transported by currents and wave action. About 2 km (1.1 n.mi.) long with little vegetation, it provides a protective barrier for Comox Harbour from easterly and southeasterly seas. On it is located an Indian Reserve and CFB QUADRA, a naval establishment used mainly for cadet training in summer at the present time but extremely busy with naval training activities during World War II. Behind Goose Spit, at the east end of Comox Harbour, is a shallow lagoon which is ecologically valuable as productive habitat for aquatic organisms and avian wildlife.

53. Oceanography

Early environmental studies in Comox Harbour, involving float observations and coliform counts, were related to the problem of sewage disposal from the town of Comox and protection of waters in Comox Harbour for recreational purposes, as well as for suitable sanitary quality of oysters grown on nearby leases (Bowering, MS, 1943; Waldichuk, MS, 1962). Surveys of oyster grounds for bacteriological quality have been continued in Comox Harbour, Baynes Sound and neighbouring waters by the provincial government and federal bodies (Tevendale, 1974a, 1974b; Kay and Tevendale, 1974; Higgs, 1976). Oyster leases in Comox Harbour were closed in 1965 following surveys in 1964 by the Canada Department of National Health and Welfare and by the B.C. Department of Health Services and Hospital Insurance. A substantial body of information on water quality in the study area has been acquired by the B.C. Pollution Control Branch (Drinnan and Webster, 1975). More recently, consultants have undertaken to study water movements across Comox Bar and into Baynes Sound, preparatory to planning a new sewerage system with possible disposal of effluent into northern Baynes Sound or into the Strait of Georgia east of Cape Lazo (Berzins, personal communication).

Oceanographic investigations were extended into Baynes Sound (Waldichuk, *et al.*, 1968) to study the potential effects of a pulp mill that had been proposed during the early 1960's for Union Bay or Deep Bay. Oceanographic surveys were further conducted in the area to provide summer data on such variables as dissolved oxygen concentration, a vital property with respect to organic-rich wastes (Waldichuk and Meikle, MS, 1969). Some of this information was later used for evaluation of estuarine conditions at the mouth of Rosewall Creek, one of the sites selected by the Pacific Biological Station of Nanaimo as a possible field station for research on genetics of salmon and other aspects of aquaculture with salmonids. The field station has since been established for this purpose.

Daily seawater observations are made at a number of lighthouse stations along the British Columbia coast (Hollister and Sandnes, 1972; Hollister, 1974; Giovando and Hollister, 1974). Some of these data have been taken continuously since the mid-1930's, giving a valuable time series on year-to-year variations of temperature and salinity in coastal waters. The closest lighthouse stations to the Courtenay River estuary, where such daily seawater measurements are being observed or have been taken, are: Cape Mudge (50°00'N; 125°12'W; January 1937 to present); Chrome Island (49°28'N; 124°41'W; April 1961 to present); Sisters Island (49°29'N; 124°26'W; May 1968 to present); and Texada Island (49°42'N; 124°33'W; May 1953 to October 1956).

Baynes Sound is an important rearing area for juvenile salmon from streams tributary to this semi-enclosed body of water, as well as from streams discharging into the Strait of Georgia further south. The freshwater phase of salmon, particularly coho, in a number of these Vancouver Island streams has been studied in the past. These include the Big Qualicum River, now the site of a major salmonid enhancement facility, Nile Creek, and Chef Creek, the latter of which drains into the southern end of Baynes Sound. A major hatchery is now being constructed on the Puntledge River for coho, chinook and steelhead. Further salmonid enhancement projects are planned for the area (see Fish). Therefore, it is of some importance to gain information on the oceanography of Baynes Sound, as a habitat for both natural and enhanced stocks of salmon during the early phase of their life cycle.

5 (ii) GENERAL OCEANOGRAPHIC CHARACTERISTICS

In contrast to the Campbell River estuary study area, which is well-mixed except for its small inner portion, the Courtenay River estuary system is highly stratified, particularly during the summer months when increased insolation and higher atmospheric temperatures warm up the surface waters and intensify the vertical stratification set up by the freshwater inflow. The Courtenay River enters the sea in Comox Harbour, where wind mixing is relatively small because of the protection provided by Goose Spit and by Denman and Hornby Islands to the southeast. Therefore, the Courtenay River estuary, Comox Harbour and contiguous waters typify the two-layered estuarine system.

Except during heavy local runoff, when the river water can be quite muddy from soil erosion, and during heavy plankton blooms of spring and summer, the waters in the Comox Harbour-Baynes Sound area are comparatively clear. In general, the waters of Baynes Sound appear to be quite rich in phytoplankton, in that oysters of this area tend to be well nourished and exhibit a high condition factor. Zooplankton is probably also abundant for nourishment of juvenile salmonids, although no detailed studies on this aspect have been reported. Regular plankton tows have been taken recently to monitor seasonal changes in plankton concentration and species in the area as part of a "Plankton Watch", initiated in the spring of 1977 to provide an alerting system for the hatchery operator at Rosewall Creek on the best time to release chum salmon fry, *Oncorhynchus keta*, (Kennedy, unpublished data). Runoff from the rich agricultural areas of the Comox Valley probably introduces much nutrients into the waters of Comox Harbour and Baynes Sound during periods of heavy precipitation. This can occasionally initiate, when other conditions are favourable, dense blooms of phytoplankton, including the dinoflagellate *Gonyaulax* sp., which apparently reached red tide proportions and led to shellfish toxicity in 1957, affecting even the oysters of Baynes Sound (Anderson, 1960; Waldichuk, 1958).

From the point of view of waste disposal, Comox Harbour and Baynes Sound may not be the ideal oceanographic system for rapid dilution and dispersion. Water-borne wastes would tend to remain in the surface waters without appreciable downward mixing or rapid flushing out of the system. Wood solids and other particulate material would tend to settle to the bottom without being widely dispersed or transported too far seaward by currents. Because of limited exchange over the Comox Bar and through the southern entrance to Baynes Sound, there would be a tendency for materials discharged into the system to be retained for appreciable periods of time. Thus, the assimilative capacity might be exceeded rather early if a large volume of waste were introduced. However, by taking advantage of the tidal current patterns that are apparent in the area, it is possible to prevent substances from entering Comox Harbour and to achieve a certain measure of dispersion of wastes within Baynes Sound and some transport out of the system. This was the technique proposed for dispersion of sewage from an outfall serving the town of Comox in the northern end of Baynes Sound (Waldichuk, MS, 1962, 1974).

5 (iii) TIDES

Tides in the Courtenay River estuary and Comox Harbour are typically mixed, mainly diurnal, generally following the character of the tide in the Strait of Georgia. There are almost always two complete tidal oscillations in a tidal day, but the heights of successive high or low waters and the corresponding time intervals may be very unequal. The reference port for Comox and for the various other secondary ports along Baynes Sound is Point Atkinson. It is generally considered that the tides from the south meet somewhere just north of Cape Lazo.

The northerly tides do not normally have a significant effect in Comox Harbour and Baynes Sound, but they can have some influence on the northern extension of the study area beyond Cape Lazo. The mean tidal range for Comox is 3.4 m

(11.3 ft), while the large tidal range is 5.3 m (17.3 ft) (Canada Dept. Fish. & Environ., 1977). The various tidal characteristics at the reference and secondary ports for the Courtenay River estuary and adjacent points are given in Table 5.1. The differences in time and height for tides at Comox and other secondary ports, in relation to the reference port, Point Atkinson, is given in Table 5.2. In general, the tidal range is somewhat greater at Comox than at Point Atkinson, and this is reflected in the heights of higher high water, which are more than 0.3 m (1.0 ft.) higher, without a comparable difference in height of lower low water, as shown in Table 5.2. The geographical position of Comox, which is 20' of latitude (37 km or 20 n.mi.) north of Point Atkinson is probably the main reason for the larger tides at Comox corresponding to the northward increase in tidal range as one proceeds from south to north along the British Columbia coast.

Typical of tides for the British Columbia coast generally, the low waters occur during the daylight hours in the summer time and near midnight during the winter months. The presence of broad tidal flats in the Comox Harbour and northern Baynes Sound area, combined with the large tidal range prevailing in early summer (late June), leads to extensive intertidal exposure for bottom organisms inhabiting this zone. This has considerable ecological effect, no doubt, in that intertidal organisms are subjected to higher prevailing atomspheric temperatures and desiccation from increased evaporation on exposure during the summer months. Large salinity fluctuations also require adaptation for survival by intertidal organisms.

5 (iv) WATER PROPERTIES

As noted in earlier sections, the main characteristic of the distribution of properties in vertical profile in the Comox Harbour-Baynes Sound area is the general vertical strati-

Table 5.1 Tidal characteristics at the reference and secondary ports in the northwestern Strait of Georgia, adjacent to the Courtenay River estuary. (From Canada Dept. Fish & Environ., 1977).

Port	Position	Duration of Tidal Records	Mean Tidal Range		Large Tidal Range	
			m	ft	m	ft
Reference Ports						
Point Atkinson	49°20'N 123°15'W	1895-Present	3.26	10.7	4.94	16.2
Campbell River[a]	50°01'N 125°14'N	1965-1968 1972-Present	2.89	9.5	4.57	15.0
Secondary Ports						
		On Point Atkinson				
Hornby Island (Ford Cove)	49°30'N 124°41'W	Aug.-Dec., 1967 Feb.-Dec., 1968 Jan.-Mar., 1969 May-Sept., 1971	3.37	11.1	5.15	16.9
Denman Island (West Side Ferry Landing)	49°32'N 124°49'W	Apr.-May, 1971	3.41	11.2	5.21	17.1
Comox	49°40'N 124°55'W	Jan.-Dec., 1948 Sept.-Dec., 1967 Jan.-Oct., 1968 Apr.-Jun., 1969 May, 1970	3.44	11.3	5.27	17.3
Little River	49°44'N 124°55'W	1967-Present	3.47	11.4	5.27	17.3
Buckley Bay Ferry Landing	49°31.5'N 124°50.5'W	Apr., 1898- Apr., 1899 Dec., 1898- Dec., 1899 Nov., 1899- Jan., 1900				

a Although Campbell River is not used as a reference port for the secondary ports listed here, its tidal characteristics are given, because there is tidal influence from Discovery Passage in the northern part of the Courtenay River estuary study area.

Table 5.2 Time and height differences for tides at secondary ports in the northwestern Strait of Georgia, adjacent to the Courtenay River estuary, relative to Point Atkinson. (From Canada Dept. Fish. & Environ., 1977).

PORT	HIGHER HIGH WATER					LOWER LOW WATER				
	Time h.m.	Mean Tide		Large Tide		Time h.m.	Mean Tide		Large Tide	
		m	ft	m	ft		m	ft	m	ft
Hornby Island	+0 13	+0.15	+0.5	+0.21	+0.7	+0 18	+0.03	+0.1	0.0	0.0
Denman Island	+0 08	+0.24	+0.8	+0.27	+0.9	+0 09	+0.09	+0.3	+0.06	+0.2
Comox	+0 03	+0.27	+0.9	+0.37	+1.2	+0 12	+0.09	+0.3	+0.03	+0.1
Little River	+0 03	+0.27	+0.9	+0.34	+1.1	+0.08	+0.06	+0.2	+0.0	0.0

fication. This prevails not only in summer but also in winter. In late January 1958, a survey was conducted in Comox Harbour and the northern end of Baynes Sound in connection with studies related to installation of a new outfall for sewage disposal from the town of Comox. Stations occupied during this period are shown in Figure 5.1. Vertical profiles of physical and chemical properties in the water at Station 2 in Comox Harbour, occupied on 28 January, 1958 are shown in Figure 5.2. The large changes in properties occured in the upper 3 m (9.8 ft.), where salinity increased from near 0 at the surface to about 26 $^0/_{00}$ at 2 m (6.6 ft.), and temperature showed a comparable gradient from 5.2°C at the surface to 7.3°C at 2 m. Temperatures remained quite uniform below 2 m, but actually showed a slight increase of a fraction of a degree in the bottom 10 m (32.8 ft.). Although temperatures tended to oppose the salinity in defining the density stratification, the density still exhibited much the same pattern of distribution as shown by the salinity. From a density [$\sigma_\tau = (\rho - 1)\ 1000$, where ρ is the density] of nearly that of fresh water at the surface, the water increased to an inshore sea water σ_τ of about 21 at 3 m (9.8 ft.), and remained fairly uniform at that density almost all the way to the bottom.

The non-conservative properties, shown in the right-hand panel of Figure 5.2, to some extent exhibited the same kind of vertical distribution as the conservative properties. Dissolved oxygen was at supersaturation in the surface waters at about 12.5 mg/ℓ but dropped off quite rapidly to normal near-saturation levels at about 9.5 mg/ℓ at 2 m (6.6 ft.). It remained nearly at that concentration all the way to the bottom, although it did show a slight depression to about 8 mg/ℓ in the bottom sample at 28 m (91.9 ft.). Evidently, the system was well oxygenated at this time of year. The pH showed only small variations from surface to the bottom sample. From a surface pH of about 7.7 it increased to about 7.9 at 5 m (16.4 ft.), and then stayed at that level all the way to the bottom. Clearly, the effects of phytoplankton photosynthesis were not present,

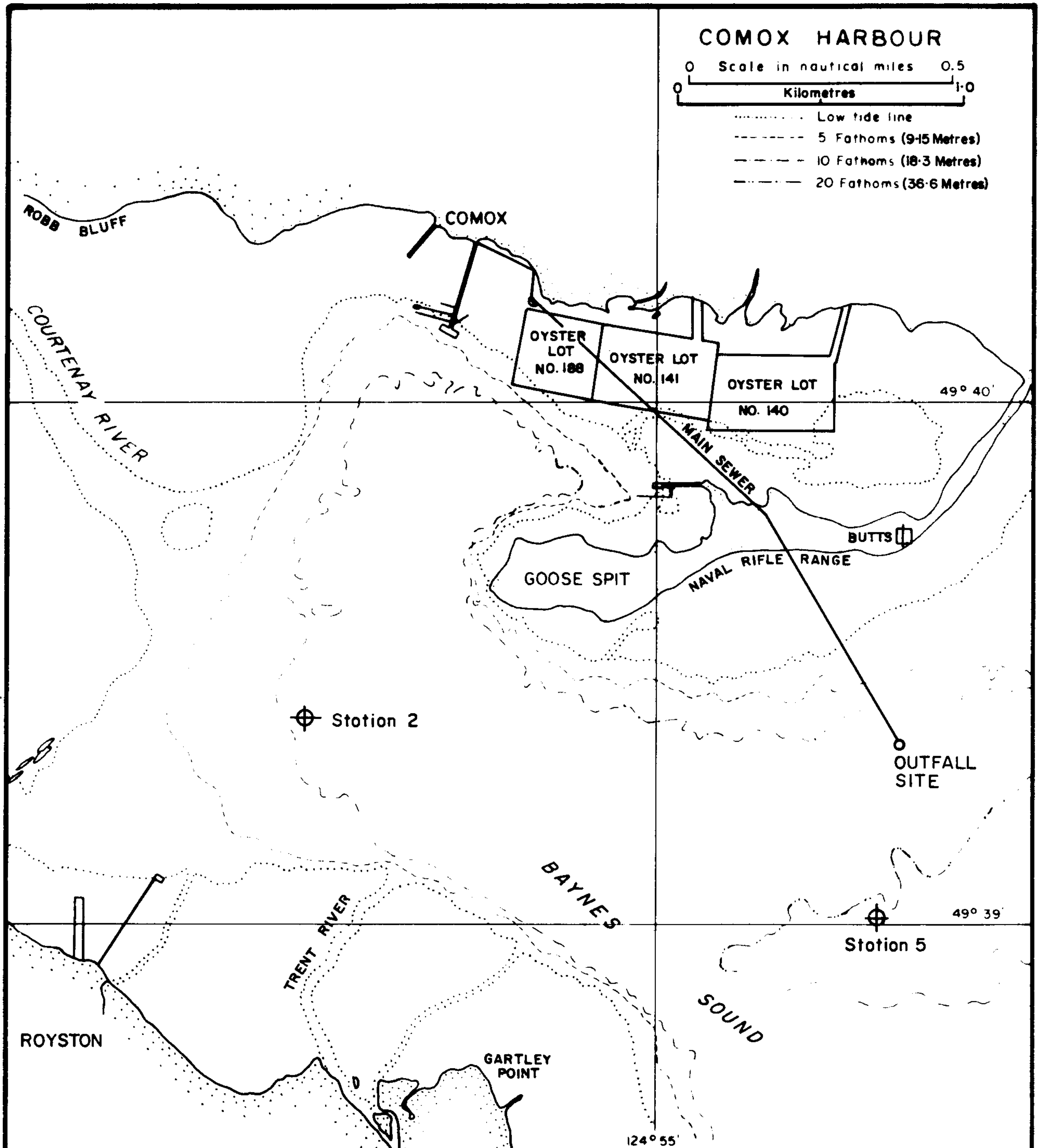


Figure 5·1 Chart of Comox Harbour and approaches, showing the location of the sewer outfall.

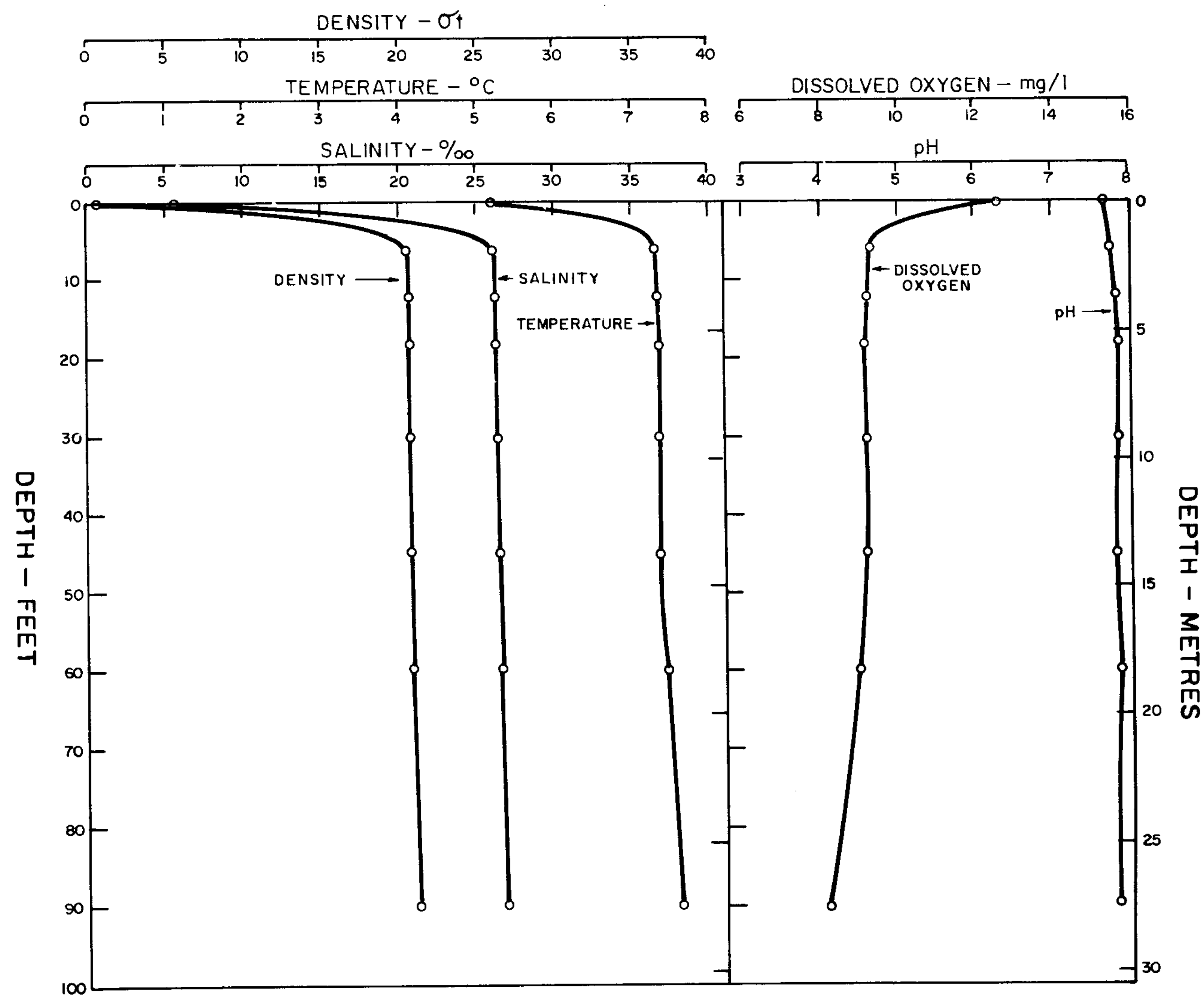


Figure 5·2 Vertical profiles of various physical and chemical properties in the water at Station 2 (see Fig. 5·1) in Comox Harbour, occupied 28 January, 1958.

inasmuch as the pH usually rises above 8.0 during the vernal bloom, when high phytoplankton photosynthesis gives rise to both dissolved oxygen supersaturation and high pH in the surface layers.

The vertical distributions of properties at a station in northern Baynes Sound (Station 5, see Figure 5.1), occupied on 28 January 1958, are shown in Figure 5.3. The vertical profiles are similar to those for the station occupied in Comox Harbour (Figure 5.2), with only a small variation below the depth of 3 m (9.8 ft.). It is remarkable that even dissolved oxygen concentration did not drop below 8 mg/ℓ in the deepest water sampled at about 37 m (121.4 ft.).

Summer conditions are somewhat different to those observed in winter. For example, temperatures are considerably higher in the surface waters than they are in the deep water. This combined with the lower salinity in the surface stratifies the density of the water even more during the summer time than in winter. The generally smaller vertical wind mixing during the summer months leads to a larger pycnocline, which inhibits transfer of material through the water from the surface layers to deeper water. This means that material introduced into the surface layer will tend to remain there unless it is heavier than sea water and sinks.

5 (v) CURRENTS AND CIRCULATION

A number of factors are involved in the circulation and current patterns of the Courtenay River estuary, Comox Harbour and the nearby area of Baynes Sound. Tidal effects may be predominant, but the tidal currents are modified by runoff and winds. Certainly, during periods of strong winds, there would be a surface wind-driven current setting in the direction of the wind. Runoff effects would be most noticeable during the period of heavy winter runoff, as well as in spring,

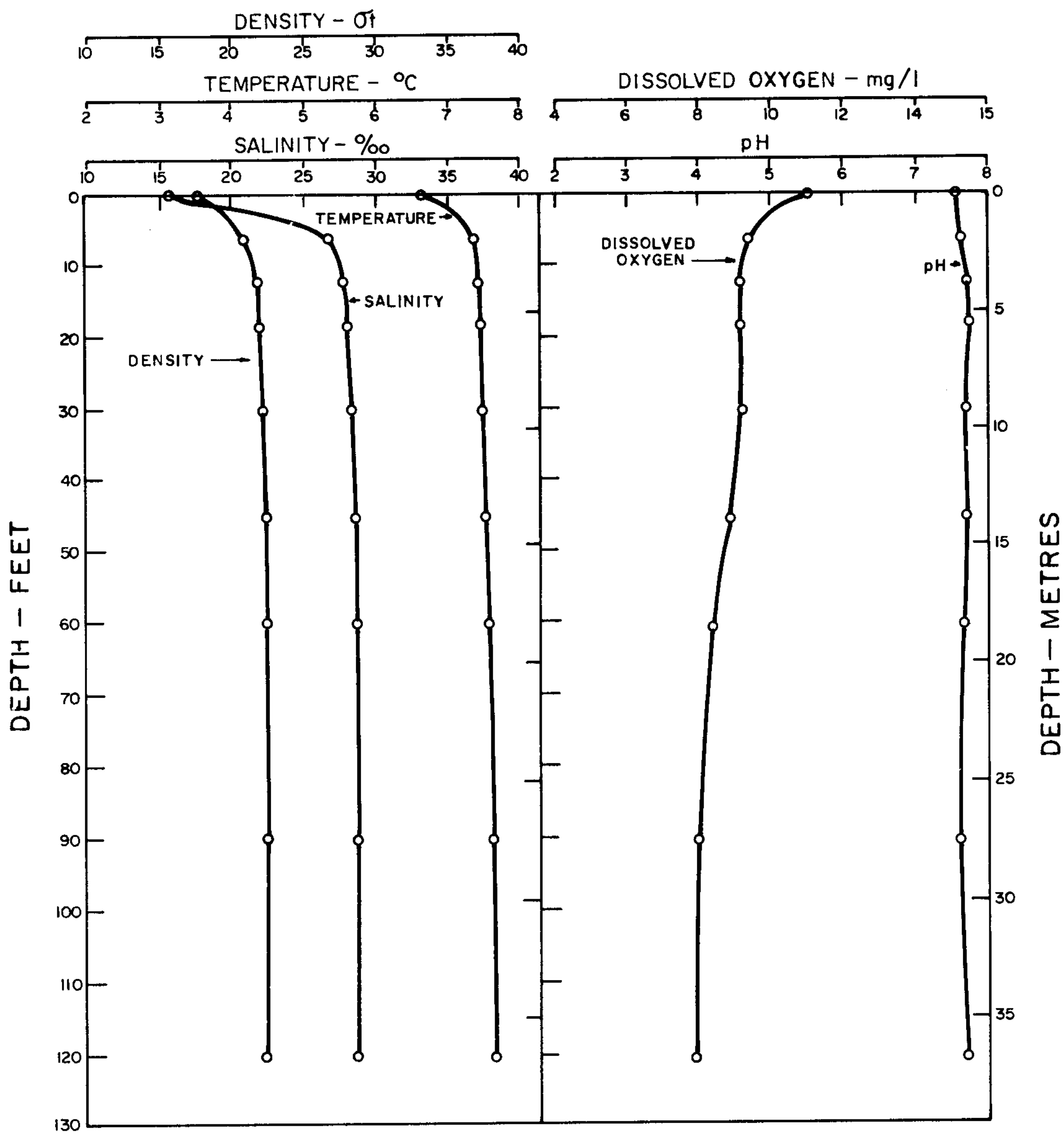


Figure 5·3 Vertical profiles of various physical and chemical properties in the water at Station 5 (see Fig. 5·1) in Baynes Sound, occupied 28 January, 1958.

when the Courtenay River discharge is bolstered by snowmelt at the higher elevations of the drainage basin. A generalized picture of surface circulation in Comox Harbour and approaches during a flood tide, is shown in Figure 5.4 for a survey period during 3-4 July,1958. It is obvious from this picture of current vectors that the flood tide brings water into Comox Harbour along Goose Spit and then forms a clockwise eddy within the harbour. It is noteworthy that the tidal stream splits as it approaches Gartly Point, the northerly portion of the stream moving into Comox Harbour and the southerly part curving to the south and setting into Baynes Sound. It was on the basis of the divergence of this tidal stream that the outfall site for the sewage pipeline from the town of Comox was chosen. It was selected in such a way that sewage would not be carried back into Comox Harbour but would be transported southward, if it came to the surface, and dispersed into Baynes Sound.

The generalized surface circulation in Comox Harbour and approaches during an ebb tide is shown in Figure 5.5, as deduced from float observations during the period 28-31 January, 1958. The general flow is out of the inner part of the harbour around Goose Spit, setting seaward into northern Baynes Sound and over the Comox Bar into the Strait of Georgia. Except during the early and later part of the float surveys on 28-31 January, when winds blew moderately from the south-southeast, most of the winds were rather variable and weak. Therefore, it is believed that there was not too much wind effect in the observed currents. There was some evidence of small eddies north of Goose Spit, and some of the floats tended to head towards the western part of the harbour, but generally the current directions were uniformly out of the harbour around Goose Spit and then seaward into Baynes Sound or into the Strait of Georgia.

Currents observed at anchor at a station south of

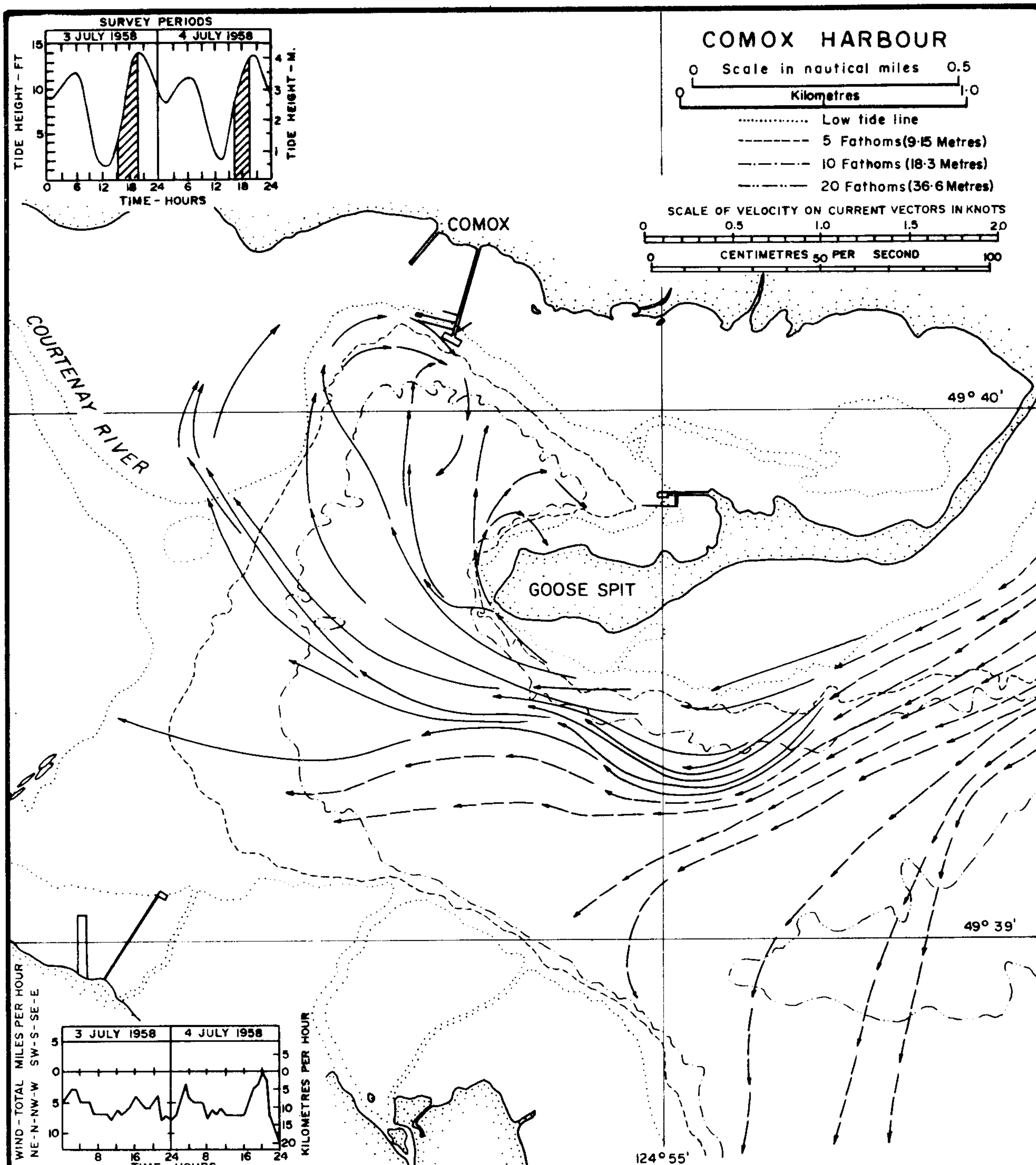


Figure 5·4 Generalized surface circulation in Comox Harbour and approaches during a flood tide. (Solid arrows give a composite picture of observations taken over a period of several hours on 3 July 1958. Dashed arrows give observed and estimated results for 4 July 1958.)

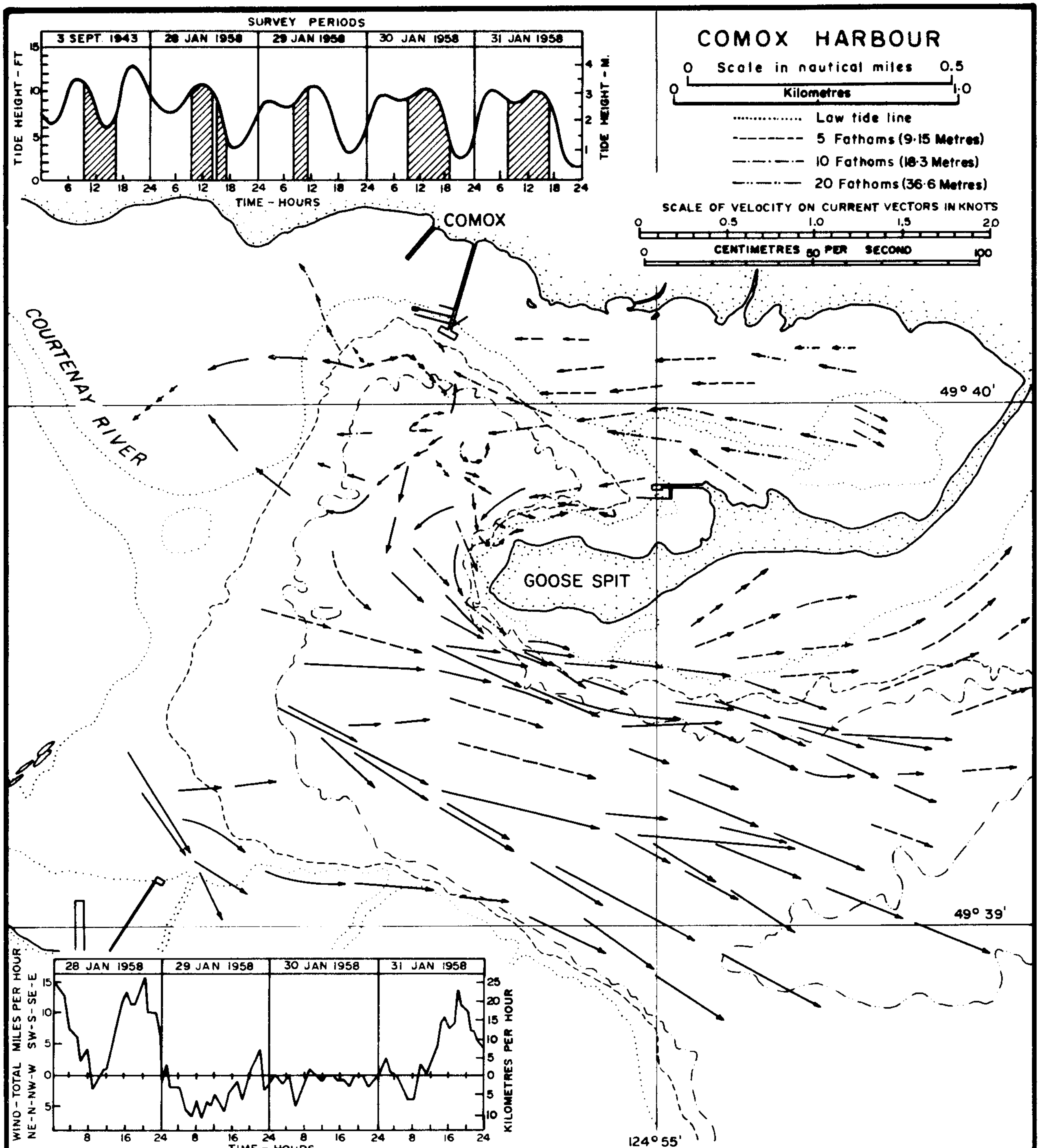


Figure 5·5 Generalized surface circulation in Comox Harbour and approaches during an ebb tide. (Solid arrows give a composite picture of observations taken over a period of several days, 28-31 January, 1958. Broken arrows give observations for 3 September, 1943. Dashed arrows are estimated currents.)

Goose Spit (Station A) and at one inside of the harbour (Station B), during 30 January - February 1958, are represented vectorially in Figure 5.6. The tides and winds during the two periods of observations are shown in the inset tidal and wind diagrams. It is clear, that at Station A the current directions can be generally grouped as setting to the southeast with a smaller proportion setting to the northwest. Not all the current vectors setting to the southeast, however, were on the falling stages of the tide. Some of them were on the flood. However, there was a definite shift of current direction to the northwest halfway through the rising stage of the first tidal cycle of observations.

Currents measured at anchor at Station B were considerably weaker than those at A. A substantial number of observations gave zero current, some of which were observed during the slackwater periods of the low and high water stages of the tide. There was a definite grouping of currents to the east on the flood stage of the tide and to the west on the ebb. This generally confirms the pattern of currents observed with floats.

Subsurface currents were observed with drogues set at 4.6 m (15 ft.) and 9.1 m (30 ft.) in Comox Harbour and its approaches during the period 28-31 January 1958, with some supplementary information from 3 September 1943 (Fig. 5.7). Although currents were considerably weaker at these depths and less regular in pattern, conforming less to the directions anticipated from the tidal cycle, they exhibited the general movement out of Comox Harbour and seaward into the northern part of Baynes Sound. Most of these observations were made on the ebbing tide, and except for a clockwise eddy, north of Goose Spit at 9.1 m (29.9 ft.) depth and some drift onto the tide flats to the west in the northern part of the harbour, adjacent to the Comox wharf, the general pattern of water flow was seaward, as expected from the tidal circulation (Fig. 5.7).

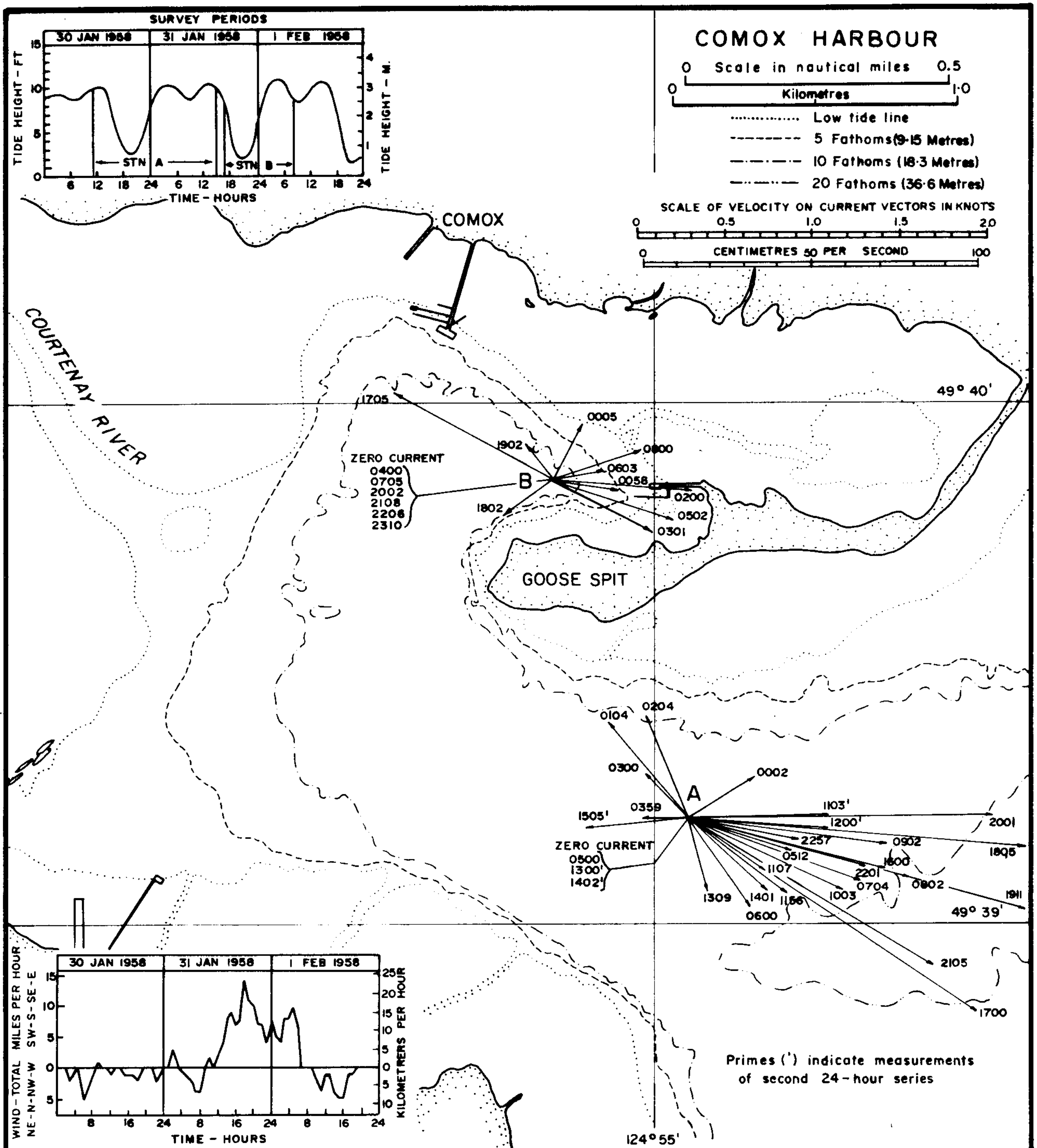


Figure 5·6 Variations of surface currents over a tidal cycle at anchor stations A, south of Goose Spit, and B, in Comox Harbour.

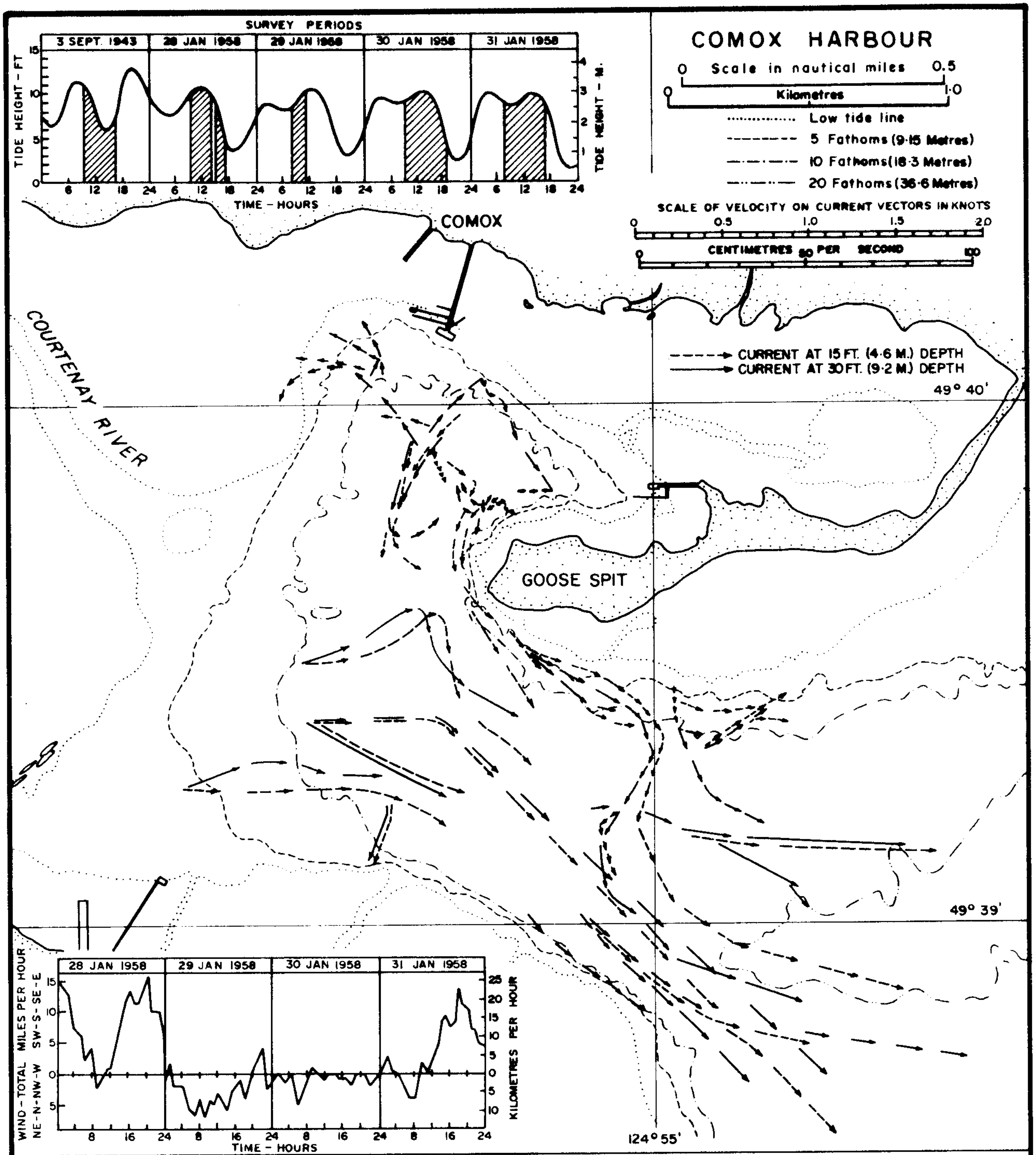


Figure 5·7 Observed circulation at 15 ft. (4·6 m.) and 30 ft. (9·2 m.) depth in Comox Harbour and approaches during the period 28 – 31 January, 1958.

Undoubtedly, there is some of the typical two-layered circulation in this estuarine system, with a residual net flow seaward at the surface and inward flow below the halocline. However, this would be difficult to identify without a long series of observations at all depths. The information available at present merely shows that there is an active circulation in the surface layers associated with the tide and river runoff. During periods of storm, there may be substantial wind-driven currents. No doubt, the formation of Goose Spit is the result of vigorous littoral transport of sedimentary materials, particularly sand, with flood tidal currents sweeping over the Comox Bar into Comox Harbour, supplemented by wave action generated by southeast winds. The littoral transport of sedimentary materials in other parts of the study area has been manifested in the formation of bars and sandy beaches. Clague (1976) analysed available oceanographic data to explain sediment dispersal patterns. He noted that sediment is transported into the troughs by rivers, currents and waves (see GEOLOGY AND SOILS).

Although currents can exceed 50 cm/s (1 kn.) at all depths in Comox Harbour and approaches, they generally exceed this speed only at the surface. On large tidal ranges and during strong winds, surface currents may reach 100 cm/s (2 kn.) and subsurface currents in the more constricted channels may reach 50 cm/s (1 kn.). One exception to the generally modest currents in the study area is the constricted southern entrance to Baynes Sound. The British Columbia Pilot (Canada Dept. Environ, 1976, p. 167) states:

> "The tidal streams in Baynes Sound attain a rate of 2 or 3 knots in the south entrance, but within the sound the rate is considerably less, decreasing as the channel becomes wider."

Concerning Comox Harbour, the Pilot (p.170) states:

> "The tidal streams in Comox Harbour are complicated by eddies due to the fresh water discharged by the Courtenay River, which causes surface currents to flow in directions different from those of the salt water underneath; in addition, these latter are complicated by the configuration of the mud banks."

5 (vi) WAVE ACTION

Although the Courtenay River estuary, Comox Harbour and Baynes Sound are comparatively well protected by Goose Spit, Denman Island and the various smaller islands extending to the north of Denman Island, the area tends to be somewhat exposed from the east and southeast. Winter storms bring in heavy seas across Comox Bar and lash the seaward beaches of Goose Spit. Because the topography of Goose Spit is not very high and it does not have forest cover, it affords rather minimal protection from winds for the inner part of Comox Harbour. For this reason, a breakwater surrounding the dock facilities in Comox was installed during the 1960's.

Summer winds are predominently from the north and northwest, as measured at Comox Airport (see CLIMATOLOGY), and except for the southern half of Baynes Sound, wave action from these winds is relatively small. The fetch is too short for the waves to develop any significant height and strength.

Winter waves probably reach a maximum height of 1.5 m (5 ft.) and impinge more strongly on the intertidal area of the south side of Goose Spit, as well as on the delta front directly westward of Goose Spit, where the Courtenay River has deposited most of its sediment. Waves generated by northwest winds probably reach the same height in the outer part of the study area, particularly on the shoals of the Seal Islets and Sandy Island to the north of Denman Island. This probably has some impact on the flora and fauna of this exposed region.

No wave measurements have actually been made in the Courtenay River estuary or in Comox Harbour and Baynes Sound. One can only presume that the inner estuary and Comox Harbour are one of the less wave-effected estuarine areas along the British Columbia coast, but the sections of the study area exposed to the Strait of Georgia may receive considerable wave impact.

5 (vii) FLUSHING ACTION

No actual computations have been made on the rate of flushing of either Comox Harbour or Baynes Sound. While it is not a tide-swept system such as Discovery Passage, it does experience a modest amount of tidal exchange. Judging by the dissolved oxygen distribution in all parts of the Comox Harbour-Baynes Sound system, there is little evidence that any of the bottom water stagnates for long. This is in part related to the comparatively shallow water in the study area. Certainly, the surface waters are steadily on the move, with a net outflow generated by freshwater runoff, superimposed on the regular to and fro motion by tidal action, and the pattern of flow occasionally modified by wind-driven currents. Currents sweeping across Comox Bar from the northeast and moving into Comox Harbour around Goose Spit on the flood tide transport Strait of Georgia water into the system. On the ebb, there is an outward flow of surface water from Baynes Sound into the Strait of Georgia partly across Comox Bar, and partly through the channel between Repulse Point on the southern end of Denman Island and Mapleguard Point near Deep Bay on Vancouver Island. Although there are no current measurements to confirm the major routes of water exchange, one could infer from the geographical configuration that the inflow on the flood is greater than the outflow on the ebb across the Comox Bar. This would lead to an outflow exceeding the inflow by a considerable margin through the southern entrance to Baynes Sound.

Currents in the deeper water of Comox Harbour and Baynes Sound appear to be moderately vigorous compared to the deep water of other basins, judging from current meter and drogue observations. Obviously, there is a moderately rapid exchange of water at subsurface depths. It is presumed that there is a net flow from north to south through Baynes Sound, although this has not been substantiated by long-term current observations. Because of topographic restrictions to the north, the bottom water would have to be exchanged through the southern entrance, which allows an exchange of the denser water lying below the maximum depth of the Comox Bar. The southern entrance has a depth below lower low tide of about 30 m (16 fathoms), whereas the deepest channel across Comox Bar averages about 3 m (1.5 fathoms). In spite of this constraint to deep-water flushing, it is believed that Baynes Sound gets replaced even in the deepest water at least once every two months.

5 (viii) NAVIGATION

There are two main charts covering the Courtenay River estuary, Comox Harbour and Baynes Sound area. No. 3590 - BALLENAS ISLAND TO CAPE LAZO is on a natural scale of 1:77,007 (at latitude 49°30'N). This chart was largely prepared from surveys of the Canadian Hydrographic Service between 1937 and 1965, with portions in the vicinity of Baynes Sound taken from British Admiralty surveys of 1898. The latest edition of this chart was prepared in August 1969 and has been corrected and reprinted as of 14 July 1978. Chart No. 3532 - BAYNES SOUND is a new edition of 9 December 1977, prepared from Canadian Hydrographic surveys of 1969 - 71. It is on a natural scale of 1:40,000. The area of the Courtenay River estuary at Comox Harbour is best represented on Hydrographic Chart No. 3599 - COMOX

HARBOUR on a scale of 1:10,000. The latest survey for this chart was conducted in 1969 and the new edition was printed in February 1972. It has been corrected from Canadian Notices to Mariners to 1974. A note to users states that local magnetic disturbance of about 2° in excess of normal is reported in the area of this chart. Also, there is a caution to mariners: "Owing to changing conditions, the aids to navigation may be moved to mark the best channel. Vessels should not attempt to enter without local knowledge. For subsequent changes of aids to navigation the Notices to Mariners and List of Lights, Buoys and Fog Signals must be consulted."

The British Columbia Pilot (Canada Dept. Environ., 1976) gives detailed directions for approaching the entrance of Baynes Sound from the southeastward in order that all obstructions can be properly cleared from Chrome Island adjacent to Boyle Point at the southern end of Denman Island, through the channel between Repulse Point and Mapleguard Point to the deeper channel within Baynes Sound. It also gives directions for crossing the Comox Bar northward of Denman Island which is a short cut for light draught vessels. The Pilot notes that there is the least depth on the leading line over the Bar of 3 m (10 ft.), but that near the western end of the bar, close to the leading line and on its northwestern side, is a head with a depth of only 2.6 m (8.5 ft.) over it. It notes that two lights, one mounted on the west shore of Baynes Sound about 2 miles west of Sandy Island, and the other about 304.8 m (1,000 ft.) southwestward of the foregoing, when kept in line bearing 222°10'T, lead over Comox Bar in the deepest water. This course is clearly marked on both charts 3590 and 3599.

Comments on the British Columbia Pilot regarding currents in the study area of concern to navigation have been noted in 5 (v).

5 (ix) OCEANOGRAPHIC CHARACTERISTICS IN RELATION TO DEVELOPMENT AND WASTE DISPOSAL

Any developments on the shoreline in the study area would alter the nearshore current patterns and the littoral drift. Such an effect would be most pronounced in those areas where currents are strongest, such as the southern entrance to Baynes Sound and the south side of Goose Spit. Sedimentation patterns could be greatly altered in the latter area, particula-rly if a breakwater or a jetty were installed normal to the shoreline and blocking the direction of flow.

It is encouraging to note that studies have been con-ducted on the feasibility and potential environmental impact of a proposed 520 m (1700-ft.) long small craft navigation channel across the Oyster River delta for a boat basin in the river (Hay and Secter, 1978). Historical changes in the delta, as a result of the meandering river channel and changes in delta configuration from alterations in littoral transport of sediments, were studied in relation to effects of and effects on the proposed boat channel. It was concluded that because of the low-level biological productivity and geomorphological character of the Oyster River delta, there would be minimal impact of the proposed navigation channel on the biophysical environment.

Waste disposal within Comox Harbour and Baynes Sound could lead to pollution problems, because of the relative confinement of these waters within the bounds of Denman Island and Comox Bar. A small volume of sewage can be reasonably well assimilated within the waters of Baynes Sound. With rapid dilution and dispersion from a diffuser at depth, the discharge of sewage from the town of Comox appeared to present no problems. However, discharge of a much larger volume of sewage or industrial waste would probably result in noticeable degradation of these waters, because of the inability of the system to assimilate the increased load, or to flush it out rapidly enough into the Strait of Georgia. Under these circumstances, in the absence of a high degree of treatment for such wastes, it would be necessary to consider discharging the effluents beyond Cape Lazo, Comox Bar and Denman Island into the deeper waters of the Strait of Georgia, where better dispersion and seaward transport by stronger currents can be expected.

Studies are now underway by Dayton & Knight Ltd., Consulting Engineers, (Berzins, pers. comm.), taking into account seasonal changes in oceanographic characteristics off Cape Lazo and in waters south of Willemar Bluff between Cape Lazo and Point Holmes, on a design of an environmentally acceptable sewage effluent outfall to serve the Canadian Forces Base Comox, and/or an integrated municipal waste disposal system for the Courtenay-Comox area as well as the military base.

6. FISH

6. (i) GENERAL DISCUSSION

There is a variety of fish species in the study area. The Courtenay River and its tributary streams, as well as nearby rivers and creeks support runs of most salmonid species. Pelagic species such as Pacific herring (*Clupea harengus pallasi*) are fished in adjacent marine waters. The sandy bottom in the northwestern part of the Strait of Georgia, particularly in the Lazo Bight, is a preferred habitat for bottom fish, such as English sole (*Parophrys vetulus*). For fisheries management purposes, the study area is in Statistical Area 14.

Jurisdiction of the salmonid fisheries is divided between the federal and provincial agencies. Steelhead (*Salmo gairdneri*) and cutthroat trout (*S. clarki clarki*) have been traditionally studied and managed by provincial Fish and Wildlife Branch biologists. Anadromous Pacific salmon (*Oncorhynchus* spp.) are the concern of the federal Fisheries and Marine Service regardless of whether the fish are at sea or in the rivers. Other species found in the area are listed in Appendix 6.1.

Most of the twenty-nine rivers and creeks between Oyster River and Deep Bay provide spawning and nursery habitats for anadromous trout (*Salmo* spp.), coho and chum salmon (*Oncorhynchus kisutch* and *O. keta*). References describing these streams are given in Appendix 6.2 The distribution of anadromous species within the study area is shown in Figure 6.1. Literature pertaining to the fish habitats provided by these streams includes: the Area 14 stream catalogue by Walker and McLeod (undated); the salmonid spawning reports (Canada Dept. Environ., annual); unpublished stream surveys of the B.C. Dept. Recreation and Conservation regional office in Nanaimo; the literature review by EPEC Consulting Western Limited (1975);

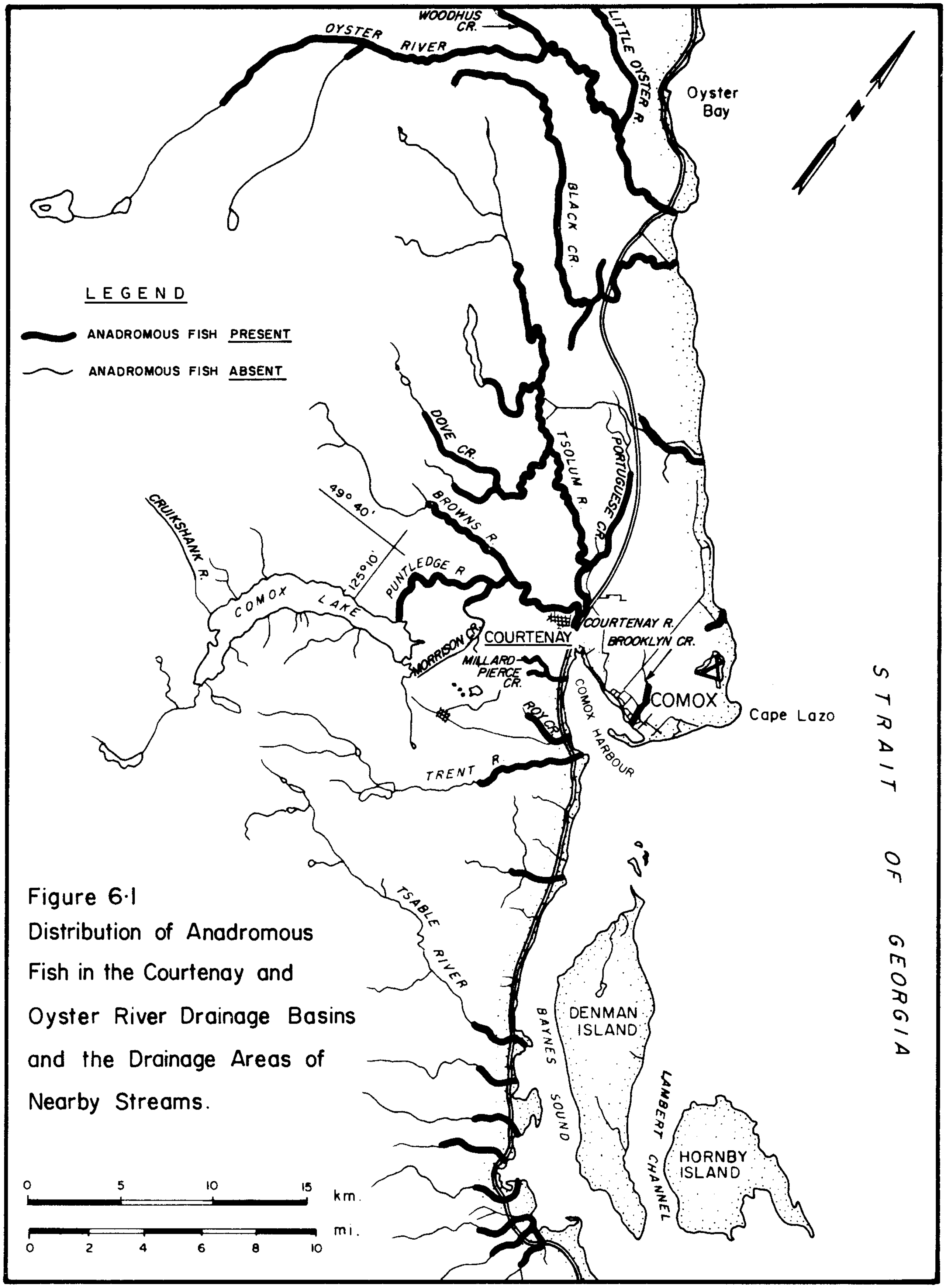


Figure 6·1
Distribution of Anadromous Fish in the Courtenay and Oyster River Drainage Basins and the Drainage Areas of Nearby Streams.

the Area 14 and Conservation District 3 annual narrative reports by the Canada Dept. Environ. (Fisheries Operations Files, Vancouver); the gas pipeline impact assessment by Paish and Associates (1974); and the report on potential Pacific coast oil ports by the Working Group on West Coast Deepwater Oil Ports (Canada Dept. Environ., 1978).

6. (ii) SPECIES ECOLOGY

1. INTRODUCTION

(a) THE COURTENAY RIVER SYSTEM AND COMOX HARBOUR

Three major rivers combine to form the very short 2.5 km (1.5 mi.) Courtenay River. These are the Puntledge, the Tsolum and the Browns rivers. Only the lower 13 km (8.0 mi.) of the Puntledge are presently accessible to spawning salmonids, as upstream migration is limited by the Comox Dam. The upper Puntledge River (35 km, 21.7 mi.), the Cruikshank River (22 km, 13.6 mi.), all the tributaries of these rivers and Comox Lake once supported large salmonid populations. Under salmonid enhancement measures they could probably be restored to the original production levels in the future (Burns, 1976; Walker and McLeod, undated). During recent years, adult salmonids in the Tsolum River have had difficulty migrating upstream owing to unstable flow regimes, aggravated by logging and by the diversion of water for agriculture (Brown, Chahley and Demontier, 1977) (see Hydrology Section). The Browns River is not used extensively by salmonids, as a waterfall situated near its confluence with the Puntledge impedes upstream migration of most species.

Important juvenile salmonid habitats located within the Comox harbour area include: (1) the marshes of the Courtenay River channel and Dyke Slough; (2) the marshes at the mouths of Millard-Piercy Creek and the Trent River; (3) the Goose Spit Lagoon - a high salinity tide pool located behind Goose Spit; and (4) the intertidal mudflats of Comox

Harbour (Figure 6.2).

(b) OYSTER RIVER AND ESTUARY

Five species of salmon inhabit the Oyster River. Cutthroat and steelhead are found throughout the river system. A waterfall located 21 km (13.0 mi.) from the estuary limits the distribution of coho, chum and pink salmon to the lower portions of the river. To determine the extent of estuarine utilization, Goodman (1974), studied juvenile salmonid feeding habits in the mouth of the Oyster River. He found a scarcity of benthic vegetation and estuarine invertebrate prey items, which led him to conclude that the Oyster River estuary did not provide a unique or highly utilized rearing and feeding habitat.

2. FRESHWATER SPECIES

The biology and distribution of landlocked species upstream of the obstructions to anadromous fish migration in the Courtenay and Oyster River systems is not yet known. Sjolund (pers. comm., 1977) has found the small Dolly Varden char (*Salvelinus malma*) in the Oyster River, and rainbow and cutthroat trout in lakes tributary to the Oyster. Comox Lake contains Dolly Varden, cutthroat, threespine stickleback (*Gasterosteus aculeatus*) and kokanee (*Oncorhynchus nerka kennerlyi*). Non-salmonid species likely to be found in these streams are: the prickly sculpin (*Cottus asper*), the coast-range sculpin (*C. aleuticus*), and the threespine stickleback. Lamprey (*Lampetra tridentatus*) have been discovered in the tributaries of the Puntledge River (Beamish, pers. comm., 1977).

3. ANADROMOUS TROUT

(a) STEELHEAD (*Salmo gairdneri*) - Specific information on the number of steelhead and migratory cutthroat spawners

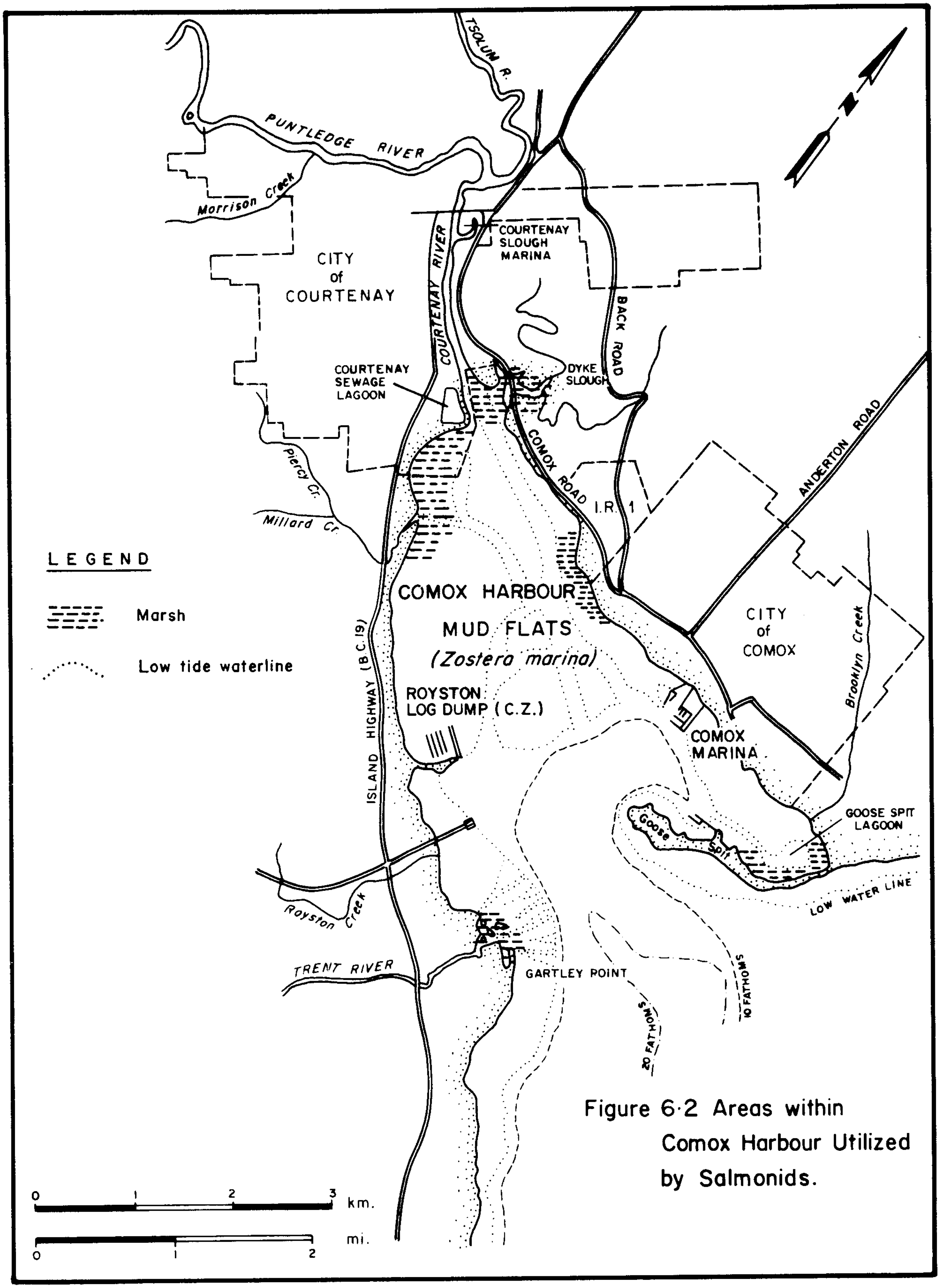


Figure 6·2 Areas within Comox Harbour Utilized by Salmonids.

in the study area is fragmentary. Catch and escapement statistics summarized in the Steelhead Harvest Analysis, are available through the Department of Recreation and Conservation, Fish and Wildlife Branch. Information on steelhead biology of the area is largely based on local knowledge (Thornton, pers. comm., 1978).

The Oyster River supports summer and winter steelhead populations. Summer steelhead runs begin the late spring or early summer and peak in late October, while winter steelhead runs begin in early December, and peak in mid-April. Both races spawn between March and July. However, the extent of sexual maturity differs. Spawning occurs on boulder substrates in Woodhus Creek and Little Oyster River. These tributaries are also noted juvenile rearing areas.

Steelhead fry are thought to emerge from the gravel in early summer. A recent study by Tautz and Slaney (pers. comm., 1978) revealed that young steelhead frequent heavy riffle areas endowed with logs and boulders for cover. They spend approximately two years rearing in freshwater prior to smolting and downstream migration. The smolts are about 15.2 - 24.4 cm (6 - 10 in.) when they migrate downstream in May. They spend little if any time in the estuary before heading into other coastal waters or out to sea, as the estuary at the mouth of the Oyster River is small.

Puntledge River steelhead once supported a sizeable recreational, freshwater fishery (Thornton, pers. comm., 1978). However, stocks have declined considerably since 1955, necessitating closure of the fishery to protect the remaining population. The run begins in late October. Fish move up the river throughout November, December and early January. Their ascent ceases during an annual early January cool period. Upstream migration resumes late in January and peaks in late March. Historical spawning areas included Comox Lake and the upper Cruikshank and Puntledge rivers. These areas also formed the principal rearing grounds. However, adults are currently prevented from spawning above the diversion dam, by the closure of the Comox Dam fish ladders, in order to avoid the high juvenile mortality usually caused by the powerhouse turbines. Loss of spawning and rearing habitats was a major factor effecting the collapse of the Puntledge River steelhead fishery.

Courtenay River steelhead have been known to reach 6.8 - 9.0 kg (15 - 20 lbs.) and larger. During their freshwater residence, juvenile steelhead feed on benthic and drifting invertebrates (Thornton, pers. comm., 1978).

Steelhead smolts make their way downstream in the Courtenay River system during May. Information on their ecology and life history in Comox Harbour is limited.

(b) CUTTHROAT (*Salmo clarki clarki*) - The following section is based on information provided by Mr. B. Thornton, past president of the B. C. Steelhead Society in Comox.

Cutthroat are found in a number of small creeks, Morrison, Portuguese, Dove, Brooklyn, Roy, Millard - Piercy and Black as well as in the Oyster, Puntledge, Trent and Tsolum rivers. They enter these streams during April and May, to feed on emergent chum and pink salmon fry. Salmon eggs form a major portion of their diet during October, when cutthroat trout will again enter these streams. Throughout the rest of the year, items of terrestrial and aquatic (both salt and freshwater) origin are consumed.

Spawning occurs between November and March, and fry emergence takes place between March and July. Cutthroat spend two years in freshwater before migrating to sea. In their subsequent years, they spend winters in freshwater and summers in the estuaries, feeding on invertebrates, young salmon and other small fish. While the estuary seems to be important to cutthroat, no formal studies analyzing its role for this species have been conducted.

4. PACIFIC SALMON

(a) GENERAL

Because of the importance of Pacific salmon in the commercial and recreational fisheries, an understanding of their movements is essential for effective management. Tagging is one of the conventional techniques to study their migration patterns. Pacific salmon have been tagged as (1) adults at sea and (2) juveniles in their home streams, in an effort to ascertain their oceanic movements. Pink salmon were tagged prior to 1961 under the auspices of the International Pacific Salmon Fisheries Commission, and the Fisheries Research Board (Pritchard, 1932; Pritchard and DeLacy, 1944; DeLacy and Neave, 1947; Manzer, 1969; Anderson and Bailey, 1974). Coho and chum were studied until 1970 by the Department of Fisheries and the Fisheries Research Board (coho: Argue and Heizer, 1974; Argue, 1976; Argue and Marshall, 1976; - chum: Pritchard, 1932; Walker, *et al.*, 1962). Chinook were studied by traditional adult sea-tag methods between 1920 and 1949. More recently, juvenile salmon have been marked with tiny coded-wire nose tags inserted in the cartilaginous tissue of the fish's nose and visibly marked by fin clipping. The Head Recovery Program requires fish heads to be submitted for removal of the nose tags and decoding of the information on them (Argue and Heizer, 1974; Heizer and Beukema, 1977; Argue and Marshall, 1976; Argue, 1976; Heizer *et al*, 1978). Basic data for the 1976 Canadian chinook and coho catch sampling and mark recovery program are now available in published data records (Cook and Heizer, 1978). The information contained in these reports will provide the reader with an understanding of the large-scale salmon migrations in which local runs participate.

Escapement figures for the Puntledge, Tsolum and Oyster rivers are shown in Appendices 6.3, 6.4 and 6.5, while escapement data for the Courtenay River system, Millard - Piercy and Roy creeks, and the Trent river are given in Table 6.1. These figures indicate that about 45,000 adult salmon (1975) and their brood currently pass through Comox Harbour on their way upstream to spawn and on their way out to sea.

In 1975 and 1976, all chinooks and most chums utilized the spawning habitats of the Puntledge River rather than those of any of the other tributary streams. Between 1975 and 1976, from 75 to 200 chum salmon found their way into the Tsolum. Many pinks spawned in the Tsolum during those two years, while a limited number used the Puntledge. The Puntledge and Tsolum each contained 1000 coho spawners in 1976, while Millard - Piercy Creek had 350, Roy Creek was used by 100 - 300, and the Trent River received only 75 spawners.

Table 6.1 Total numbers of salmon that entered streams tributary to Comox Harbour in 1975 and 1976 (includes the Courtenay River system, Trent River and Roy and Millard - Piercy creeks. Data from Canada Dept. Fish. Environ., annual).

Year	Sockeye	Chinook	Coho	Chum	Pink	Total
1975	(few)	754	6,100	28,100	10,400	45,354
1976	(few)	605	2,635	35,335	10,350	48,915

(b) CHINOOK SALMON (*Oncorhynchus tshawytscha*) - Alternate names for chinook salmon are spring, commonly used by Canadian commercial fishermen, and Tyee, the large strains over 13.6 kg (30 lbs.), prized by sports fishermen.

Summer-run chinooks begin entering the Courtenay -

Puntledge river system in late May or early June (Canada Dept. Fish., 1958). Peak upstream migration occurs in mid-July. Spawning begins in early October, peaks in mid-October and is complete by early November. Most fish utilize the Puntledge spawning channel as the natural sites formerly used between the diversion dam and the impounding dam are currently inaccessible. Minor spawning beds include Barber's Pool (below the diversion dam), Nib Falls and Bull Island (above Stotan Falls) (Figure 6.3).

Fall-run chinooks arrive at the mouth of the Courtenay River in early September. Most fish migrate upstream during late September and early October. Spawning takes place throughout October in the Puntledge River, primarily in the section between Morrison Creek and the Condensory Bridge, and adjacent to the powerhouse and directly below it, with some egg deposition as far upstream as Stotan Falls and as far downstream as the Tsolum River junction (see Figure 6.3).

Fry of both summer and winter run races emerge from the gravel in March. Some migrate downstream immediately following emergence, while others move downstream as smolts the following year.

Healey (1978) conducted a brief study to determine the timing and relative abundance of chinook fry moving downstream, whether or not migrant fry were holding and rearing in the intertidal portion of the Courtenay River, and the physical characteristics of their preferred habitat. The greatest concentrations of fry were found during May. They inhabited areas ranging in salinity from $10^{o}/_{oo}$ to $27^{o}/_{oo}$. At high tide, they dispersed to the margins of the estuary. The most extensively used sections were the river channel and marshes, north and west of the cement works, although the entire channel and associated marshes east to Comox Marina were exploited.

Chinook fry were found to consume adult and larval

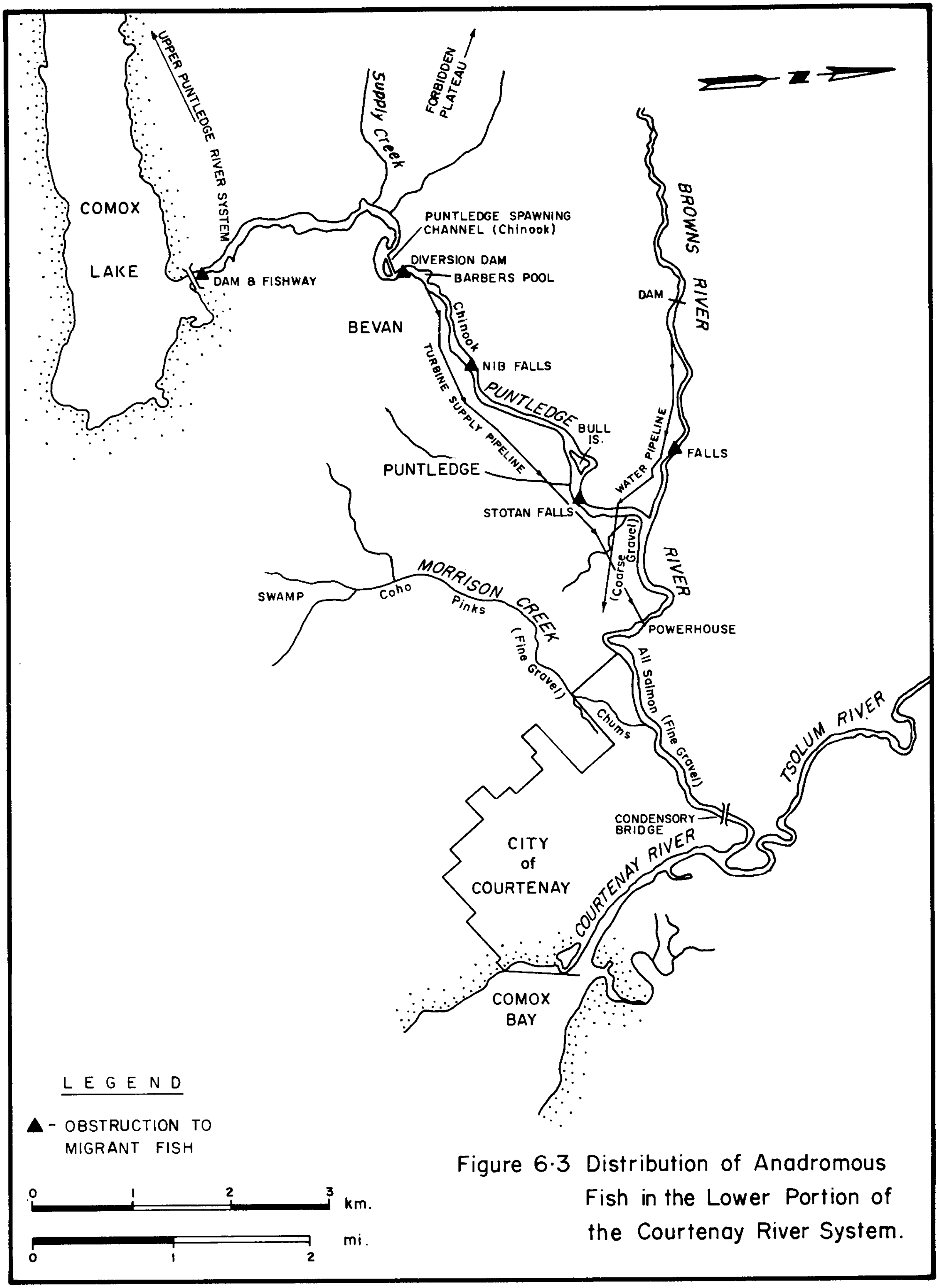


Figure 6·3 Distribution of Anadromous Fish in the Lower Portion of the Courtenay River System.

insects, harpacticoid copepods, amphipods, crab and other decapod larvae, mysids, fish larvae and fish eggs. Healey (1978) concluded that Comox Harbour was an important nursery area for juvenile chinook salmon.

(c) CHUM SALMON (*Oncorhynchus keta*) - Some chum salmon enter the river in early October, although major upstream migrations do not occur until late October (Canada Dept. Fish., 1958). Runs reach their maximum in mid-November and are virtually complete by mid-December. Spawning is confined primarily to the lower reaches of the Puntledge and the Tsolum rivers. It is most intensive on and near the Condensory Bridge grounds, as well as below the powerhouse, and as far downstream as the Tsolum River junction (Figure 6.3).

The chum fry migrate directly downstream following emergence. The runs peak in mid-May and are generally finished by early June. Chum fry utilize Comox Harbour as a nursery ground (Healey, 1978). They were often found in association with chinook fry, east of Comox and in the Goose Spit lagoon. No chum fry were collected after May 31, 1978, suggesting that chum salmon leave the estuary earlier than chinook.

(d) COHO SALMON (*Oncorhynchus kisutch*) - Coho congregate in pools below their respective spawning tributaries, for variable periods of time, starting in mid-September (Canada Dept. Fish., 1958).

Upstream migration of coho salmon commences when the flows in their respective spawning streams increase, i.e. late October and early November. Spawning continues throughout November and December. It is most intensive in Black and Morrison creeks, and Little Oyster, Puntledge and Tsolum rivers (Figures 6.1 and 6.3).

Coho fry emerge in April, then disperse throughout the system to nursery-rearing areas, where they spend a year in fresh water. Most coho migrate downstream the following spring as smolts; however, some migrate as fry. Both groups descend their stream of origin in May. Seaward movement continues throughout the summer in association with reduced river discharge and increased size of the fish.

Healey (1978) sampled Comox Harbour to determine the timing and abundance of juvenile salmon moving downstream during June. Coho were caught in Dyke Slough and in Comox Marina. In mid-May, they were again found in Dyke Slough, indicating that the Courtenay River channel may be an important rearing area for juvenile coho.

(e) PINK SALMON (*Oncorhynchus gorbuscha*) - The Puntledge River represents the most southerly, economically viable commercial run of even-year pink salmon on Vancouver Island (Canada Dept. Fish., 1958). They may be seen in the river any time after mid-August. Near the end of September, they move up the river to Stotan Falls (6.4 km, 3.9 mi.) from the river mouth), and spawn shortly afterward.

Important spawning grounds include the Condensory Bridge area and the Tsolum River. In large-run years, fish spawn at the base of Stotan Falls, as well as in the Browns River and in the Puntledge River stem above the powerhouse. Spawning distribution is largely determined by the size of the run (Canada Dept. Fish., 1958).

The fry emerge in April and begin swimming downstream immediately. Seaward migration is greatest during mid-April, and finished by early May (Healey, 1978).

(f) SOCKEYE SALMON (*Onorhynchus nerka*) - There is little information available regarding the stream ecology of Puntledge River sockeye, as their numbers are small and observation is difficult.

Puntledge River sockeye are thought to be the vestige of populations introduced during the 1920's. With habitat improvement, it is believed that they are capable of forming the nucleus of a rehabilitated, larger run (Windsor, 1958). Sockeye move into the Courtenay River during August and remain there for a month (Canada Dept. Fish., 1958). Prior to the closure of the Comox Dam fish ladders, it was assumed that sockeye salmom migrated upstream into Comox Lake during early October and spawned in the lake and nearby tributaries in late October.

The fry were thought to emerge in April, spend a year rearing in the lake, then migrate downstream the following May as yearling smolts.

5. NON-SALMONID MARINE SPECIES

(a) HERRING - (*Clupea harengus pallasi*) - A portion of the southern Vancouver Island herring population spawns in Statistical Area 14. Spawn deposition in the area declined during the late 1960's. In 1969 and 1970 no spawning occurred (Humphreys and Webb, 1970). In recent years, it has been increasing (Trent, pers. comm., 1979).

Humphreys and Webb, (1970, 1771, 1973) Webb (1974, 1976) and Webb, *et al.* (1977) documented the occurrence of herring spawn in coastal British Columbia waters between 1970 and 1977. Limited spawning occurred in Comox Harbour during April and May, 1977. Intermittent spawning has been noted in the harbour since the 1920's. Spawn was also deposited on aquatic vegetation bordering Baynes Sound and Lambert Channel (see Figure 6.4).

Herring hatch approximately 10 days after egg deposition. They then enter a pelagic larval stage. As summer approaches, the young herring congregate in schools adjacent to sheltered shoals, whey they feed extensively on copepods, diatoms and invertebrate eggs. By the end of the first summer, they resemble adults and move offshore, into the Strait of Georgia and to feeding and rearing grounds on the west coast

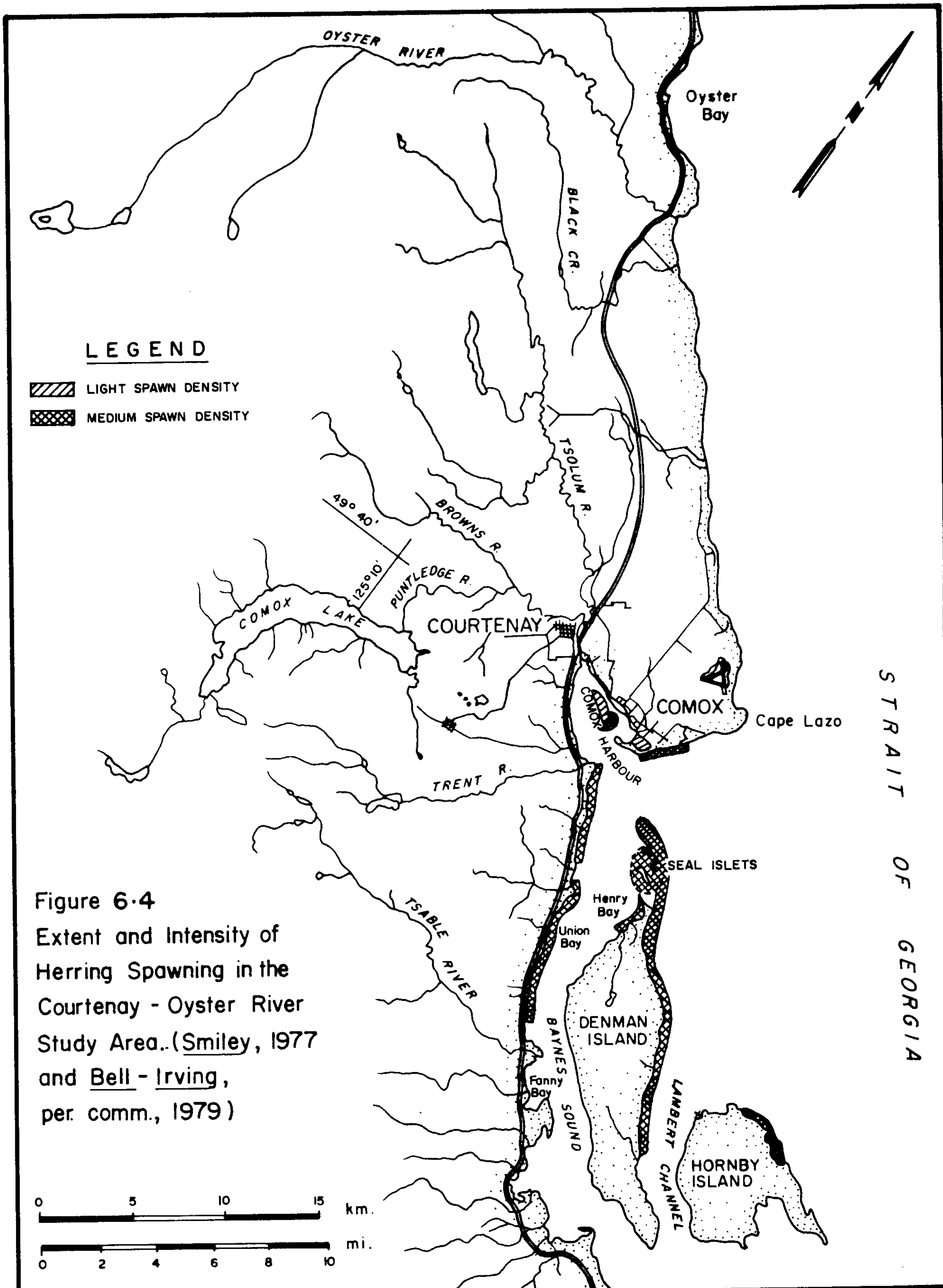


Figure 6·4
Extent and Intensity of Herring Spawning in the Courtenay - Oyster River Study Area. (Smiley, 1977 and Bell - Irving, per. comm., 1979)

of Vancouver Island. They return to the east coast of Vancouver Island two to three years later to spawn in the general vicinity where they originated (Hart, 1973; Boyd, pers. comm., 1978).

As larvae, herring are prey for many fish and invertebrates. Maturing herring are food for salmon, waterfowl, dogfish, sea lions and whales. Throughout their life cycle, herring are important components of the marine food chain.

6. SALMONID ENHANCEMENT

The objective of the current British Columbia Salmonid Enhancement program is a doubling of the existing production of salmonids to the historical, pre-development level. The Courtenay-Puntledge chinook stocks are of great concern to the Fisheries Service because they provided "Tyee" fishing in the Comox area that rivalled the famous Campbell River fishery. Reduction of the Puntledge stocks has now diminished this fishery (Canada Dept. Environ.; summary presented to B.C. Hydro in 1973, Fisheries Operations file 31-3-P1). A hatchery was finally proposed in 1973 to restore chinook stocks and other salmonid species to their former abundance. However, previous to that, several other schemes were implemented.

The first scheme was the construction of two fishways, one built at the Canadian Collieries Limited dam site (Comox Lake outlet), and the other at the diversion dam further downstream. These fishways were unsuccessful until 1946, when a new fishway was constructed adjacent to the lake dam, opening the upper watershed to salmonids once more. Fisheries officials maintain that the effectiveness of this fishway was negated by the expansion of hydro-electric facilities. They believe the B.C. Hydro expansion may be responsible for causing the deaths of many adult chinook in the powerhouse tailrace and of juveniles in the turbines, resulting in the decline of Puntledge River fall-and-winter-run chinook. Therefore, the B.C. Hydro and Power Authority constructed an artificial spawning channel adjacent to the diversion dam in 1965. The channel has been used annually by chinook, and operators hope to rebuild the run. In support of this endeavour, the Comox Dam fishway has remained closed for two reasons: firstly, to encourage chinook to use the channel; and secondly, because of the belief of fisheries biologists that permitting salmonids to migrate above the B.C. Hydro penstock intakes is futile, as many fry migrating downstream after hatching perish in the turbines. The problems of tailrace and turbine mortality and remedial measures are summarized in Table 6.2.

Table 6.2 Summary of fisheries problems and remedial measures undertaken. Adapted from Marshall (1973).

Event	Problem	Remedial Measures Required
Flow reduction between diversion dam and powerhouse.	Increased hazard (delay and injury) to migrating adult salmon at Nib and Stotan Falls.	1954-1971. (a) establishment of optimal minimum flows of (300-500 cfs) in falls section.
Increased flow at powerhouse tailrace.	Attracted upstream migrants which delayed upstream migrating adults and caused injury to fish in the draft tubes.	1956. Installation of protective gratings over powerhouse draft tube. 1969-present. Establishment of minimum flow criteria.
Modification of intake works increasing diversion flow.	Major portion of downstream migrant juveniles passing through the turbine and incurring 30 - 40% mortality.	1955-1965. Conducted various types of salvage operations for juveniles. 1965. Spawning channel constructed to replace spawning areas above diversion dam and introduce migrant juveniles downstream of Puntledge powerhouse intake works.

More recent work involved the installation of flow deflectors at the diversion barrier (1970), construction of a migration weir at Stotan Falls, and establishment of controlled flows during rearing (1971). Marshall (1974) reviewed agreements between B.C. Hydro and the Fisheries and Marine Service on the matter of flow control at critical times of the year (see Hydrology Section). Finally, hatchery propagation was instituted on a small scale in 1972.

Despite remedial measures undertaken, poor production of chinook salmon ensued owing to heavy prespawning mortality, reduced egg deposition, and low egg-to-fry survival. As a result, the channel maintained at the reduced level, rather than increased, chinook populations native to the Puntledge River, and emphasis shifted to more extensive hatchery propagation.

The Fisheries and Marine Service proposed construction of a $4 million hatchery near the old powerhouse (Sinclair, pers. comm., 1977; Acres Consulting Services, 1973). Construction of the hatchery was authorized in May, 1978, and completion is expected some time in 1979 (Hearnden, 1978). Improvements to the site adjacent to the diversion dam were also included. The projected combined hatchery output available for commercial and recreational fisheries is expected to be about 130,000 coho, 75,000 chinook and 8,000 steelhead (Hearnden, 1978).

Objections to the hatchery have been raised by those who would prefer to see the miles of Upper Puntledge and Cruikshank River systems used again as they were before 1913 and during 1946 - 1965 (Burns, 1976). This would involve the construction of protective louvers in front of the turbine intakes at the diversion dam.

Between 1968 and 1972, the culture and migration of pink salmon in Headquarters Creek and the Tsolum River were studied by Bams, (1972, 1973, 1974, 1976a) and Bams and

Crabtree (1976). The hatchery project was attempting to discover novel and efficient methods of propagating salmon. Genetic investigations were concerned with the ability of transplanted and hybrid pink salmon to return to the Tsolum River, into which they had been released as fry. These studies involved marking or treating a high percentage of the Tsolum River run of pinks, which since 1972, except for 1973, has been at an escapement level of about 10,000, the highest since 1959.

Morrison Creek was cleared and modified in 1976 by members of the Courtenay and District Fish and Game Protective Association, who worked with technical and financial assistance from the Salmonid Enhancement Program of the federal Fisheries and Marine Service. Morrison Creek is used by adult coho and pink salmon for spawning, and by juveniles for rearing.

Hoskins and Hulstein (1977) have examined fish from the Puntledge River system and Rosewall Creek for the presence of disease. Both streams are of particular interest owing to the salmonid enhancement projects in progress there.

(iii) THE FISHERIES RESOURCE

The Annual Narrative Reports for Conservation District 3 and salmon histories for Area 14 contain information on commercial fishing in the Courtenay/Comox area. Both report series are on file with Fisheries and Marine Service in Vancouver. Information on economic aspects of the fishing industry is available through the Economics and Statistical Services Division, Vancouver, B.C.

1. THE COMMERCIAL FISHERY

SALMON

Salmonids originating in the Courtenay and Oyster River systems contribute substantially to catches in the Strait of Georgia and surrounding areas. Anderson (1973, 1975, 1976, 1977), and Anderson and Bailey (1974) analyzed pink and chum salmon catch, escapement, and exploitation data for the Strait of Georgia region. From this information they ascertained stock recruitments, total stocks, and stock rehabilitation trends. Table 6.3 and Figure 6.5 show the relationship between total stock and escapement.

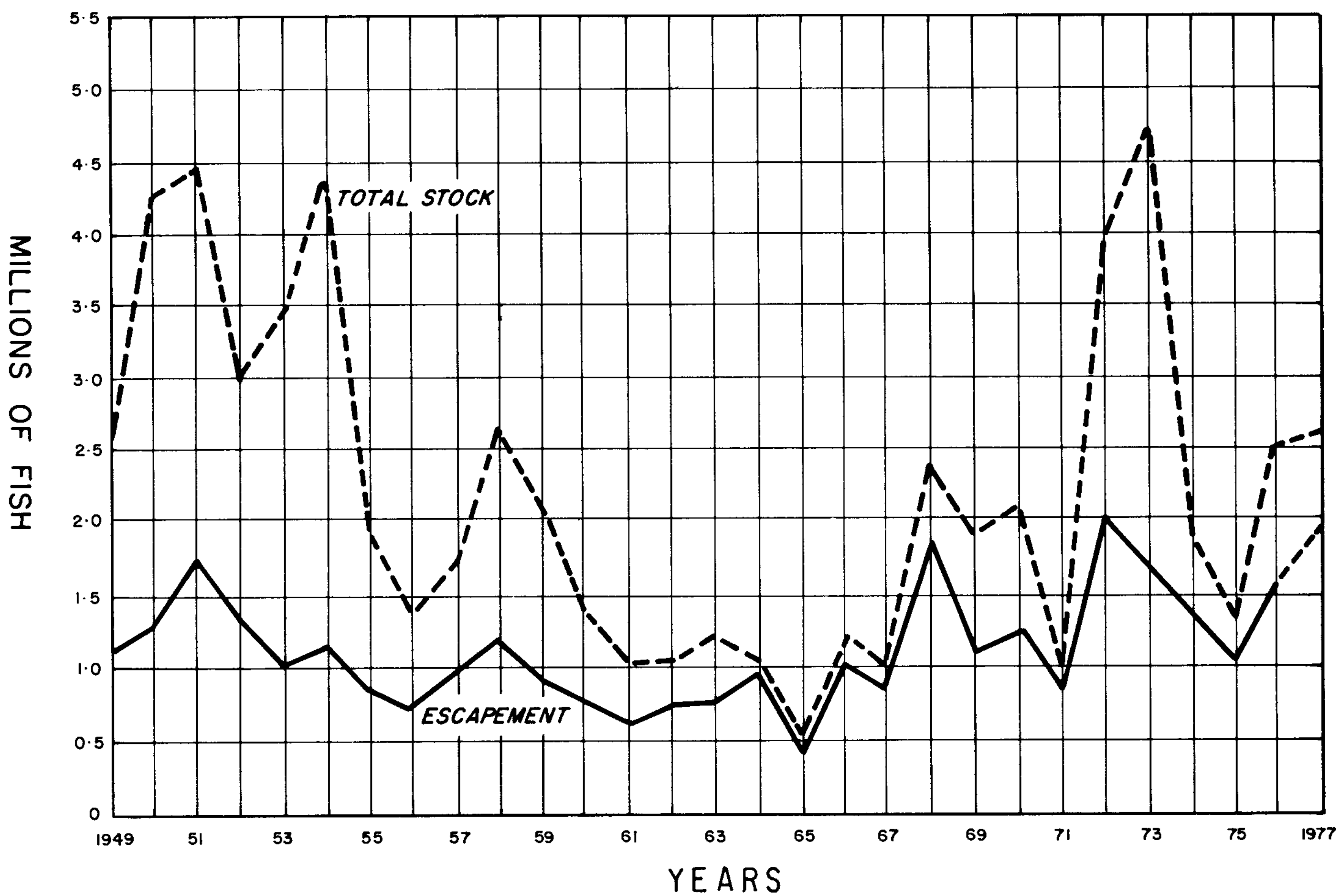
Table 6.3 Catch, escapement and percent exploitation of Strait of Georgia chum salmon.

Year	Catch	Escapement	Total Return	Percent Exploitation
1970	1,025,200	1,157,000	2,182,200	47
1971	116,200	721,200	837,400	14
1972	1,936,200	1,971,700	3,907,900	50
1973	2,896,700	1,820,500	4,717,200	61
1974	367,700	1,434,000	1,801,700	20
1975	513,900	754,100	1,268,000	40
1976	1,035,800	1,306,900	2,342,700	44
AVERAGE	1,127,400	1,309,200	2,436,600	46

Chinook, coho and chum form the basis of commercial salmon catches in the Courtenay - Comox area. The most extensively fished areas in the region are the Hornby Island and Cape Lazo grounds. Authorized harvesting methods in these areas include seine, gillnet and troll gear.

Commercial fishing statistics for Area 14 are presented in Appendix 6.6. In 1977, approximately 346,402 kg (736,000 lb.) of salmon were harvested, at an estimated value of $852,000. The total catch for other fish landed in the area was about 1,045,450 kg (2,300,000 lbs.), valued at about

Figure 6·5 Total Stock and Escapement of Johnstone Strait - Strait of Georgia Area Chum Salmon for 1949 - 1976 and Forecast for 1977. (Anderson, 1977)



$4,000,000. Herring comprised 97% of the non-salmonid catch, sole 0.08% and Pacific cod 0.07% (Canada Dept. Environment, annual).

PACIFIC HERRING

FOOD AND BAIT FISHERY

About 665,455 kg (1,464,000 lb.) or 12% of the total 1975-76 B.C. herring catch was harvested in Statistical Area 14. The total British Columbia catch for the 1975-76 herring season was approximately 5,519,100 kg (2,142,000 lb.) and valued at about $720,000 (Webb, 1976). The food and bait fishery was most intensive during November, December and January. Commercial bait requirements were also met during this period, while herring for the sport bait trade was landed throughout the entire year.

ROE FISHERY

The herring roe fishery was primarily restricted to gillnetting in Area 14 during 1976. The southern ends of Denman and Hornby Islands were closed to the herring roe fishery, in addition to Baynes Sound, exclusive of the Deep Bay-Buckley Bay area. The remainder of Statistical Area 14 was open to fishing.

By mid-March 1976, there were approximately 300 gillnetters operating in the area and about 1,500 tons of herring had been harvested. The average catch per boat per day was 9 - 10 tons. Fisheries officers observed 344 skiffs in the area at the height of the season, serviced by 75 packer boats. When the season closed in late March, an estimated 4,660 tons of herring roe had been harvested.

GROUNDFISH

Trawl fisheries within the study area have been monitored extensively since 1951. Consequently, reasonably complete fishing statistics are available. Historical information, groundfish biology and catch statistics to 1972 for the Strait of Georgia and regulated sections of Statistical Area 14 are contained in Forrester and Smith (1974). Forrester and Ketchen (1963), Forrester and Holmberg (1967) and Forrester and Prest (1968) also discuss the Baynes Sound and Strait of Georgia trawl fisheries. More recent information is available from the Pacific Biological Station in Nanaimo.

Forrester and Smith (1974), noted that total groundfish catches in the Baynes Sound area decreased from 2.7×10^6 kg (6.0×10^6 lb.) in 1956 to less than 1.36×10^6 kg (3.0×10^6 lb.) in 1972. Regional fishing effort declined during that same period from 18,400 hours to 5,180 hours. However, the catch rate increased from 73.0 kg/h (161 lb./hr.) in 1945-46 to 243.1 kg/h (536 lb./hr.) in 1971-72.

About 453,600 kg (1,000,000 lb.) of Pacific cod were landed annually in the Baynes Sound region between 1960 and 1972 (Forrester and Smith, 1974). English sole was the second most important species harvested, representing 13% of the total region catch. Average annual landings of English sole during the 1960-72 period were about 175,543 kg/yr (387,000 lb./yr.) Like the Pacific cod fishery, effort was most intense during the winter months (October - March). The average annual lingcod catch was 78,019 kg (172,000 lb.), of which 63% was harvested during the winter. Lingcod were the third most abundant species in the catch, between 1960 and 1972. Other species caught included rock sole (*Lepidopsetta bilineata*), starry flounder (*Platichthys stellatus*), rockfish (*Sebastes* spp.) and skate (*Raja* spp.). These species accounted for about 253,397 kg (541,000 lb.) or 16% of the total catch.

Major restricted trawling areas within Statistical Area 14 include the Yellow Rock, Cape Lazo and Union Bay grounds (see Figure 6.6). The Yellow Rock grounds support

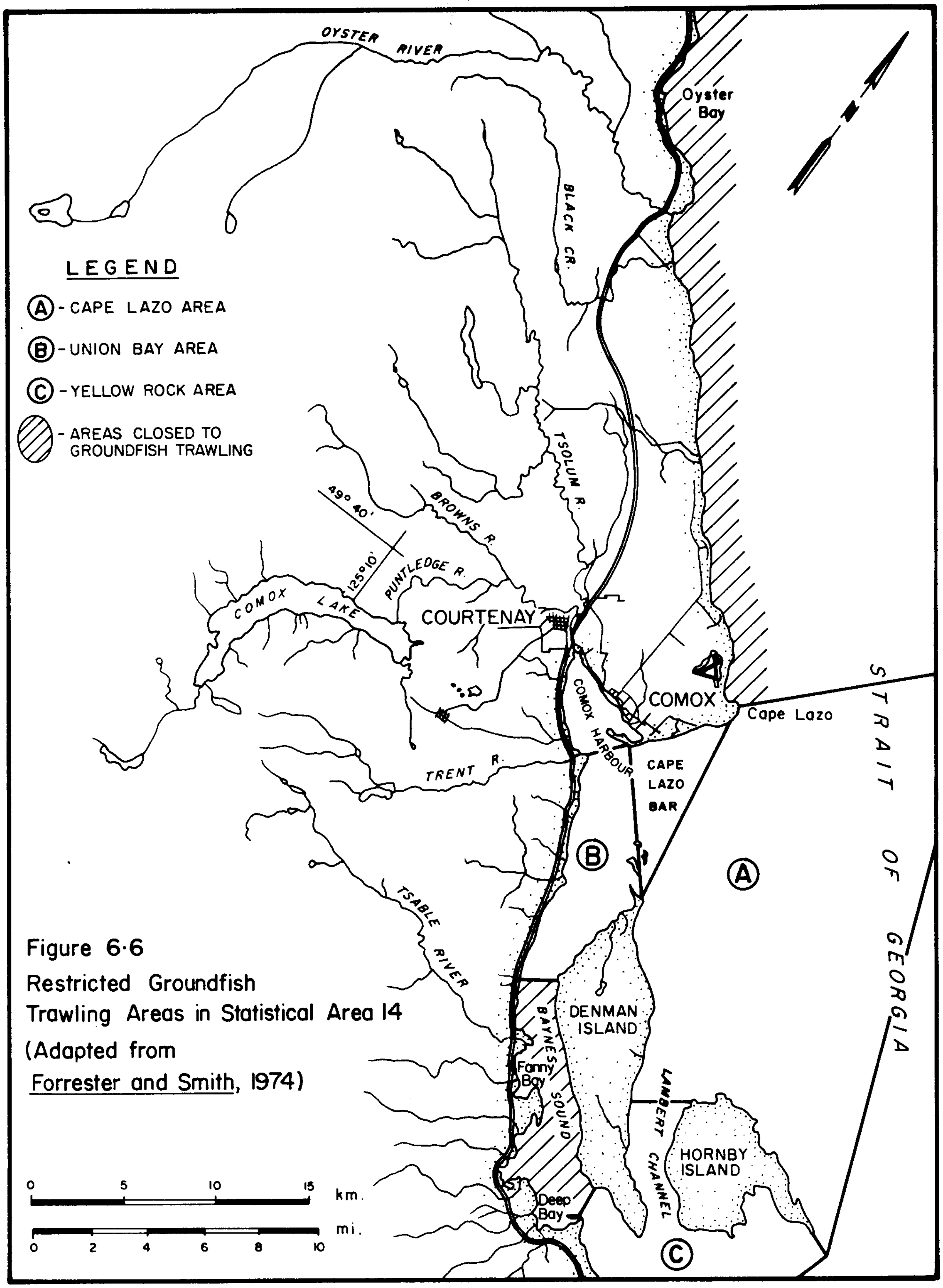


Figure 6·6
Restricted Groundfish Trawling Areas in Statistical Area 14
(Adapted from Forrester and Smith, 1974)

Pacific cod and rock sole populations, which constituted 47% and 13%, respectively, of the landings for that area (Westrheim, pers. comm.,1979). Between 1960 and 1972, English sole represented 43% of the Cape Lazo groundfish catch, and Pacific Cod accounted for 37%. English sole also formed the majority of the Union Bay catch. Groundfish populations in the latter two regions are currently under investigation because recruitment trends do not adequately explain the observed population declines and fluctuations (Westrheim, pers. comm.,1979).

2. RECREATIONAL FISHING

FRESHWATER SPORT FISHING

The Puntledge and Oyster rivers are the most heavily fished of the major streams in the Courtenay - Comox area. During the 1975 - 1976 season, 210 anglers visited the Puntledge River, while about 400 individuals fished the Oyster. The most extensively fished section of the Puntledge was the area between the powerhouse and the Condensory Bridge, whereas the Oyster River was most actively fished from the Highway Bridge to four to five miles upriver, with salmon, cutthroat, rainbow and steelhead trout being the principal species caught.

The steelhead season begins in December and lasts until about April. While cutthroat are caught in the spring and fall, rainbow trout are the object of a summer fishery. Steelhead catches in the Puntledge and Oyster river systems have declined recently (see Appendices 6.7 and 6.8). In 1957-58, the Puntledge River steelhead catch was estimated at 1,260 pieces (B.C. Dept. Recreation and Conservation, 1962). The steelhead catch for the 1977-78 season was 103 pieces for the Puntledge River and 108 for the Oyster River (B.C. Dept. Recreation and Conservation, annual). The Fish and Wildlife Branch attributed the catch decline between 1957-58 and 1977-78 to reductions in fishing effort and success. Puntledge River fishing effort dropped from 1,250 angler-days in 1975-76 to 333 in 1977-78. Similar declines were apparent in Oyster River statistics. The total estimated fishing effort ranged from 1,360 angler-days in the 1975-76 season to only 570 in the 1977-78 season. Over the past four years, the catch/day decreased from 0.54 in 1974-75 to 0.19 in 1977-78. The success rates for the Puntledge River for the same period fluctuated between .54 and .16.

TIDAL SPORT FISHING

Over 1,000 sports-fishing boats a day may be sighted in Area 14 at the height of the recreational fishing season (Canada Dept. Environ., 1973b). Mos and Harrison (1974) conducted a survey of recreational boating activity in the Strait of Georgia. Results showed that 30% of the residents in the Courtenay - Comox area owned boats and that 87% of these people used their boats during the summer months (June - September). Of the owners surveyed, 92% indicated fishing was their primary boating activity. Appendix 10.1 illustrates the extent of local resident participation in the tidal sport fishery. Regional sport fisheries center around Deep Bay, Chrome Island, Hornby Island, Comox, Bates Beach and Little River. British Columbia residents constitute about 60% of the anglers fishing in the Courtenay - Comox area, while out-of-province Canadians and American tourists comprise the remainder.

The greatest tidal sport fishing effort in the province was recorded in the Courtenay - Comox area (Canada Dept. Fish. Environ., 1976). Fishermen spent a total of 85,350 boat days fishing during 1977. However, the catch per boat day remained at the 1976 level of 1.6 fish.

In 1977, 136,806 salmon (approximately 20% of the total provincial sport catch) were caught in Area 14 (Canada Dept. Fish. Environ., annual). Between 1976 and 1977, coho catches increased by about 10% and pink catches increased nearly 20%, while chum and sockeye landings remained low and chinook catches declined nearly 20%. Chinook caught in the Courtenay - Comox fishery average about 9.1 kg (18 lb.), although fish weighing over 13.5 kg (30 lb.) "Tyee Salmon" have been landed (B.C. Dept. Recreation and Conservation, 1962; Canada Dept. Environ., 1976). The Georgia Strait Head Recovery Bulletins indicated that chinook originating in Area 14 are caught in the Strait of Georgia sport fishery from Discovery Passage (northern Strait of Georgia) to Saanich Inlet (southern Strait of Georgia) (Canada Dept. Fish. Environ., 1978). Tidal sport fishing statistics for Area 14 are presented in Appendix 6.9. They are open to question and currently under review because recent studies indicate that the recreational fishing catch is underestimated (Canada Dept. Fish. Environ., annual).

There is also a non-salmonid tidal sports fishery within Statistical Area 14. Rockfish species and lingcod were the principal species caught in 1976 and represented the majority of the catch. During the same year, 1,200 kg (2,870 lb.) of herring were landed by the recreational fishery for food and bait. The remainder of the catch was composed of Pacific cod, sablefish (*Anoplopoma fimbria*), and halibut (*Hippoglossus stenolepsis*) (Canada Dept. Environ., 1976).

The regional economy derives about $4,678,800 directly from the recreational fishery. Revenue is also generated indirectly through fishery-associated businesses. In addition, fishermen receive benefits, not readily quantified. Therefore, it is difficult to assess the exact value of the Courtenay - Comox recreational fishery.

3. INDIAN FOOD FISHERY

The Indian food fishery in the Comox vicinity has been monitored since 1951. Fisheries officers' reports are contained in the Annual Narrative Reports for Statistical Area 14.

105. Fish

Between 1951 and 1960, Indians of the Comox area procured fish for food under permit. Average annual landings during this period totalled 656 salmon. The catch was composed of chum, pink and coho. Chums accounted for 75% of the total average annual salmon catch, pinks 25% and coho 1%.

Permits were issued intermittently between 1961 and 1970, gaff and seine net being the principal fishing methods authorized. The Indian food fishery in Area 14 declined during the late 1960's because the Comox Indians commenced seining operations in Area 13. These fisheries supplied most of their food requirements and the traditional fisheries became auxiliary food sources. In addition to Area 13, chum, coho and chinook salmon were obtained from the Qualicum and Puntledge River system, and distributed among the Vancouver Island east coast bands.

The trend towards co-operative fishing ventures among the Vancouver Island east coast Indians intensified during the 1970's. Several bands operated seiners in the area. The Puntledge and Qualicum hatcheries became increasingly important sources of salmon. Chum salmon comprised the majority of the harvest, although a few coho and chinook were also taken.

Approximate values of fish caught may be ascertained from the B.C. Fish Marketing Reports. The Indian salmon catch for 1976 was composed of 5,305 chum, 1,057 coho and 93 chinook for a total of 6,455 fish. The estimated value of the fishery was $6,060. Chum accounted for $4,240, coho $1,638 and chinook $177. The average price per pound was $0.80 for chum, $1.55 for coho and $1.90 for chinook.

7. INVERTEBRATES

7. (i) TERRESTRIAL AND FRESHWATER INVERTEBRATES

Scudder, Northcote and Mundie (pers. comms., 1977) are not aware of any studies of these fauna in the Oyster River-Deep Bay area. Mounce (1973) wrote a guide to freshwater insects of Vancouver Island and Scudder is preparing a checklist of insects in British Columbia. The Canadian Forestry Service will be surveying forest insect pests in the Courtenay and Oyster drainage basins (Wood, pers. comm., 1977), although insects populations are not there in epidemic proportions (Canadian Forestry Service, 1977).

An examination of the stomach contents of chinook salmon caught by beach seines in the mouth of the Oyster River between April and August of 1973 revealed that 97% of the diet consisted of unidentified terrestrial invertebrates. In a similar investigation, Mason (1974) and Mason and Machidori (1976) analyzed the stomach contents of juvenile coho and chum salmon, and two species of sympatric sculpins (*Cottus aleuticus* and *C. asper*) from Rosewall, McNaughton, Chef and Lymn Creeks. Mason (1974) found that abundant amphipod populations in the upper estuary of Lymn Creek were the main food source of resident coho and chum fry. *Anisogrammarus confervicolus* constituted 80% of the diets of both species. The distribution of various vertebrate taxa in both the drift and the benthos of Lymn Creek estuary was also examined.

7. (ii) ESTUARINE AND MARINE INVERTEBRATES

Estuarine fauna are found in Comox Harbour and a small area of the Oyster River mouth (Goodman, 1974), while quasi-estuarine conditions exist at the mouths of the rivers flowing into the Strait of Georgia and Baynes Sound (EPEC Consulting Western Ltd., 1975). The fauna found between Oyster River and Cape Lazo and along Baynes Sound is typically marine.

1. COURTENAY RIVER ESTUARY

An examination of the intertidal invertebrates along the outer shores of Comox Harbour (PCB, 1974) revealed typically marine fauna (Appendix 7.1). Substrate character was considered to be the dominant influence on species distribution. A greater diversity of fauna was found on cobble and rock substrates than on the beaches of the Comox Harbour foreshore and the extensive mud flats exposed at low tide, which consisted primarily of sand, mud and gravel.

Of the thirty species collected, the most abundant epifauna were beach crabs (*Hemigrapsus nudus*), barnacles (*Balanus balanus*), mussels (*Mytilus edulis*), limpets (*Acmaea pelta* and *A. digitalis*), rock whelks (*Thais lamellosa*) and Pacific oysters (*Crassostrea gigas*). The commonest infauna were polychaetes, ghost shrimp (*Callianassa californicus*) and pelecypods. Associations of these marine animals were found as close to the Courtenay River as the mouth of Millard Creek and the foreshore of the town of Comox. Marine organisms in areas of low salinities can be expected to be under stress. Oysters in leases behind Goose Spit in Comox Harbour have a softer shell and poorer meat quality than animals grown in Baynes Sound (Tarnowski, pers. comm., 1977).

A survey of the intertidal foreshore of Comox Harbour by Bell-Irving (unpublished data) revealed the presence of many bivalves, i.e. Pacific oysters, edible mussels (*Mytilus edulis*), and numerous clam species; crustaceans, i.e. barnacles (*Balanus* spp.), beach crabs, Oregon crabs (*Hemigrapsus oregonensis*), hermit crabs (*Pagurus* spp.); gastropods, i.e. limpets (*Acmaea* spp.); anthozoans; polychaetes and anoplans. Quayle (1969b) also reported that Comox Harbour contained low numbers of the preditory Japanese oyster drill (*Ocenebra japonica*) which was introduced through transplantations of oysters from Salish Bay in Washington in 1941. The gastropod *Batillaria cumingi*, found on sand or firm mud, was introduced with oyster spat from Japan to Comox Harbour (*Ibid.*).

2. OYSTER RIVER ESTUARY

A survey of the stomach contents of fish caught in the delta between April and August 1973 revealed few estuarine invertebrate fauna (Goodman, 1974). Bivalves, gastropods and decapods made up the major component of the benthic biomass in the sand - gravel substrate that dominates the estuary.

3. BAYNES SOUND AND ADJACENT STRAIT OF GEORGIA

The protected waters and extensive tidal flats in Baynes Sound support one of the province's most abundant assemblages of bivalves, including the commercially important Pacific oyster. The native west coast oyster, *Ostrea lurida* is likely to be present in small numbers (Bernard, 1970), but is far less abundant than the carefully tended Pacific oyster, brought in from Japan in the 1930's (Quayle, 1969b).

Baynes Sound is particularly suited to the biological requirements of butter clams (*Saxidomus giganteus*) and manila or Japanese little-neck clams (*Protothaca staminea*), although scientists are not sure why (Bourne, pers. comm., 1977). Studies of sympatric clam communities in the intertidal zone around the Seal Islets have been extensive, dating back to 1941, when the B.C. Department of Fisheries began its bivalve investigations under D.B. Quayle. Bourne and Smith (1972) carried out detailed studies of the biology of the horse clam (*Tresus capax*) on the Seal Islets, and the present studies are aimed at obtaining an understanding of the ecology of clams at the site (Bourne, pers. comm., 1977). The reader interested in bivalves of the area surrounding the Courtenay River estuary (Comox Harbour) is referred to Bernard (1970), Bourne and Smith (1972), Nelson and Goyette (1976), Quayle (1961, 1964, 1966, 1969a, 1971), Quayle and Bourne (1972) and Quayle and Smith (1976).

Based on information supplied by geoduck fishermen, geoducks (*Panalope generosa*) are located in four main beds. In the Willemar Bluff-Cape Lazo bed, geoducks ranging between 0.8 and 0.9 kg (1.8 and 2.1 lb.) are abundant. Off Comox Bar, the majority of geoducks range between 1.4 and 2.3 kg (3 and 5 lb.), but they can range from as much as 1.1 to 3.6 kg (2.4 to 8 lb.). Geoducks of 1.4 to 1.8 kg (3 to 4 lb.) are common place off Kye Bay. While a small bed of geoducks near Henry Bay range in weight between 0.67 - 0.78 kg (1.8 and 2.1 lb.).

Surveys of prospective shrimp beds in the Strait of Georgia between Haro Strait in the south and Cape Mudge in the north by Butler and Légaré (1954) revealed a large population of shrimp and prawns from Cape Lazo to Denman Island. Eight tows in 70-110 m (38-60 fathoms) depths yielded an average of 160 kg/h (352 lb./hr.), 89% of the catch being smooth pinks (*Pandalus jordani*), while the remainder was humpback shrimp (*Pandalus hysinotus*) and prawns. Further studies of shrimps and prawns have been carried out on the Cape Lazo ground since that time (Butler, pers. comm., 1977).

As part of a general shrimp and prawn prospecting program on the coast of British Columbia by the Nanaimo Biological Station in 1954, prawn explorations were carried out in the Strait of Georgia to the north end of Denman Island in December, 1954 (Bulter and Dubokovic, 1955). No commercially exploitable prawn concentrations were found. A study was conducted on the distribution of the smooth shrimp in relation to the sediments in the area between the Cape Lazo Reef and Comox Bar by Sheldon and Warren (unpublished manuscript).

The bottom of the Oyster River was found to be unsuitable for shrimp trawling, but was presumed to have good potential for trapping (Bulter and Légaré, 1954).

7. (iii) ZOOPLANKTON

Zooplankton species in waters up to 40 - 50 m

(21.8-27.3 fathoms) are thought to differ from those in deeper, offshore waters (Fulton, pers. comm., 1977). No research has been conducted to substantiate this however.

Large numbers of bivalve and decapod larvae can be found in the marine waters near Comox Harbour at various times of the year (Bourne, pers. comm., 1977; Fulton, pers. comm., 1977), probably because of unusual combinations of wind, tide and river runoff which can generate currents that will: (1) import offshore zooplankton to the shallow waters near the estuary; and (2) carry estuarine zooplankton from the estuary into the nearby marine waters. Mason (1974) studied the major food sources for salmonids in the Oyster River and in Lymn Creek, respectively, and found that the species of marine zooplankton consumed by salmonids varied with the types and abundance of zooplankton species found in ebbing and flooding tides. Goodman (1974) noted that harpacticoid copepods were the major food source for coho and pink salmon, while harpacticoid copepods and cumaceans are commonly eaten by chum salmon.

As part of the Salmonid Emhancement Program, a "Plankton Watch" was initiated in Baynes Sound in April 1977, and patterned after the plankton monitoring system being carried out in Japan for some time in support of chum salmon *Oncorhynchus keta* hatcheries (Kennedy, pers. comm.) . The Baynes Sound zooplankton program is designed to alert the hatchery operator at the Rosewall Creek facility to the presence of a peak zooplankton standing crop so chum salmon fry can be released. The monitoring consists of 20 stations occupied 5 days per week on the incoming tide, where surface temperatures, Secchi disc readings and a 5-minute plankton tow at 1 metre depth are taken at each station. A sampler with a cross sectional area of 0.01 m^2 at the open end and net with 200 μm mesh size is used to capture zooplankton. Unfortunately, the program missed the peak plankton period in 1977, but was commenced earlier in 1978 and was more successful in meeting its main goal.

7. (iv) THE INVERTEBRATE FISHERY

The abundance of invertebrate fauna in the study area, has resulted in a very active invertebrate fishery which harvests oysters, shrimps, clams, geoducks, crabs and abalone.

The most abundant shellfish resource is the Pacific oyster. In Statistical Area 14, from Oyster River to Dorcas Point, a total of 341.2 ha (842.43 ac.) of intertidal foreshore was leased from the Provincial Government by June 1976 for oyster culture (see Figure 7.1). Of that, 35.2 ha (87.1 ac.) were leased in Comox Harbour, 18.9 ha (46.9 ac.) in Lambert Channel and 285.3 ha (704.4 ac.), or 42% of British Columbia's oyster growing leases, along Baynes Sound. Over a five-year period, 1971-1975, the Fisheries and Marine Service (unpublished) determined that 68.3% of the production of British Columbia oysters came from Baynes Sound.

Pacific oyster seed, collected from Pendrell Sound, (northern Strait of Georgia) and Hotham Island, (Jervis Inlet), is used by commercial growers because the oyster spat fall there is regular and predictable (Quayle, 1969a, b, 1971). After a period of development, the seed oysters are spread onto leased oyster grounds. The clusters of oysters are broken apart and relaid after one another to prevent them from becoming mis-shapen through crowding. Following three years of development, they are harvested by hand or, occasionally by dredge, and transported either by truck or scow to processing plants in Baynes Sound or Victoria.

The total amount of oysters harvested in Statistical Area 14 for January - December 1976 was 80,326 U.S. gallons shucked and 34,786 dozen in the shell (Marine Resources Branch, unpublished). Between April 1977 - March 1978, 61,703 gallons of shucked oysters (230,798 lbs.) and 8,726 dozen oysters in the shell were sold either to B.C. Packers or directly to the consumer.

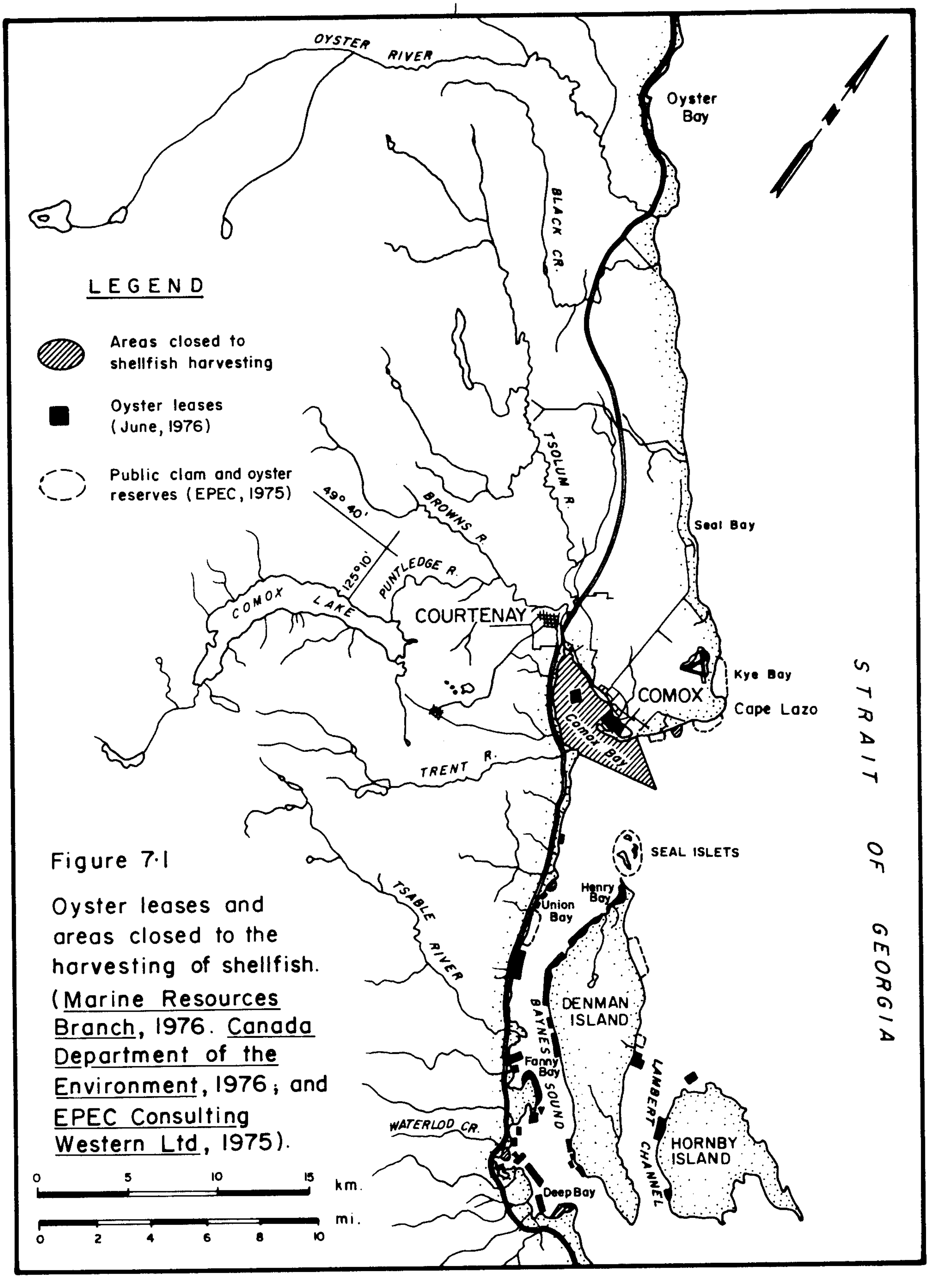


Figure 7·1

Oyster leases and areas closed to the harvesting of shellfish. (Marine Resources Branch, 1976. Canada Department of the Environment, 1976; and EPEC Consulting Western Ltd, 1975).

In 1976, the total value of oysters sold, retail and wholesale, totalled $1,013,337 (Marine Resources Branch, unpublished). Between March 1977 and April 1978, the growers received a total of $809,233 for shucked oysters, $11,483 for Oysters sold by the pound and $12,263 for oysters sold by the dozen.

Marine Resources Branch has set aside specific reserves where oysters are relaid for recreational harvesting. In Baynes Sound, the Union Bay area has been reserved for this purpose (see Figure 7.2).

Shrimps are the second most intensively harvested shellfish. Both shrimp and prawns are harvested between Cape Lazo and Denman Island, off Oyster River, Little River and Kye Bay (Figure 7.2). The two major species caught are the smooth pink and the humpback shrimp (Butler, pers. comm., 1977). A summary of shrimp and prawns harvested by trawling or trapping is shown in Table 7.1. The annual catch statistics for Comox Bar alone from 1953-1974 are outlined in Table 7.2 based on information supplied by Boutillier (pers. comm., 1977).

Table 7.1 Commercial landings of invertebrates from Canada Dept. of Environ. Fisheries for Statistical Area 14 in $000, from 1968-1976. Compiled from Fisheries and Marine Service 1A Worksheets (less than $1,000:*. Data unavailable: θ)

YEAR	SHRIMP PRAWNS	CRAB	CLAMS	OCTOPUS
1977	11	1	9	*
1976	5	θ	8	*
1975	6	θ	18	*
1974	8	*	15	*
1973	7	θ	5	*
1972	9	θ	11	*
1971	5	*	11	*
1970	3	θ	3	*
1969	4	θ	11	θ
1968	8	*	9	*

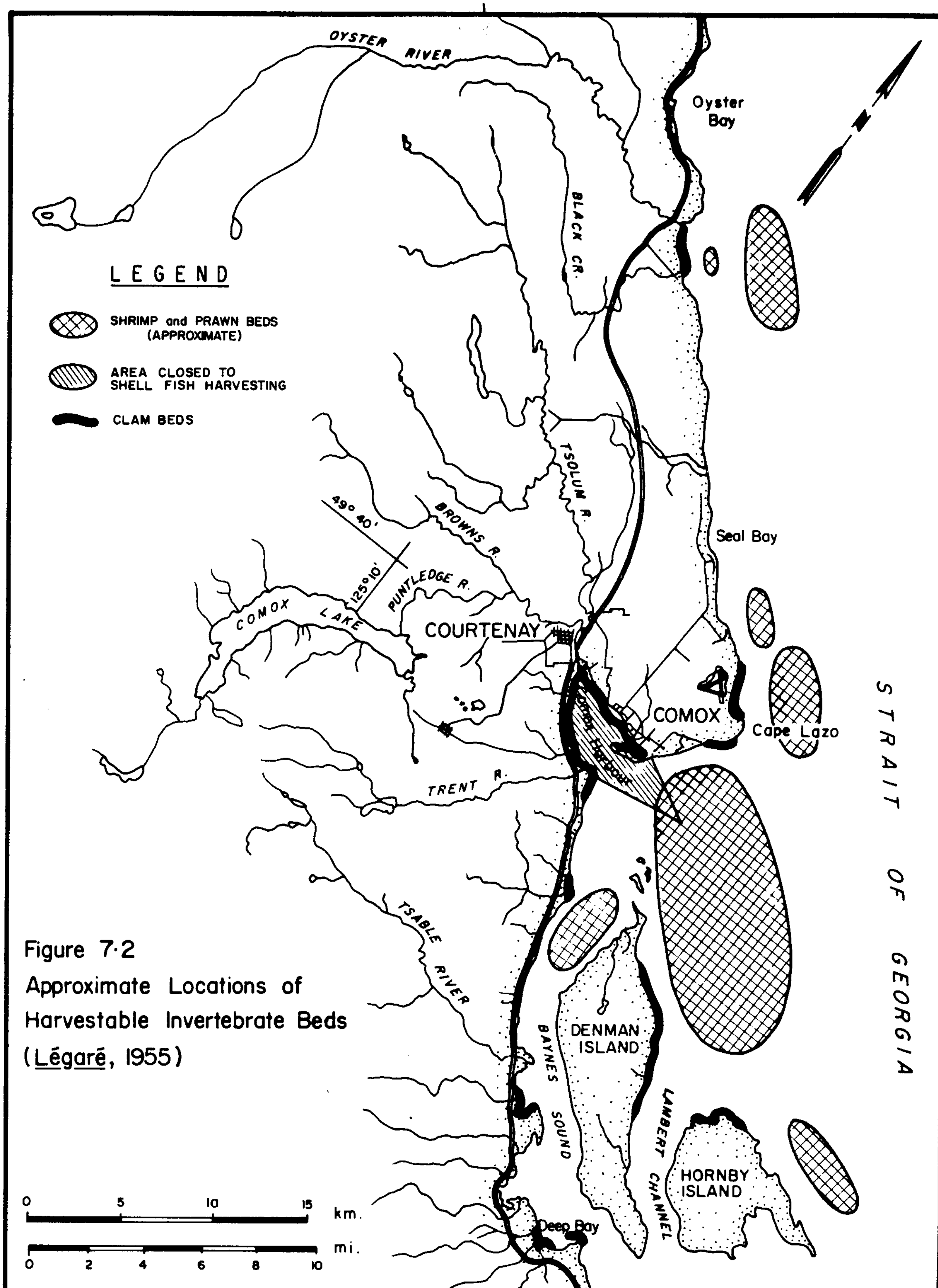


Figure 7·2
Approximate Locations of Harvestable Invertebrate Beds
(Légaré, 1955)

Table 7.2 Area 14 shrimp trawl landings. Most of the catch is off the Cape Lazo Gully (see Figure 7.1) and includes smooth pinks (*Pandalus jordani*) and humpbacks (*P. hypsinotus*). Original data were reported in pounds, rounded to the nearest 100, caught during the shrimp season (Boutillier, pers. comm., 1977). Number marked with an asterisk (*) are from Area 14, 1A worksheets (Fish. Mar. Serv. Vancouver, B.C.)

YEAR	CATCH (Kg)	CATCH PER DAY
1953-53	49,915	150
1954-55	24,270	180
1955-56	14,274	89
1956-57	36,869	137
1957-58	74,645	144
1958-59	3,046	95
1959-60	30,867	115
1960-61	18,775	140
1961-62	23,639	101
1962-63	27,685	96
1963-64	13,865	51
1964-65	8,864	46
1965-66	184,249	167
1966-67	26,640	96
1967-68	23,735	110
1968-69	2,046	95
1969-70	8,956	84
1970-71	5,182	θ
*1971-72	5,364	θ
*1972-73	11,369	θ
*1973-74	9,092	θ
*1974-75	8,283	θ

θ : Data unavailable

Clams are commercially harvested in Fanny Bay, Union Bay, off Seal Islets, eastern Denman Island, north Hornby Island and Kye Bay. The major species of calms harvested include the razor, butter and Japanese little-neck clams (see Figure 7.1). The landed value of the clams harvested in area 14 is seen in Table 7.1.

The geoduck fishery is very recent in the area. In 1977, 20,000 lbs or 4% of the coast wide total were harvested. Up until August 1978, 306,000 lbs (27% of the coast-wide total) were harvested in the study area indicating that there is an expanding market for these clams (Birtwell, memo to Environmental Protection Service, 1978).

All shellfish may become contaminated by fecal bacteria from sewage or by paralytic shellfish poison. Federal Department of Fisheries and Marine Service puts out schedules called Schedule I, and posts public notices explaining where contaminated shellfish beds are located. Shellfish become contaminated by fecal bacteria because they are ingested with other food. When the concentration of bacteria exceeds 240 MPN/100 mg of meat, the shellfish is unfit for consumption. Oysters being harvested in contaminated areas are moved to clean areas so the bacteria can be excreted. They are then sold.

Paralytic shellfish poisoning is caused by two types of dinoflagellates *Gongaulux catanella* and *G. acatanella* (Prakash and Taylor, 1966). The reason for the blooms of these phytoplankton is not known, but it is believed that a combination of nutrients and ideal oceanographic and meteorological conditions can stimulate them (Waldichuk, 1958; Anderson, 1960 and Quayle, 1969a). A major outbreak of paralytic shellfish poisoning in Baynes Sound during the autumn of 1957 affected both oysters and clams (Waldichuk, 1958; Anderson, 1960). Most bivalves excrete the toxin from the dinoflagellates within a three-month period after ingestion. Butter clams, however, may remain toxic for several years afterwards because the toxin binds with molecules in the siphon and is more difficult to excrete (Cox, pers. comm., 1978). For current specific information on beds with paralytic shellfish poisoning, contact Jack Trent, federal Fisheries Officer, Comox, British Columbia.

8. FLORA.

8. (i) TERRESTRIAL VEGETATION

Krajina (1965, 1970), first proposed a method for dividing British Columbia into biogeographic zones based on climate, soil type and topography. The broad vegetation zones, based on climax vegetation, reflect the long-term growing conditions of an environment. Definitions of these zones were revised by Packee (1974 a, b). Of the seven subzones found on Vancouver Island, five of these were found in the study area. They include: the Douglas-fir dry subzone, the Douglas-fir wet subzone, the western hemlock dry subzone, the western hemlock wet subzone and the mountain hemlock subzone (Figure 8.1). Forest associations found on the east coast of Vancouver Island have been summarized in Krajina and Spilsbury (1953).

The north shore of Comox Harbour and the Oyster River estuary lie within the Douglas-fir dry subzone, the warmest and driest subzone in the study area. The forests of the subzone range from dry open oak woodlands to closed canopy forests of Douglas fir (*Pseudotsuga menziesii*) 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 cactus (*Opuntia fragilis*) (Packee, 1974a).

The Douglas fir wet subzone extends along the southern shoreline of Comox Harbour, covering most of the watershed areas and Baynes Sound. Douglas fir is the characteristic dominant. Below 305 m (1,000 ft.) asl, arbutus (*Arbutus menziesii*) and grand fir are common. Western hemlock (*Tsuga heterophylla*) may occur as a climax species in the watershed areas. As it is intolerant to drought, western hemlock is usually found in the understory.

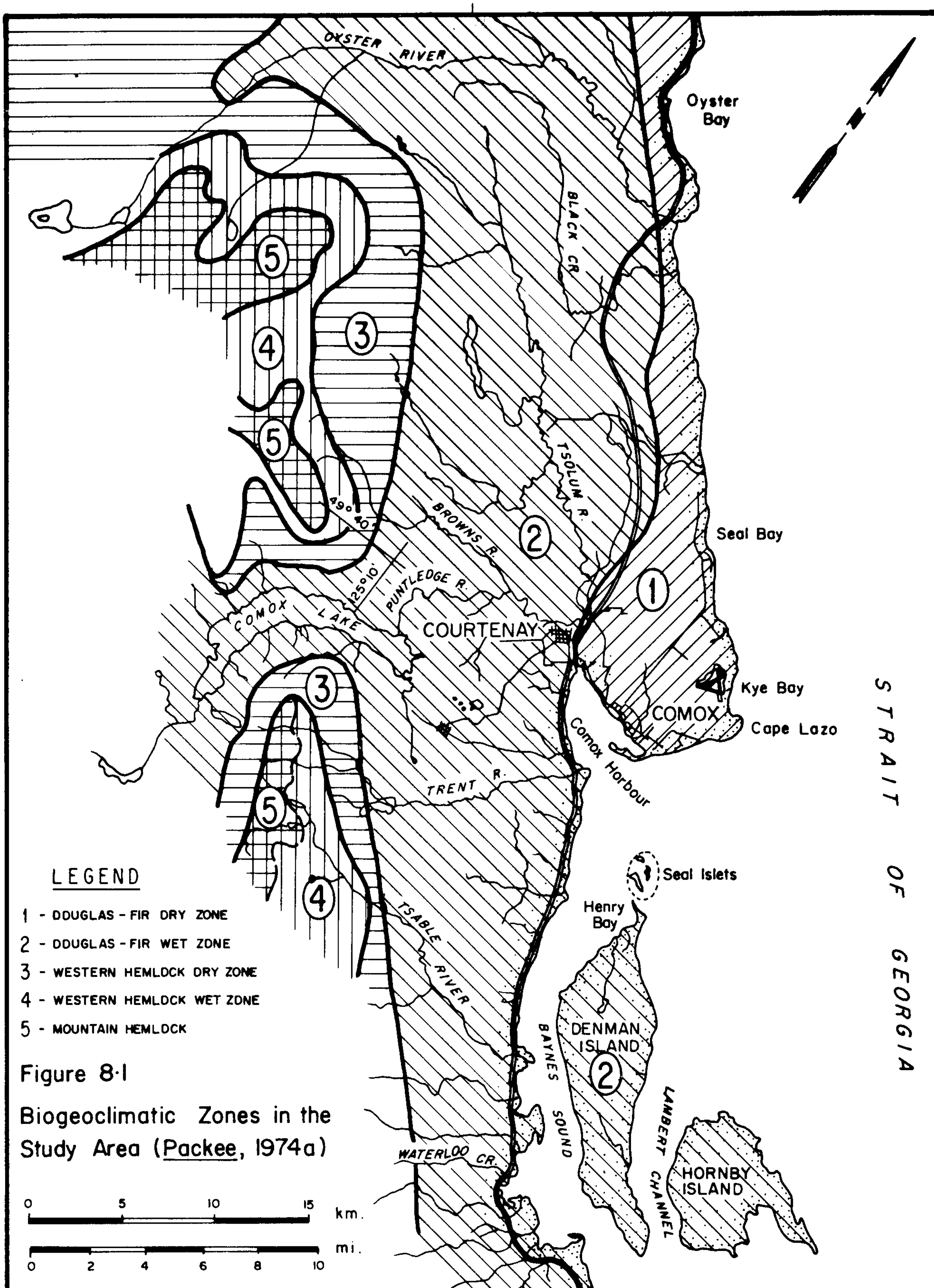


Figure 8·1

Biogeoclimatic Zones in the Study Area (Packee, 1974a)

The other three subzones, the western hemlock dry and wet subzones and the mountain hemlock subzone, are found near the headquarters of the Courtenay and Oyster River watersheds at successively higher elevations. Climatic vegetation and indicator species are described by Packee (1974a).

The watershed areas are owned by or leased to logging companies and have been logged extensively since the 1900's. The present forest cover is, therefore, second growth.

Crown Zellerbach, MacMillan and Bloedel and Weldwood have current forest cover maps giving details of the acreage, dominant species in a stand and the quality of the trees in a stand. Crown Zellerbach and MacMillan Bloedel cover maps also give information on height, age and volume of the trees in each stand.

When a stand is logged, the dominant species in that stand are replanted. Juvenile spacing (thinning young trees to 400 stems/acre) and fertilization (200 lb. N/acre of urea which is 46% N) enhance growth (Leslie, pers. comm., 1978).

Ecosign (undated) noted that at Mount Washington, the subordinant or understory vegetation varied from alpine grasses and flowers in the upper elevations to a predominance of black mountain huckleberry (*Vaccinium membranaceum*) in lower elevations. Fireweed (*Epilobium angustifolium*) was found to occur in abundance on the lower slopes where logging had occurred.

Streambank vegetation is an important contributor to stream ecology, not only helping to maintain lower temperatures in summer, but also providing food in the form of falling leaves and insects for aquatic species, including coho salmon and cutthroat trout.

No streambank surveys of vegetation have been done. Mason (1974) noted, however, that along the first 5 km (3.1 mi.) of Lymn Creek, which flows into Deep Bay, alders (*Alnus* spp.) lined the streambanks. The understory consisted of dense salmonberry (*Rubus spectabilis*), stink currant (*Ribes bracteosum*), salal (*Gualtheria shallon*), and swordfern (*Polystichum munitum*).

B.C. Fish and Wildlife Branch (undated) surveyed Comox Lake banks and found western red cedar, balsam fir and western white pine (*Pinus monticola*). The major understory vegetation included salal, western teaberry (*Gualtheria ovatifolia*), swordfern and Labrador tea (*Ledum groenlandicum*). Mosses and lichens were seen on rock cliffs.

8. (ii) FRESHWATER FLORA

Very little documented information exists on freshwater flora. Canada Dept. of Fish. (1958), found *Tabellaria* spp. and *Navicula* spp. of diatoms present in Comox, Willemar and Forbush lakes. The phytoplankton, *Ceratium* spp., were common in Comox Lake and present in Forbush Lake while *Dinobryon* spp. of phytoplankton were found in Comox and Willemar lakes.

8. (iii) ESTUARINE FLORA

1. COMOX HARBOUR

The vegetation of Comox Harbour has been catalogued by Kennedy and Waters (unpublished). Kennedy (M. Sc., in progress, University of British Columbia), identified and described the emergent vascular flora and Pollution Control Branch (1974) did a brief survey of the benthic algae in the harbour. Results by Kennedy and Waters (*Ibid.*) showed that in the Goose Spit area, 50% of the flora was broom (*Cytisus acoparius*). Near Fields Sawmill, in the forested area, 40% of the species seen were trees and shrubs while reeds, grasses and sedge (*Graminae*) constituted another 40% of the cover. In the meadow area near Fields Sawmill, the predominant (60%) species was the sedge (*Carex lyngbyei*) and 55% of the species near Courtenay sewage lagoon was sedge and 20% was saltwort (*Salicornia virginica*).

Kennedy (unpublished) assembled a species list (Appendix 8.1) and identified thirteen plant communities in the intertidal zone of Comox Harbour, each with the following characteristic dominants:

1. Three square bulrush (*Scirpus americanus*).
2. Tufted hairgrass (*Deschampsia cespitosa*), cinquefoil (*Potentilla pacifica*) and Lyngby's sedge (*Carex lyngbyei*).
3. Small fruit bulrush (*Scirpus microcarpus*) and *Carex lyngbyei*.
4. *Carex lyngbyei*.
5. *Potentilla pacifica* and spring bank clover (*Trifolium wormskjoldii*).
6. Reed canary grass (*Phalaris arurdinacea*), willow dock (*Rumex salicifolius*) and wild rye (*Elymus mollis*).
7. *Deschampsia cespitosa*, spike thrush (*Eleocharis palustris*) and *Potentilla pacifica*).
8. Sitka spruce (*Picea sitchensis*).
9. Baltic rush (*Juncus balticus*), *Potentilla pacifica* and *Carex lyngbyei*.
10. *Deschampsia cespitosa*, *Potentilla pacifica*, *Carex lyngyei* and Henderson's checker-mallow (*Sidalcea hendersonii*).
11. Cattail (*Typha latifolia*).
12. Water parsley (*Oenanthe sarmentosa*).
13. Western manina grass (*Glyceria occidentalis*).

The distribution of these plant communities is seen in Figure 8.2 and the species within these communities are listed in Appendix 8.1.

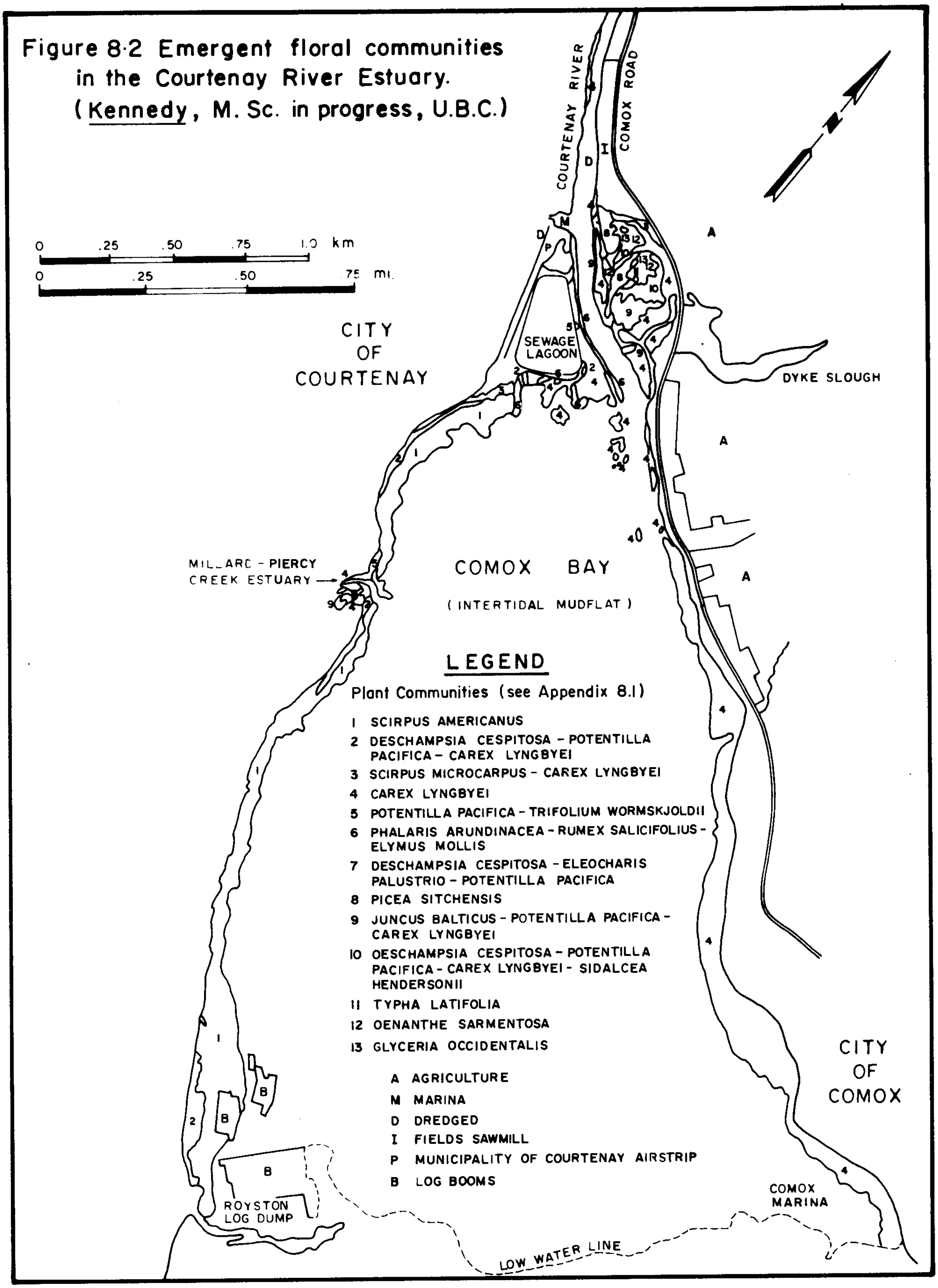


Figure 8·2 Emergent floral communities in the Courtenay River Estuary. (Kennedy, M. Sc. in progress, U.B.C.)

Examination of the algae found at various depths in Comox Harbour revealed that extensive beds of eelgrass (*Zostera marina*) and large patches of brown algae (*Sargassum muticum* and *Porphyra miniata*) were found in the low intertidal zone (Pollution Control Branch, 1974). Green algae (mostly *Ulva* spp.) were fairly abundant in the middle intertidal zone, while *Fucus distichus* and several species of *Enteromorpha* (mostly *E. linza*) were present in the high intertidal area. The diversity of algae in the transects in Comox Harbour was lower than in surrounding marine waters.

Eelgrass is an important form of intertidal vegetation as it supplies food for waterfowl, substrate for spawning herring and habitat for invertebrates and fish. Eelgrass also supplies large amounts of detritus to the food web (Harrison and Mann, 1975) and its roots stabilize soils preventing the erosion of sediment. McRoy *et al* (1972) demonstrated the importance of eelgrass in recycling phosphorous from the sediments in the water column.

Eelgrass is plentiful south of the Oyster River estuary (Harris, unpublished memo). Infra red aerial photographs of Comox Harbour by Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Habitat Protection Directorate, Vancouver, B.C., show the presence of extensive patches of eelgrass on the mudflats. These are not found in the river channels. Eelgrass is estimated to grow up to about one metre above lower low tide. Records sent by the local fisheries officer, Jack Trent, indicate that there has been a gradual increase in the amount of eelgrass in the harbour although severe storms resulted in heavy losses in the 1978-1979 winter (Trent, pers. comm., 1979).

2. OYSTER RIVER

In the Oyster River, Kennedy (M. Sc. in progress) described the amphibious vascular flora while Coon (1973) did a quick survey of the benthic flora in the estuary. A list of the emergent benthic fauna was compiled by Kennedy (M.Sc., in progress). Six communities were recognized in the Oyster River estuary. They include:

1. *Carex lyngbyei.*
2. *Elymus mollis - Carex lyngbyei.*
3. *Juncus balticus,* salt grass (*Distichlis spicata*) and bentgrass (*Agrostis alba*).
4. *Juncus balticus* and *Potentilla pacifica.*
5. Douglas fir (*Pseudotsuga menziesii*) and bracken (*Pteridium aquilinum*).
6. *Elymus mollis.*

The distribution of these communities is shown in Figure 8.3. The species within these communities are found in Appendix 8.2.

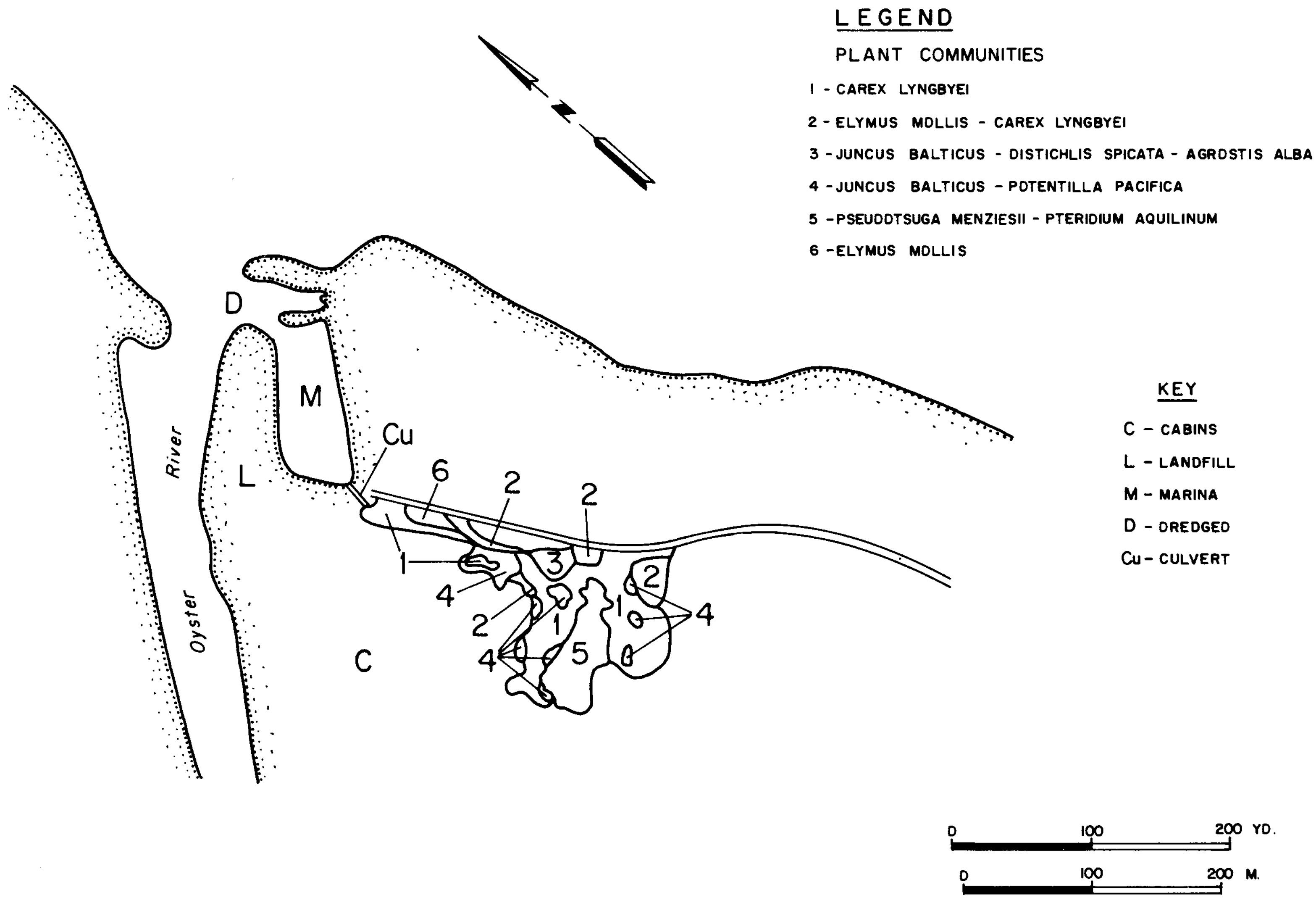
Carex lyngbyei is a very important member of the sedge family because its roots and rhizomes provide cover for the amphipod *Anisogammarus* spp. and for harpacticoid copepods. These make up a major portion of the diet of juvenile coho (*Oncorhynchus kisutch* and chinook (*O. tshawytscha*) salmon in some adjacent areas (Goodman, 1974).

Coon (1973) concluded that there were no concentrated stands of algae in the Oyster River estuary. Sparse populations of *Fucus distichus* and the marsh plant *Salicornia* were seen. McKelvey (unpublished) noted that eelgrass was also present in the estuary.

8. (iv) MARINE VEGETATION

A summary of macrophyte research carried out in the study area was included in a report by Foreman and Root (1975).

Figure 8·3 Emergent Floral Communities in the Oyster River Estuary
(Kennedy, M.Sc. in progress, U.B.C.)



Notes on early collections of macrophyte marine algae in the Cape Lazo area were presented by Collins (1913). Widdowson (1964) investigated the morphology of *Alaria* spp. in the intertidal zones off Cape Lazo, Black Creek and Miracle Beach. Foreman and Root (1975) also indicated that of the 52,000 specimens at the University of British Columbia Phycological Herbarium, several of these specimens were collected off Willemar Bluff and Cape Lazo.

Based on aerial and ground surveys of the study area, Austin and Adams (1972) compiled a species list of marine algae and identified eleven associations. The distribution of 10 associations, *Iridaea cordata - Prionitis lyalli - Plocamium coccineum, Cryptosiphonia woodii - Iridaea heterocarpa,* Japweed (*Sargassum muticum*), subtidal brown algae, *Porphyra* spp., intertidal green algae, rockweed (*Fucus distichus*) - *Gigartina stellata,* kelp (*Nereocystis luetkeana*), *Rhodomela larix* and *Zostera marina*, were mapped on charts, at a scale of 1:10,000. The charts include the east coast of Denman Island, Willemar Bluff to Little River coast, Little River to Williams Beach coast and Elma Bay to Shelter Point. The information provides a good baseline from which the effects of human activity can be assessed (Austin, pers. comm., 1977).

The distribution of algae was found to depend primarily on substrate composition and depth. In the high intertidal regions, *Rhodemala larix* was found on sedimentary rock, or pebbles in seepage areas while the *Fucus distichus - Gigartina stellata* association was primarily found on boulders.

Green algae, i.e. *Enteromorpha intestinalis*; *Sargassum muticum* and *Cryptosiphonia woodii - Iridaea heterocarpa* associations were found to predominate in the mid to low intertidal zone. Green algae were attached to pebbles while *Sargassum muticum* was found on pebbles, cobbles and boulders. In deeper areas, *Cryptosiphonia woodii - Iridaea heterocarpa* inhabited cobble and boulder areas.

Six algal associations were found below the low tide line. *Priontis lyalli - Iridaea cordata - Plocamium coccinaeum* were attached to pebbles or boulders. A sub-association, *Callophyllis violacaea - Polyneura latissima*, was found on similar substrates at lower depths. On pebbles bordering these associations was *Laminaria groenlandica*. *Alaria tenuifolia* and *Costaria costata* were also found growing on pebbles, generally at lower levels. On sand substrates, *Desmarestia aculeata - Neoagardhiella baireli* and eelgrass (*Zostera marina*) associations were found. *Zostera marina* predominated in deeper areas.

Off Oyster River, Coon (1973) observed sparse beds of *Iridaea cordata*, sea lettuce (*Ulva* spp.), *Laminaria* spp. and *Gracilariopsis sjoestedtii* in the mid to low intertidal region.

Information on the lignicolous or wood-inhabiting marine fungi in the area is limited. Hughes (1969) identified the Fungi Imperfecti: *Humicola allopallonella*, *Zalerion maritimum*, *Z. varium* and the *Ascomycetes* species: *Amylocarpus encephaloides*, *Lignicola laevis*, *Marinospora calyptrata*, *Remispora maritima*, and *R. ornata* from intertidal wood near Oyster River. Booth (1969) sampled marine fungi from halomorphic (salt laden) soils at Oyster River. Several Monocentric chytrids and Chytridiaceous species from this station were described.

Although studies of phytoplankton and primary production have focused on the Strait of Georgia, a few sample sites occur in the study area (Stephens *et al.*, 1969; Parsons *et al.*, 1970; Stockner *et al.*, unpublished). Measurements of chlorophyll *a* at the water surface near Oyster River ranged from a low of 1 mg chlor a/m^3 in March to a high of 3-4 mg chlor a/m^3 in June (Stephens *et al.*, 1969). Based on these findings, Parsons *et al.*, (1970) concluded that there was no apparent influence of pollution on the pelagic production.

Results of an indepth study by Stockner *et al*., (unpublished), showed that for Baynes Sound, the amount of chlorophyll *a* in the surface layer (0 - 5 m), varied from a minimum of 12.2 mg per m^2 in the winter to a maximum of 149.2 mg per m^2 in late spring. Primary production of the Baynes Sound area was calculated to be 465 g $C.m^{-2}\ yr^{-1}$. In an area from the base of Baynes Sound, Comox Harbour and around to Cape Lazo, primary productivity was considered to be very high (400g $C.m^{-2} yr^{-1}$). Stockner *et al*., (unpublished) concluded that primary productivity is found in regions affected by industrial or, as in the case of Comox Harbour - Baynes Sound area, domestic discharge (see Pollution and Water Quality Section).

A phytoplankton monitoring system is being carried out at the base of Baynes Sound as part of the Salmon Enhancement Program. The aim of the plankton watch is to time the release of chum fry from the Rosewall Creek hatchery facility coinciding with peaks in phytoplankton and zooplankton. No data have been reported yet as the program was only initiated in early 1977 (Kennedy, pers. comm., 1978).

The results of a survey of diatoms in the Strait of Georgia showed that near Comox Harbour, diatoms were found to occur in moderate concentrations while high concentrations of diatoms were found near Hornby Island (Légaré, 1957). The concentrations of diatoms was found to be the greatest near the water surface. Fewer diatoms were found in November than June because the water was in an almost homogeneous state.

8. (v) SEAWEED INDUSTRY

Attempts have been made to establish a viable seaweed industry in the study area. Surveys of kelp began in 1915 (Greenius, 1967). In 1944 - 1947, surveys of the *Nereocystis* beds in the Cape Lazo area showed that there was an estimated 21,000 tons. The algin in *Nereocystis* is used as a colloid for food and industrial use.

Nereocystis was harvested in the Cape Lazo area during the summer of 1968 by Seakem, in conjunction with Intertidal Industries (Coon, pers. comm., 1978). No records of the amount of kelp harvested are available.

Austin and Adams (1972) noted that a total standing crop of 810 ± 346 metric tons (893 ± 381 short tons) of the red algae (*Iridaea cordata*) was located in the study area. About 460 ± 196 metric tons (507 ± 216 short tons) of *Iridaea* were found in Kye Bay, 350 ± 150 metric tons (386 ± 165 short tons) grew off Cape Lazo and 290 ± 124 metric tons (320 ± 137 short tons) of *Iridaea* were located off Denman Island, Willemar Bluff and Williams Beach. At $650/dry tons, the *Iridaea* is valued at between 301,600 and 751,600 dollars (Coon, pers. comm., 1978).

In 1977, a trial harvest, conducted by Canadian Benthic (Bamfield) Limited, Marine Colloids Limited (Dartmouth, N.S.), and B.C. Marine Resources Branch, resulted in the collection of 24.6 wet metric tons of *Iridaea* off Kye Bay (Coon, pers. comm., 1978). At seaweed prices prevalant at the time, (550/dry ton) and with the harvesting technique utilized, it was decided that harvesting would only be marginally profitable at best.

No one is currently harvesting seaweed in the study area.

9. WILDLIFE

9. (i) BIRDS

1. GENERAL

Although the abundance of natural resources in the study area attracts large numbers of birds of various species, little site-specific data on these species exists.

On-site information is available from the Provincial Museum, the Comox-Strathcona Natural History Society, the B.C. Parks Branch, EPEC Consulting Western Ltd., the B.C. Fish and Wildlife Branch, the Canadian Wildlife Service and the Pacific Biological Station. Most of the literature for on-site studies, lists of local sitings, breeding records and bird counts of species in the study area is located in the B.C. Provincial Museum, Birds and Mammals Section. Historical observations on bird density, nesting areas, behaviour and feeding habits provided by H.M. Laing and the late T. Pearse, are also found in the Provincial Museum.

Annual Christmas bird counts are conducted by the Comox-Strathcona Natural History Society. The group has covered a wide variety of habitats between the Oyster River and Lymn Creek; their species lists are published every April in "American Birds", formerly "Audubon Field Notes". The society has also published "A Naturalist's Guide to the Comox Valley" (Henderson and Capes, undated).

General ecological information on the birds inhabiting Miracle Beach Provincial Park, at the mouth of Black Creek, and Helliwell Provincial Park, on the southeastern tip of Hornby Island, is available from the B.C. Parks Branch (Ministry of Environment).

EPEC Consulting Western Ltd. (1975) summarized the general biology of many of the birds found in the study area.

Surveys of the numbers of waterbirds (Davies, *et al.*, unpublished), and numbers of nesting waterfowl (Smith and Smith, unpublished) have been made by the provincial Fish and Wildlife Branch (B.C. Ministry of Environment), who manage the non-migratory bird species.

The federal Canadian Wildlife Service (Canada Department of the Environment), responsible for the management of migratory birds, has also conducted surveys of waterbirds in the study area (McKelvey and Kaiser, unpublished; McKelvey, unpublished; Dawe, unpublished). The ecology of the marine birds found in the study area was summarized by Taylor, (unpublished).

Research on several of the species of ducks found within the study area was conducted by the Pacific Biological Station (Canada Department of Fisheries and the Environment) (Munro, 1931, 1949; Clemens and Munro, 1932, 1937, 1939).

Appendix 9.1 provides a summary of all the bird species reported to be in the study area. Unless stated otherwise, bird nomenclature is based on Godfrey (1966), except where recent taxonomic revisions take precedence (American Ornithologists Union (A.O.U., 1973, 1976).

2. TERRESTRIAL BIRDS

Surveys of terrestrial birds have been carried out in the Rosewall Creek - Mud Bay area (Dawe, unpublished), Comox Harbour (McKelvey, unpublished) and the Oyster River estuary (McKelvey, unpublished). The results of these surveys are shown in Table 9.1.

The blue grouse (*Dendragapus obscurus*) is the only terrestrial bird in the study area that has been well researched. Since 1954, Bendell and his graduate students have been studying the biology of blue grouse populations in the Tsolum River watershed. Reports on the ecology of the blue grouse include papers by Bendell, (unpublished, 1955); Bendell and Elliot, (1966, 1967); Redfield, (1972); Bendell, *et al.*, (1972); Zwickel and Bendell, (1972a, 1972b); Zwickel, (1965, 1972a, 1972b, 1975, 1977) and Zwickel and Dake, (1977). For a more complete list of papers see Mr. W. Campbell, Vertebrate Zoology, Provincial Museum, Victoria, B.C.

Table 9.1 Terrestrial birds seen near Comox Harbour and Oyster River Estuary during the winter of 1974-1975 and Rosewall Creek to Mud Bay between April 1975-April 1977. (McKelvey, unpublished; Dawe, unpublished).

S - Summer W - winter

SPECIES	COMMON NAME	Comox Harbour	Oyster River	Rosewall Creek - Mud Bay	
Haliaeetus leucocephalus	Bald Eagle	X	X	X	S,W
Columba livia	Rock Dove	X			
Selasphorus rufus	Rufus Hummingbird			X	S
Megaceryle alcyon	Belted Kingfisher	X			
Hirundo rustica	Barn Swallow			X	S
Cyanocitta stelleri	Steller's Jay	X			
Corvus caurinus	Northwestern Crow	X	X	X	S,W
Parus rufescens	Chestnut-backed Chickadee	X		X	S,W
Turdus migratorius	American Robin	X		X	S
Sturnus vulgaris	Common Starling	X		X	S
Eupagus cyanocephalus	Brewer's Blackbird			X	S
Carduelis tristis	American Goldfinch			X	S
Junco hyemalis	Dark-eyed Junco		X	X	W
Spizella passerina	Chipping Sparrow			X	S
Melospiza melodia	Song Sparrow	X		X	S

3. WATERBIRDS

Data on waterbird utilization of the coastline of the study area was summarized by the B.C. Fish and Wildlife Branch (1976). The information is based on data collected by the provincial Fish and Wildlife Branch (Victoria, Nanaimo), the Parks Branch (Victoria), the federal Environmental Protection Service

(EPS, West Vancouver), the Canadian Wildlife Service (Delta) and the Pacific Biological Station (Nanaimo).

Based on utilization by waterfowl, the Canada Land Inventory (1967a), divided the waterfowl habitat in the study area into three basic types: class 2S, class 3M and class 7. The Courtenay - Tsolum River region was designated as being very important for wintering and migrating waterfowl (class 2S). Other important wintering areas (class 3M) included Oyster Bay to Oyster River, Comox Harbour and Fanny Bay to Deep Bay. The rest of the study area is considered to be unsuitable for waterfowl (class 7).

About 21,000 waterbirds were sighted along the coastline between Elma Bay and Deep Bay by McKelvey and Kaiser (unpublished) and Davies, *et al.* (unpublished), during aerial surveys flown in January, 1976.

A total of 21 species of nesting waterbirds were observed in the study region (Smith and Smith, unpublished). Eighteen of these species were found in the Tsolum River - Comox Harbour area (Appendix 9.1). Near Northey Lake on Black Creek, breeding pairs of red-necked grebes (*Podiceps grisegena*), pied-billed grebes (*Podilymbus podiceps*), greater white-fronted geese (*Anser albifrons*), American wigeons (*A. americana*), wood ducks (*Aix sponsa*), ring-necked ducks (*Aythya collaris*), common goldeneyes (*Bucephala clangula*), bufflehead (*B. albeola*), hooded mergansers (*Lophodytes cucullatus*), common mergansers (*Mergus merganser*) and American coots (*Fulica americana*) were observed. Pied-billed grebes, mallards, blue-winged teals (*Anas discors*), wood ducks, ring-necked ducks and hooded mergansers were seen nesting at Williams Beach and pairs of mallards, common pintails (*Anas acuta*), green-winged teals (*A. carolinensis*), wood ducks and common goldeneye were found at Yerex Marsh, near Merville. Smith and Smith concluded that the study area is an important waterbird breeding area.

a. COURTENAY RIVER ESTUARY (COMOX HARBOUR)

A daily mean number of 10,000 waterbirds were seen utilizing Comox Harbour by Davies, *et al.* (unpublished) and McKelvey and Kaiser (unpublished) during two separate aerial surveys conducted in January, 1976.

In more detailed weekly ground surveys, McKelvey (unpublished), who observed the number and distribution of waterbirds between December 1974 and April 1975, noted that the number of birds ranged from a maximum monthly mean of 6,000 in December (sum of waterbirds seen in four visits divided by four), to a minimum monthly mean of 3,500 in March. Of the waterbirds seen in the estuary, 56% were diving ducks, primarily bufflehead, scoters (*Melanitta* spp.) and goldeneye. Dabbling ducks, particularly mallards, pintails and American wigeons, made up 24%, while 15% of the waterbirds were gulls and shorebirds. The dominant species included glaucous-winged gulls (*Larus glaucescens*), herring gulls (*L. argentatus*) and mew gulls (*L. canus*). The dunlin (*Calidris alpina*) was the most abundant shorebird (Comox - Strathcona Natural History Society, 1975). Other groups of birds seen in Comox Harbour included swans (*Olor* spp.), geese (*Branta* spp.), loons (*Gavia* spp.), cormorants (*Phalacrocorax* spp.), grebes (*Podiceps, Aechmophorus* and *Podilymbus* spp.) and various alcid species (McKelvey, unpublished).

One of the largest concentrations of wintering trumpeter swans (*Olor buccinator*) on Vancouver Island is located in Comox Harbour (Smith and Blood, 1971). Between 6 - 50 birds were found wintering in the harbour in the winter 1970 - 1971. Davies, (unpublished) reported that the number of swans has been increasing rapidly. As many as 120 wintering swans in one day were observed concentrated in the sheltered areas near Millard Creek and behind Goose Spit in 1976 - 1977 (Davies, pers. comm., 1977). McKelvey (pers. comm., 1978) reported that during the 1977 - 1978 winter, a maximum daily count of 264 trumpeter swans was made near Millard Creek.

The entire estuary is important to waterbirds as feeding habitat. The distributions of dabbling ducks, geese and swans which use Comox Harbour (Figure 9.1) appear to correspond closely with the distribution of marsh vegetation. Diving birds such as diving ducks, loons and grebes utilize deeper water and the mud-and-sand flats (when flooded by the tide) to feed on invertebrates and small fishes).

b. OYSTER RIVER ESTUARY

The slope of the Oyster River is much steeper than that of the Courtenay River estuary. Consequently, whereas the substrate of the Courtenay River estuary is mud and sand, the bottom of the Oyster River estuary is mainly gravel and small boulders.

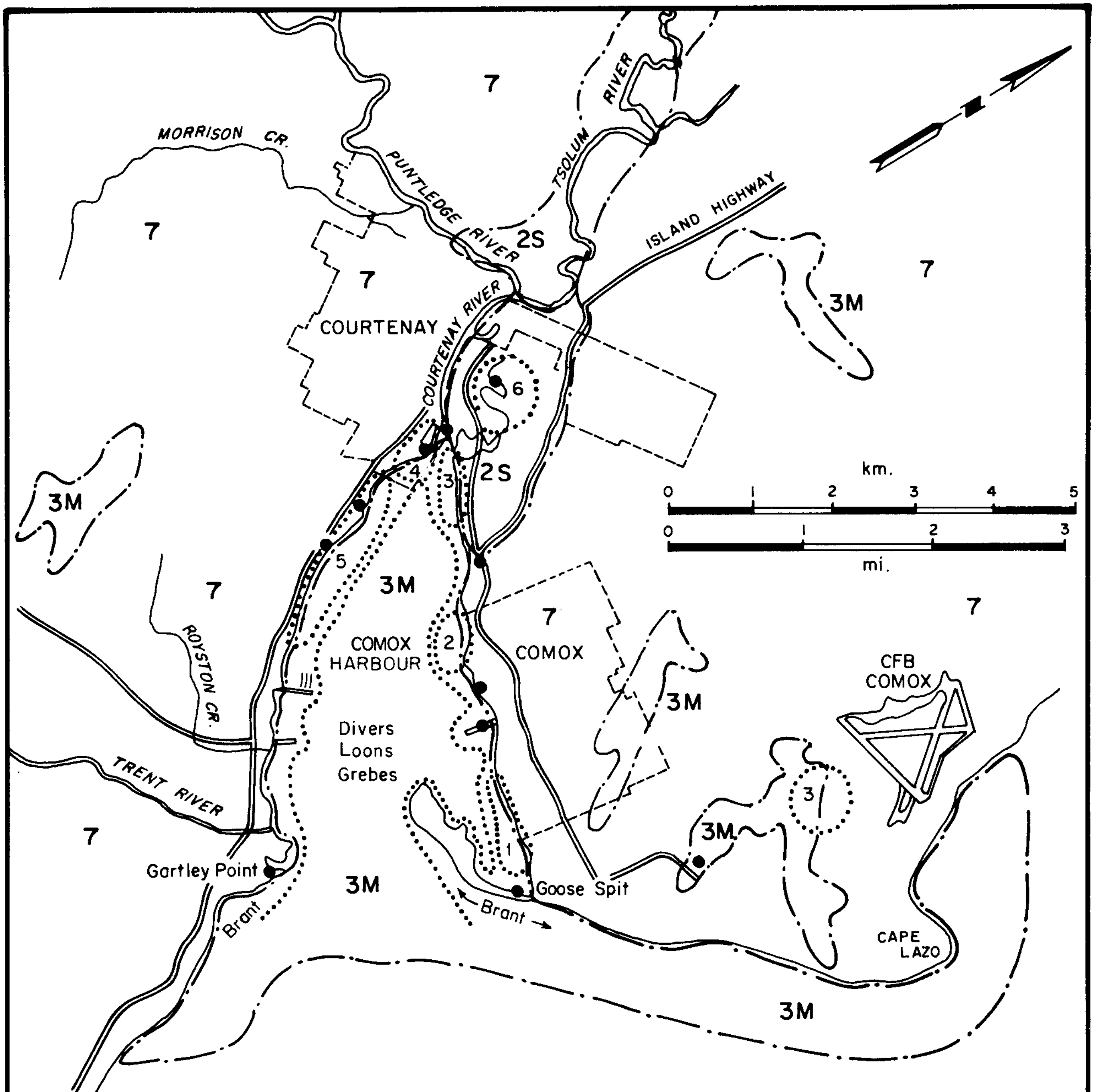
The number and distribution of water birds found utilizing the Oyster River estuary, in a weekly survey conducted between December 1974 and April 1975, showed that the mean monthly number of birds fluctuated from a minimum of 483 in March to a maximum of 1,180 in April (McKelvey, unpublished). Of the water birds seen, 67% were diving ducks (scaup *(Aythya* spp.*)*, scoters, bufflehead, and harlequin ducks *(Histrionicus histrionicus)*). Gulls, mostly glaucous-winged and mew gulls, and shorebirds, mainly dunlin (Canada Dept. Environ., unpublished), constituted 14% of the waterbirds present (McKelvey, unpublished).

Grebes, loons, cormorants and alcids amounted to less than 10% of the total number of waterbirds (McKelvey, unpublished).

The distribution of both diving ducks and swans is seen in Figure 9.2.

c. BAYNES SOUND

Most of the information on waterbird use of Baynes



LEGEND

- ● Observation Point
- 1 Dabblers and Swans
- 2 Dabblers and Geese
- 3 Dabblers
- 4 Gulls and Crows
- 5 Dabblers, Swans and Gulls
- 6 Swans and Dabblers
- 3M, 7, 2S — Canada Land Inventory Codes (See Text)

Figure 9·1 Migratory bird use of the Courtenay River Estuary, Winter 1974 - 1975. (McKelvey, 1975, unpublished, Trethwey, pers. comm. and Canada Land Inventory Classification for Waterfowl Capability, Map Sheet 92F/10, 92F/11).

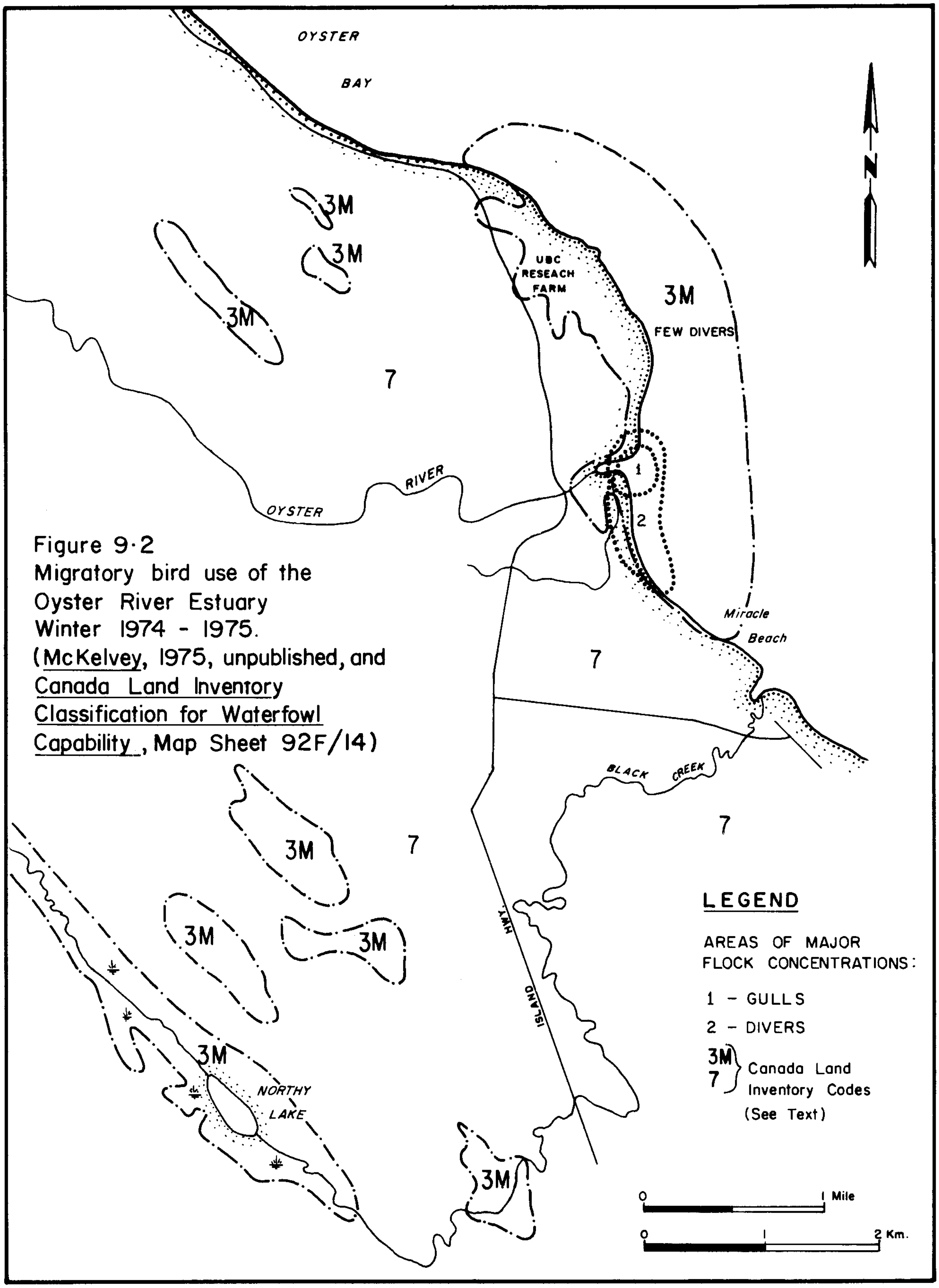


Figure 9·2
Migratory bird use of the Oyster River Estuary Winter 1974 - 1975. (McKelvey, 1975, unpublished, and Canada Land Inventory Classification for Waterfowl Capability, Map Sheet 92F/14)

Sound pertains to the land owned by Canadian Wildlife Service, which is located between Rosewall Creek and Mud Bay.

The extensive mudflats and a lagoon in Mud Bay, surveyed between December 1973 and April 1977, were reported to support a maximum monthly mean of 3,007 waterbirds in March and a minimum of 1,178 waterbirds in April (Dawe, unpublished). Huge flocks of wintering western grebes (*Aechmophonis occidentalis*) formed 49% of the total number of waterbirds seen. The year before, on November 26, 1975, one flock of 14,800 western grebes was seen. As large flocks are unusual (Dawe, pers. comm., 1978), the monthly mean number of birds utilizing the area in the winter of 1976 - 1977 was recalculated omitting the grebe population. The revised mean numbers of waterbirds observed fluctuated between 859 in December and 1,246 in March (Dawe, unpublished).

The remainder of the waterbirds seen in Rosewall Creek consisted mainly of diving ducks (22%), gulls and shorebirds (18%), and dabbling ducks (9%). The most common species comprising these three groups were: diving ducks - scoters, bufflehead, common goldeneye, and greater scaup (*Aythya marila*); gulls and shorebirds - mew gulls, Thayer's gulls (*Larus thayeri*) and dunlin; dabbling ducks - mallards.

Trumpeter swans have only recently begun to winter in Rosewall Creek. Smith and Blood (1971) did not report any swans in the Rosewall Creek area. Dawe (unpublished), however, noted that in the winter of 1976 - 1977, a peak number of 14 trumpeter swans were observed between Rosewall Creek and Mud Bay.

The area also supports a large number of northward migrating brant in the spring. On April 21, 1976, 4,000 brant were seen utilizing the Rosewall Creek area (Davies, *et al.*, unpublished).

The major species of waterbirds using Rosewall Creek-

Mud Bay area during the summer of 1976 included great blue herons (*Ardea herodias*), scoters, common mergansers, glaucous-winged gulls, mew gulls, Bonaparte's gulls (*Larus philadelphia*) and assorted shorebirds (Dawe, unpublished).

(ii) TERRESTRIAL MAMMALS

Of the twenty-eight species of mammals native to Vancouver Island, one species, the Vancouver Island marmot (*Marmota vancouverensis* and nine subspecies have ranges limited to the island (Guiguet, pers. comm., 1978) (Appendix 9.2).

Very little is known about mammals in the study area. Sitings have been recorded by the Provincial Museum, the Comox - Strathcona Natural History Society and the B.C. Parks Branch. Naturalists from the Parks Branch have compiled lists of mammals in Miracle Beach and Helliwell provincial parks.

Endangered and rare mammals found in the study area include the Vancouver Island marmot (Smith, unpublished), the American water shrew (*Sorex palustris brooksi*), (McTaggart-Cowan and Guiguet, 1973; Ministry Environ., unpublished), the wolf (*Canus lupus crossodon*), (Davies, pers. comm., 1978; Rodgers, pers. comm., 1978), the wolverine (*Gulo gulo vancouverensis*), (McTaggart-Cowan and Guiguet, 1973; Hebert, pers. comm., 1978) and the short-tailed weasel or ermine (*Mustella ermina anguinae*) (*Ibid*).

Mammals likely to be seen near Comox Harbour include the beaver (*Castor canadensis*), the muskrat (*Ondatra zibethicus*), an occasional (American) black bear (*Ursus americanus vancouveri*), the racoon (*Procyon lotor*), the American marten (*Martes americana*), American mink (*Mustella vison*), river otter (*Lontra canadensis*) and mule deer (*Odocoileus hemionus*) (Rodgers, pers. comm., 1978).

The general ecology of some of these mammals, primarily the mule deer, the elk (*Cervus elaphus roosevelti*), the cougar (*Felis concolor vancouverensis*), the American black bear and the wolf was summarized by EPEC Consulting Western Ltd. (1975).

Population trends in deer are associated with logging practices (Davies, pers. comm., 1978). Deer require a dense upper canopy, mature forest for protection from adverse weather conditions during the winter and open areas to provide food during the rest of the year. In clearcut areas, slash and new growth provide highly nutritious food resulting in large increases in the deer population. Where maturing second growth is of one age class, one species and spaced evenly over a large area, i.e. in reforested regions, open areas are gradually eliminated. Shrubs that initially provided food are shaded out, reducing forage abundance and quality. Deer numbers then drop to a level below those found in pre-logged areas.

At elevations below 1,000 ft., deer numbers can remain relatively high in areas where forests and farmland occur. Between 1,000 ft. and 2,500 ft. (the upper limit of deer winter range), mature stands become increasingly important to deer because they provide a canopy which intercepts snow, reducing on-ground snow depth and protect deer against wind. This insulating effect minimizes body heat loss and enables deer to gain access to blowdowns, which provide litterfall and lichens for food.

Estimates of deer densities, based on hunting statistics, show a gradual decrease from the coast to the mountains. On average, the following densities can be expected (B.C. Fish and Wildlife Branch, 1977a):

(1) sea level to 152.5 m (500 ft.) elevation - 25 - 40 deer per 259 ha (1 sq. mi.)

(2) 152.5 m - 305.0 m (500 - 1000 ft.) elevation - 15 - 25 deer per 259 ha (1 sq. mi.)

(3) in the mountainous and recently logged areas - 5 - 15 deer per 259 ha (1 sq. mi.)

Note these figures are biased, because lower elevations are more accessible so that the unit effort is probably less.

Good elk habitat extends south through the Oyster - Black - Tsolum river area only (Canada Land Inventory, 1976b).

Only a few elk are estimated to exist in the Upper Quinsam - Tsolum River area. "Few" is classified by the B.C. Fish and Wildlife Branch as being 1 elk per 1036 - 2590 ha (4 - 100 sq. mi.) (B.C. Fish and Wildlife Branch, 1976b). As elk inhabit climax forests, their numbers have been greatly reduced by logging (Davies, pers. comm., 1978).

(iii) HUNTING

The study area lies within Management Unit 6, which is divided into 12 sub-units. The Oyster River - Deep Bay area is found within eight of these sub-units (6-3 to 6-10). In Management Unit 6, open season in 1977 - 1978 existed for buck black-tailed (mule) deer, (American) black bear, cougar, red fox (*Vulpes vulpes*), raccoon, blue grouse, ruffed grouse (*Bonasa umbellis*), spruce grouse (*Canachites canadensis*), (ring-necked) pheasants (*Phasianus colchicus*), ducks, coots (*Fulica* spp.), common snipe (*Capella gallinago*), snow geese (*Anser caerulescens*), greater white-fronted geese, Canada geese (*Branta canadensis*), band-tailed pigeons (*Columba fasciata*), and brant (Ministry of Recreation and Conservation, 1978).

Estimates for deer harvested in 1975 are based on questionnaires returned to the B.C. Fish and Wildlife Branch, Nanaimo. In the eight sub-units, an estimated 520 deer were killed. Of the 296 hunters checked, only 3 kills were found (Table 9.2).

Table 9.2 Hunting Statistics for Management Unit 6 in 1975 (B.C. Fish and Wildlife Br., unpublished).

Sub-units	Deer Harvests[1]	Hunters Checked	Kills Checked
3 - Bowser	20		
4 - Tsable	30	31	
5 - Denman Island	30		
6 - Hornby Island	10		
7 - Trent	30	16	
8 - Comox	100	64	1
9 - Black-Tsolum	200	137	1
10 - Oyster	100	48	1

[1]These figures are only estimates from questionnaires, not actual harvests.

Prior to 1974, information was collected by mail-in questionnaires and from Crown Zellerbach. More questionnaires were returned from hunters in sub-units with high deer densities so the estimates in these areas are likely to be more accurate than those estimates in sub-units where there are few deer. The results show a decline in the number of buck and doe mule deer caught per hunting season since 1968 (Table 9.3).

Similar declines are evident in the summary of deer harvested on Crown Zellerbach leased land (Table 9.4).

Statistics show that the numbers of blue and ruffed grouse killed on Crown Zellerbach land have increased between 1965 and 1972 (Table 9.5).

No information exists for other game birds. The mail-in questionnaires yield little information on birds hunted in Management Unit 6, because the data are summarized for the birds hunted throughout Vancouver Island (Ministry of Recreation and Conservation 1976).

Table 9.3 Preliminary Statistics from Analysis of Old Hunter Sample Questionnaires for Management Unit 6.

Year	Catch/ Unit Effort[1]	Estimated Anterless Deer Harvests	Estimated Deer Harvest	Estimated Hunter Effort[1]
1965	1.00	750	2,590	2,540
1966	1.30	980	3,620	2,830
1967	1.20	720	2,100	1,720
1968	1.40	870	3,280	2,400
1969	1.00	480	1,980	2,000
1970	1.10	630	2,820	2,540
1971	0.80	500	1,970	2,450
1973	0.60	290	1,440	2,490
1974	0.70	120	1,480	2,180

[1] One effort is equivalent to one hunting season.

Table 9.4 Summary of number of Deer Harvested from Crown Zellerbach Leased Land, 1965 - 72*

AREA	1965	1966	1967	1968	1969	1970	1971	1972
Comox Lake	272	222		392	109	164	158	90
Wolf Lake	218	228		459	185	156	221	101
Oyster River	-	49		-	63	34	41	12
Total	490	499	557	751	447	454	420	203

*Results of survey conducted by Crown Zellerbach (Gibson, pers. comm.)

Table 9.5 Summary of Numbers of Grouse Harvested from Crown Zellerbach Leased Land, 1965 - 72*

AREA	1965	1966	1967	1968	1969	1970	1971	1972
Comox Lake	125	104		72	68	161	151	214
Wolf Lake	181	176		250	319	576	437	410
Oyster River	-	8		-	16	61	10	10
Total	306	288	297	322	403	799	598	634

*Survey results conducted by Crown Zellerbach (Gibson, pers. comm.)

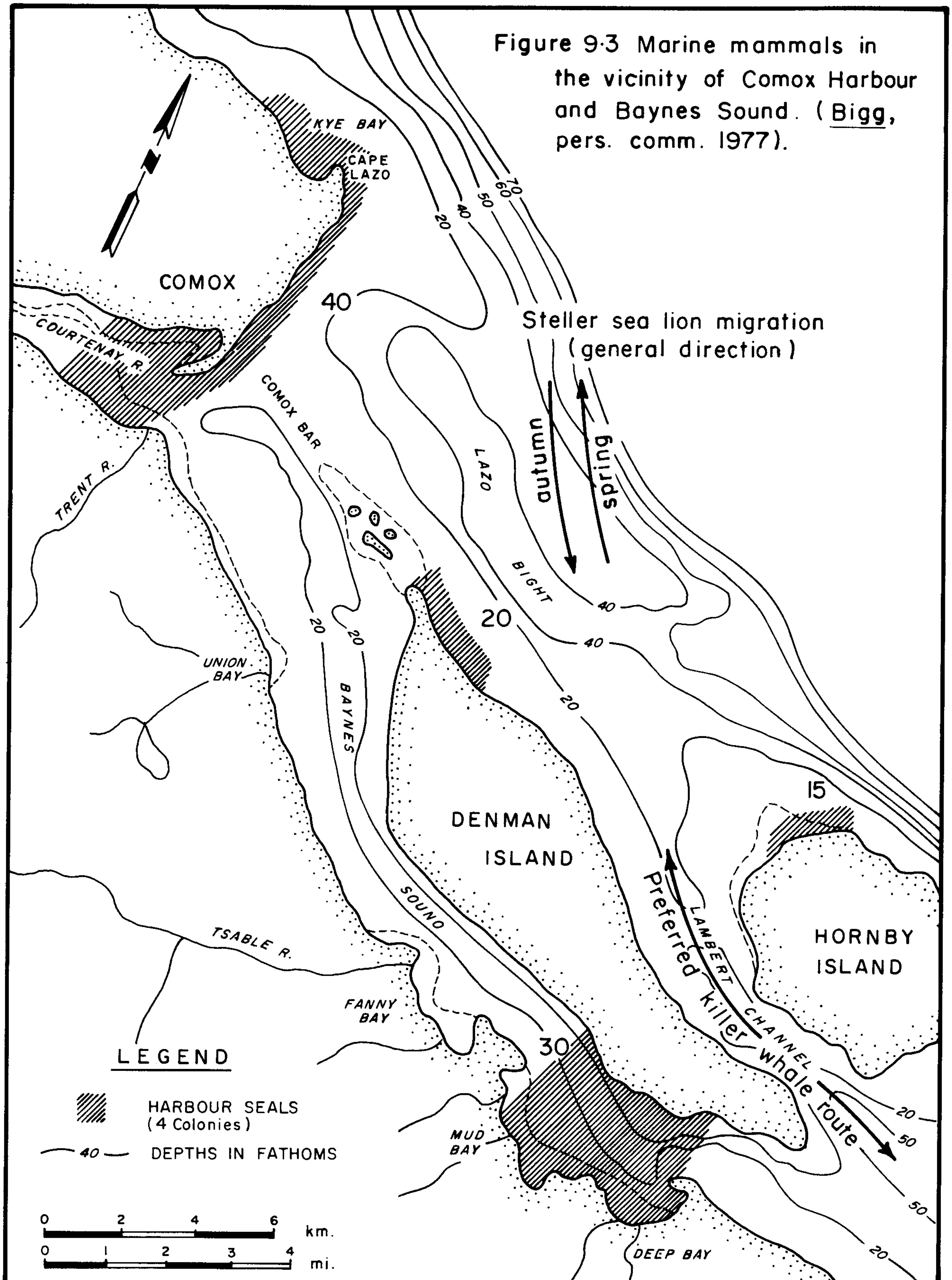
(iv) MARINE MAMMALS

At least 8 species of marine mammals use Comox Harbour and the nearby Strait of Georgia (Appendix 9.2). Four groups of harbour seals (*Phoca vitulina*) (Bigg, pers. comm., 1977), are known to inhabit the vicinity of Comox Harbour (Figure 9.3). From recent observations, one group of 40 seals hauls out nightly on log booms at Royston (McKelvey, pers. comm., 1978) and on the shores of Kye Bay, (Bigg, pers. comm., 1977) after spending the day feeding in nearby waters. The other three groups are comprised of: 20 seals that haul out on the northeastern tip of Denman Island; 15 seals on the north shore of Hornby Island; and 30 seals in southern Baynes Sound. Some of the latter group have been seen lying on log booms in Mud Bay (Dawe, pers. comm., 1978).

Common transient marine mammals in the area include the killer whale (*Orincus orca*) and the Stellar's (northern) sea lion (*Eumatopias jubata*) (Bigg, pers. comm., 1977). Approximately 120 killer whales, organized into 8 pods, utilize the resources in the area during migration. Four of these pods, consisting of 70 whales, use Lambert Channel, between Hornby and Denman Islands on a regular basis (Figure 9.3). Stellar's sea lions are present in the hundreds during their annual migrations, when they work their way north in the Strait of Georgia in the spring and back south again in the autumn.

Harbour and dall porpoises (*Phocoena phocoena* and *Phocoenoides dalli*) are frequently seen in the study area in small numbers (Bigg, pers. comm., 1977). Individuals of these nomadic species are unlikely to remain for any length of time. Rare visitors include the northern fur seal (*Callorhinus ursinus*) (Cowan and Guiguet, 1973) and the gray whale (*Eschrichtius robustus*) (Bigg, pers. comm., 1977). According to Bigg (*Ibid*), one juvenile of the latter species spent at least two weeks in Baynes Sound during April, 1977, presumably feeding on the infauna of the soft bottom of the sound.

Figure 9·3 Marine mammals in the vicinity of Comox Harbour and Baynes Sound. (Bigg, pers. comm. 1977).



(v) HISTORY OF WHALING

The following information was supplied by Haigland, (pers. comm., 1978), a former whaler who is currently writing a book entitled "Whaling No More", on the history of whaling in Pacific waters.

Between 1868 and 1872, three whaling stations were located in the area. The first station was initially established on Chrome Island, then at Whaleton, Cortez Island, and finally at a station on Hornby Island. The whales caught were humpback (*Megaptera novaeangliae*) and grey whales, because they moved slowly and remained in an area for fairly long periods of time. Haigland estimates that an absolute maximum of 30 whales were caught per year. The whalers used small steamers and were armed with harpoons. The whales were lanced and taken to the shore stations where oil was extracted.

In 1892, a shore station was set up in Blubber Bay on Texada Island. Humpback and to a lesser extent, grey whale, were hunted between Cape Lazo and Powell River.

Between 1904 and 1909, a station was set up in Hammond Bay, north of Departure Bay. The steamers were armed with cannons at this time and were able to catch an occasional finback whale (*Balaenoptera physalus*) and sei whale (*Balaenoptera borealis*), as well as the humpback and grey whales. Haigland speculated that the Pacific right whale (*Balaena glacialis*) may have been caught also. Again, no more than 30 whales were caught per year.

No whaling has been done on the east coast of Vancouver Island since 1909.

LAND AND WATER USE

10. (i) GENERAL

The study area covers about 194,250 ha (480,000 ac.) of the Regional District of Comox-Strathcona. The boundaries are approximately commensurate with those of School District 71. Included in this area are the City of Courtenay, the Town of Comox, the Village of Cumberland, and the surrounding rural districts, Electoral areas A, B, and C (Figure 10.1). The population is concentrated in the Comox Valley. In 1976, 7,733 people lived in Courtenay, 5,359 in Comox and 1,697 in Cumberland (Regional District of Comox-Strathcona, 1979). Approximately 14,400 rural inhabitants live within 3.22 km (2.0 mi.) of Comox and Courtenay.

The Regional District of Comox-Strathcona adopted a detailed Regional Plan on March 28, 1977. The purpose of the Plan was to establish comprehensive objectives regarding future land use in the region and to formulate definitive policies, enabling the Regional Board to effectively govern future decisions with respect to zoning changes, alteration of subdivision regulations, parks and regional recreation, provision of water, sewer and similar services and land use as it pertains in general to energy conservation and transportation.

A map denoting current and future status for the Courtenay River estuary is contained in a report on regional land use and resources (Regional District of Comox-Strathcona, 1975). The Official Plan (1977) includes maps outlining proposed land usage for Oyster Bay, Black Creek, Comox Valley, Union Bay and Fanny Bay (Figure 10.2). Most of the land in this region is designated as rural resource area, consisting of tree farm licences and agricultural reserve lands. Within the Plan are directives regarding rural community densities and developments,

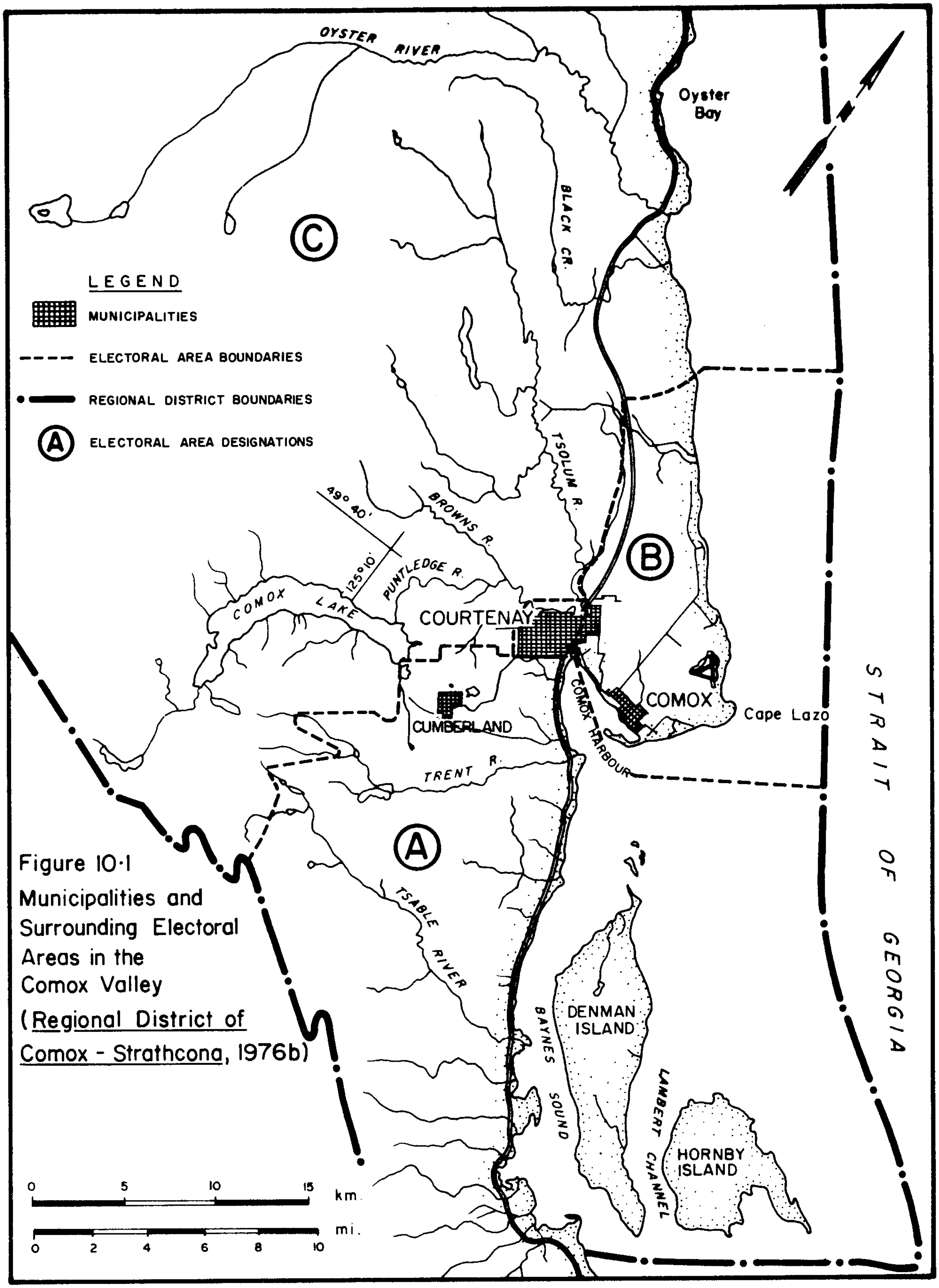


Figure 10·1
Municipalities and Surrounding Electoral Areas in the Comox Valley
(Regional District of Comox - Strathcona, 1976b)

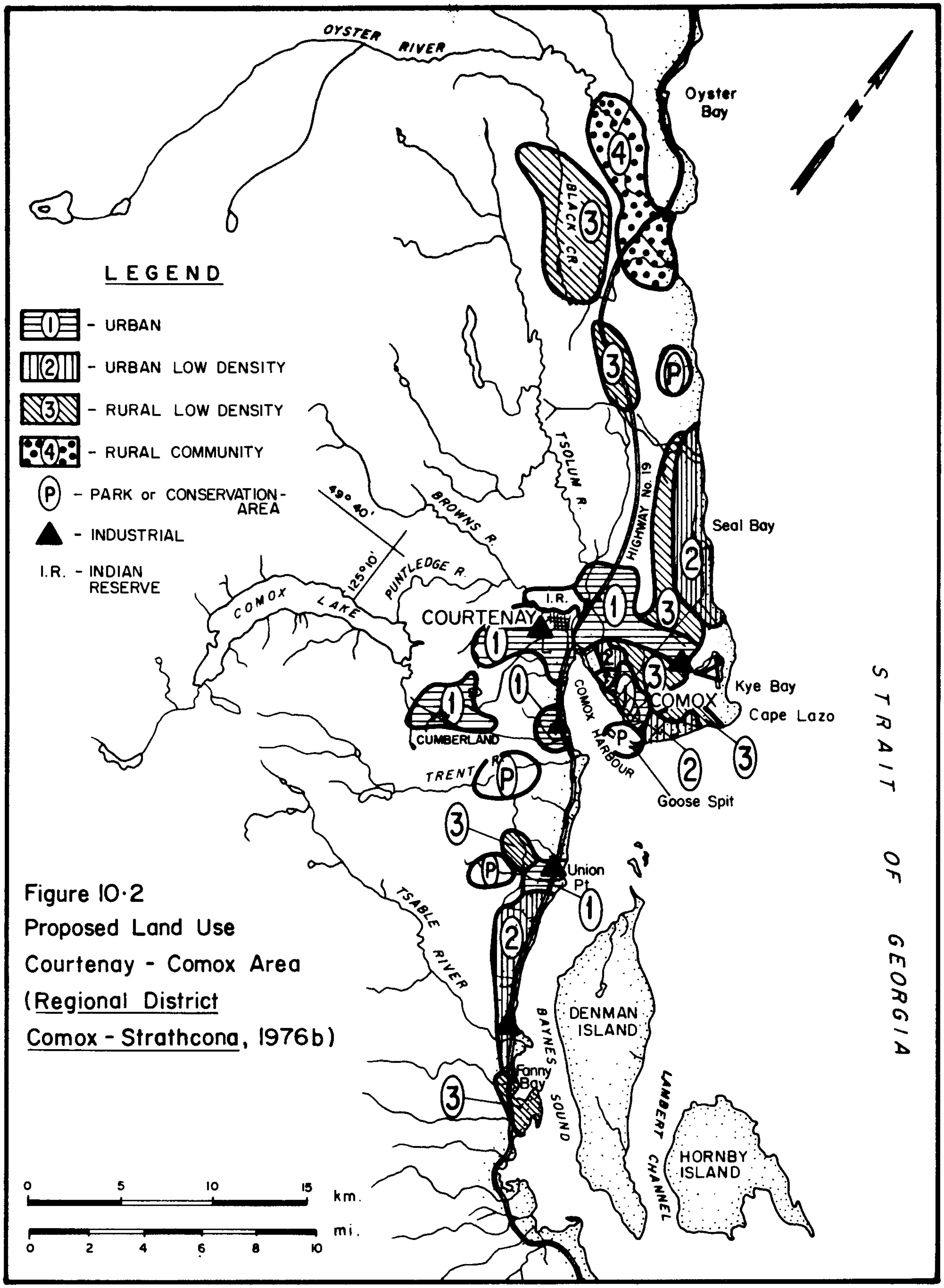


Figure 10·2
Proposed Land Use
Courtenay - Comox Area
(Regional District
Comox - Strathcona, 1976b)

urban growth, commercial areas and industrial sites. Areas are also allocated for mining, fishing, recreation and residential development of varying types (Regional District of Comox-Strathcona, 1977).

Courtenay and Comox are recognized principal urban centers, maintaining administrative, office, retail, and service facilities. They are classified as Urban Commercial Centers under the Regional Plan.

Public administration and Defence are the largest employers in the Comox Valley while retail services are the second largest employers, and community-oriented services are the third (Regional District of Comox-Strathcona, 1979a). Primary industries employ few people by comparison, though logging and lumber manufacturing contribute substantially to the local economy. The major forest industries operating in the Comox Valley are timber extraction and sawmilling.

Maps compiled by the British Columbia Lands Service provided extensive information regarding land and water use in the study area. Departmental reference maps R 92F/10-E, R 92F/11-E, and R 92F/14-E½ show foreshore leases within Comox Harbour, Oyster Bay and associated environs at a scale of one inch to one-half mile. Principal leases corresponding to lot numbers and locations shown in figures 10.3 and 10.4 are listed in Table 10.1.

Canada Land Inventory (CLI) maps provide basic information on land capability for agriculture, forestry, recreation, ungulates and waterfowl within the estuary. Indexes and lists of available maps are obtainable from the Environment and Land Use Committee Secretariat library in Victoria, B.C. Canada Land Inventory land capability maps, B.C. Lands Service departmental

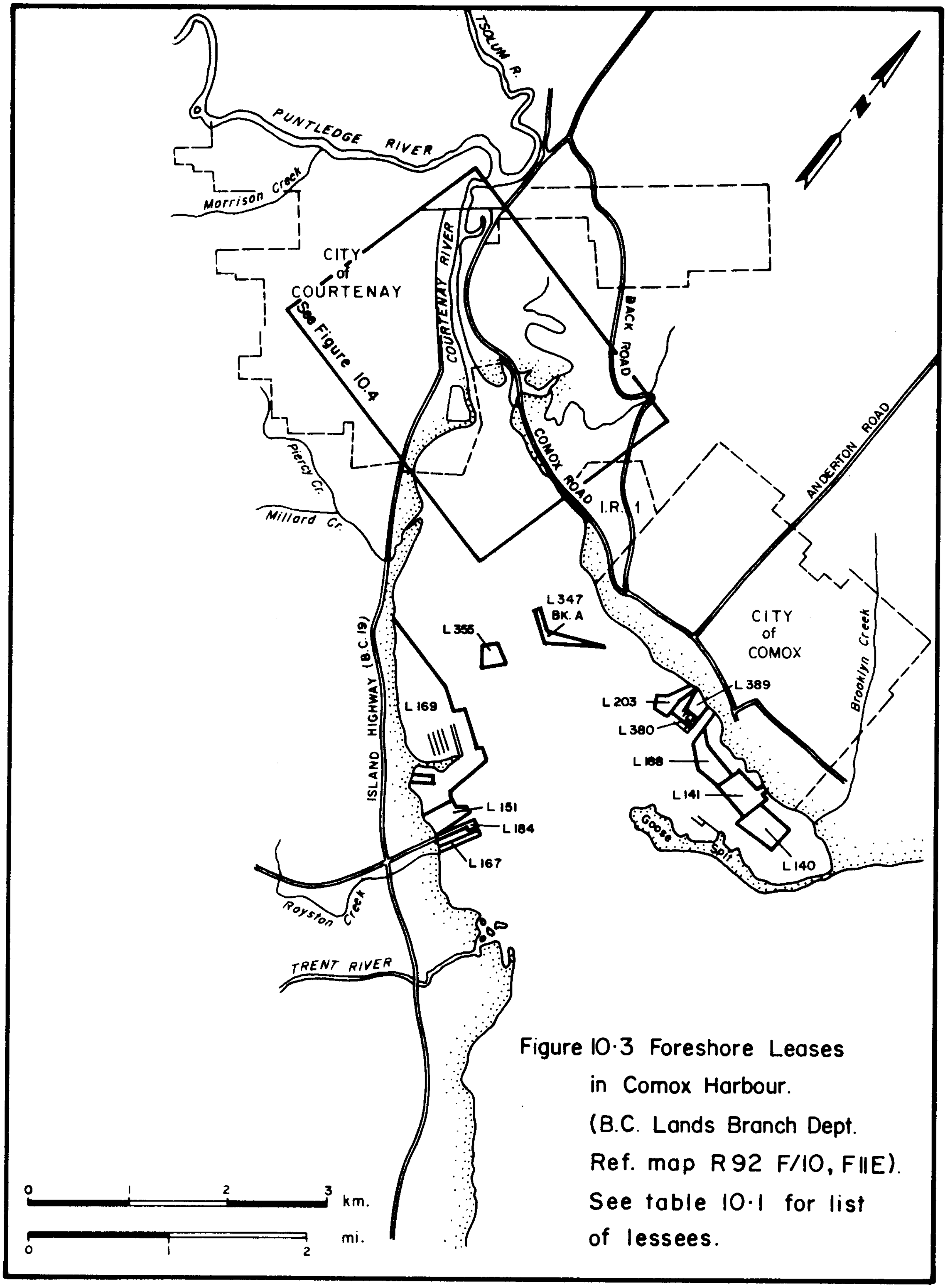


Figure 10·3 Foreshore Leases in Comox Harbour. (B.C. Lands Branch Dept. Ref. map R92 F/10, F11E). See table 10·1 for list of lessees.

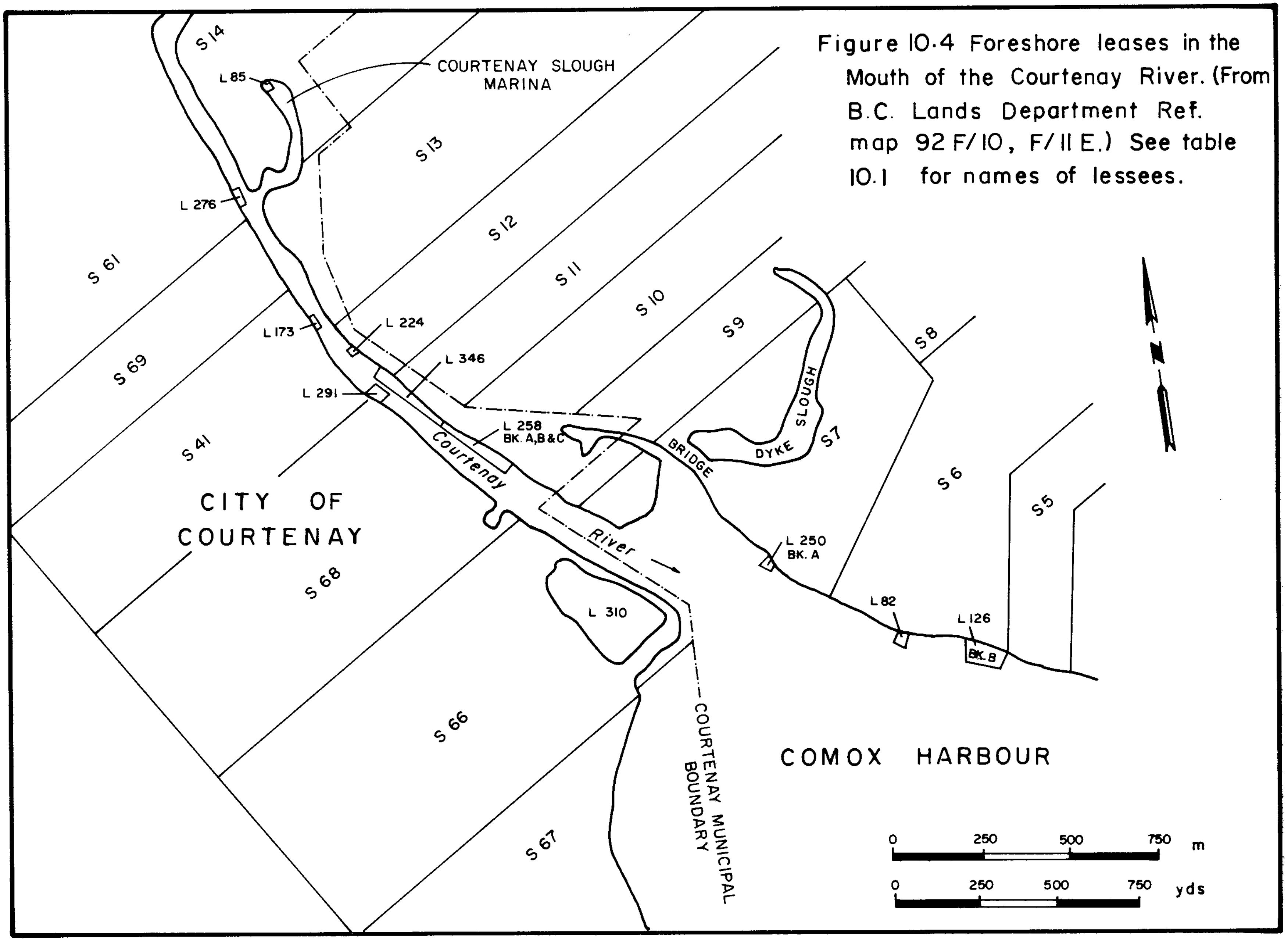


Figure 10.4 Foreshore leases in the Mouth of the Courtenay River. (From B.C. Lands Department Ref. map 92 F/10, F/11 E.) See table 10.1 for names of lessees.

Table 10.1 Foreshore leases in Comox Harbour and the Courtenay River Estuary (Ministry of Lands, Parks and Housing, 1979). (For lot location see Figures 10.3 and 10.4).

LESSEE	LOT NO.	SIZE Ha	SIZE Ac	LEASE EXPIRY DATE	USE
Emerson Billie	82	.04	.11	Dec., 1990	Boat way
R.E.M. Kirk	85	.02	.04	Apr., 1987	Wharf
B.C. Packers Ltd.	140	10.70	26.40	Sept., 1984	Oyster culture
B.C. Packers Ltd.	141	4.16	10.28	Mar., 1983	Oyster culture
	(151)*				
	(167)*				
Crown Zellerbach Canada Ltd.	169	45.44	112.20	May, 1992	Log booming
Chevron Canada Ltd.	173	.20	.50	Nov., 1979	Wharf site, petroleum distribution
Shell Canada Ltd.	184	1.13	2.81	July, 1982	Wharf site, petroleum distribution
B.C. Packers Ltd.	188A	7.04	17.40	June, 1993	Oyster culture
Comox Marine Industries Ltd.	203	4.85	11.98	unknown	Wharf site
Roy Parker Marine Ltd.	224	.07	.18	Sept., 1992	Wharf and float

Table 10.1 (cont'd)

LESSEE	LOT NO.	SIZE Ha	SIZE Ac	LEASE EXPIRY DATE	USE
LaFarge Canada Ltd.	250A	.08	.20	June, 1980	Scow and barge docking
Field Sawmills Ltd.	258 A,B & C	1.07	2.65	June, 1979	Log booming
J.D. & H.R. Veloso	267 B	.67	1.65	Apr., 1985	Fish canners, fish market restaurant, residential
McPhee Holdings Ltd.	276	.10	.25	Dec., 1980	Barge grid and landings
Riverhouse Enterprises Ltd.	291	.06	.16	Nov., 1979	Wharf and float lease
Corporation City of Courtenay	310	5.10	12.60	Sept., 1983	Sewage lagoon
Field Sawmills Ltd.	346	.50	1.12	June, 1979	Log booming
Pacific Coast Shellfish	347 A	3.40	8.40	June, 1986	Oyster associated activities
Joe Turnowski	355	3.85	9.50	Feb., 1987	Oyster associated activities
Town of Comox	380	3.13	7.73	Sept., 1993	Marina purposes
	(389)*				

*Lots 389, 167 and portions of Lot 151 reserved for recreational purposes reference maps, topographical and geographical maps, charts, aerial photographs and other miscellaneous information relative to the Courtenay/Comox region are listed in Appendix 10.2.

10 (ii) RESIDENTIAL LAND USE

Based on population forecasts prepared by the Regional District Planning Department, assuming the present growth rate of 2.8% continues, the population of School District 71 is expected to reach about 58,600 by the year 2001 (Regional District of Comox-Strathcona, 1979b).

Residential land use in the Courtenay River estuary is east-west oriented. There are additional pockets of residential land along the coast. Future land use proposals to accommodate anticipated growth favour extension of present residential districts rather than development of new subdivisions. The general trend is to encourage development in previously established population centres (Regional District of Comox-Strathcona, 1977).

Three Indian Reservations are located in the study area. Reservation 2, the largest in the Comox Valley is situated at the junction of the Puntledge and Tsolum rivers. Reservation 1, adjacent to Comox, has shoreline frontage as does Reservation 3, which is located on Goose Spit and occupies the smallest area of the three.

10 (iii) RECREATIONAL LAND AND WATER USE

The Courtenay River estuary and associated environs exhibit moderate to high recreational value. Sport fishing, hiking, camping and skiing are popular throughout the area. Other recreational activities include scuba diving, cruising, sailing, hunting, and wild-life photography. Recreational land capability maps, revised in 1972, are available for Comox Harbour and the Courtenay River watershed at a scale of 1:250,000.

The sheltered side of Goose Spit is used extensively for pleasure boating, sailing, water skiing and tidal sports fishing. Limited development in the estuary attracts migratory waterfowl; many birds utilize the estuary as a stop over and rallying point however, some species over-winter there providing excellent opportunities for bird watching. Exclusive of Goose Spit, the estuary foreshore is largely privately owned, placing the spit under considerable demand as a public recreational site.

Courtenay has 11.2 ha (28.0 ac.), Comox 6.9 ha (17.0 ac.), and Cumberland 2.0 ha (5.0 ac.) of developed municipal parkland (Regional District of Comox-Strathcona, 1975). Table 10.2 provides a summary of parks located within the study area.

Mount Washington and Wood Mountain Park are located on the outskirts of Strathcona Provincial Park. Adjoining Forbidden Plateau is the Comox Glacier Nature Conservancy Area. This section of the park is dedicated to the maintenance and preservation of the natural environment and indigenous flora and fauna.

Wood Mountain Park is noted for its ski slopes. A variety of facilities is available, catering to skiers of differing proficiencies. The ski season lasts approximately 120 days, during which time an average of 555 skiers per day use the slopes.

The Courtenay-Comox hinterland is recognized for its fishing, hiking, and hunting, but access to the area is limited. Construction of a road along the southern shore of Comox Lake has been proposed. It would provide access to the hinterland, opening the area to wilderness recreation. In addition, the road would facilitate trade and communication between the Comox Valley and the Port Alberni region.

Table 10.2 Parks located within Courtenay River study area
B-boating F-fishing P-picnicking S-skiing
C-camping H-hiking PG-playground s-swimming

Park	Size Ha. (ac)	Location	Jurisdiction	Usage
Kin Beach	6 (15)	North of Kye Bay	Provincial	C, B, s, P
Kye	2286 (5644)	Between Kin Beach and Cape Lazo	Provincial	B, F, s, P
Comox Lake	2 (5)	West of Cumber- land	Provincial	C, B, F, H, s, P
Sandy Island	33 (81)	Northwest of Denman Island	Provincial	B, P, F, s
Miracle Beach	135 (334)	South of Oyster River	Provincial	C, P nature house
Finlongley	23 (57)	Denman Island	Provincial	C, P
Helliwell	69 (171)	Southeast Hornby Island	Provincial	H, P.
Rosewall Creek	67 (166)	between Mud Bay and Deep Bay	Provincial	H, P
Kitty Coleman	9 (21)	Strait of Georgia near Merville	Provincial	C, P
Goose Spit	1 (3)	Comox Bay	Federal Regional Administ- ration	B, s, P
Puntledge	4 (10)	City of Courtenay adjacent to Punt- ledge River	Municipal	s, P, PG
Lewis	6.8 (17)	City of Courtenay	Municipal	s, P, PG
Wood Mountain	97 (240)	southwest of Courtenay	Provincial local Parks board Admin- istration	H, S

10 (iv) INDUSTRIAL LAND AND WATER USE

Industrial development in the Comox Valley is limited. It is overshadowed by a well developed public administration and service sector, which may have an influence on the character of land use in the study area. Land designated "industrial" is confined to two industrial parks in Courtenay, one in Comox, and some development in Royston (Regional District of Comox-Strathcona, 1977, 1979a).

The estuarine zone of Comox Harbour covers approximately 816,89 ha or 2017 ac. Log booming and storage encompass about 46.97 ha (116.0 ac.), commercial leases such as marinas, wharf sites and the like compose 10.37 ha (26.61 ac.), and oyster leases occupy 29.12 ha (71.89 ac.) of the harbour (Ministry of Lands, Parks and Housing, 1979). Foreshore and submerged lands are provincially owned. Disposition of these is by lease only (Pollution Control Board, 1974).

1. THE FOREST INDUSTRY

Nearly 85% of the Courtenay River watershed area is owned by forest companies. Crown Zellerbach and Weldwood of Canada Limited are the principal operators. Both companies maintain extensive tree farm licences. Crown Zellerbach's tree farm No. 2 covers about 93,600 ha (231,140 ac.). The annual allowable cut from tree farm licence No. 2 is 4,983.9 x 10^6 m^3 (17.6 x 10^6 ft.), close to 11% of the regional log production (Regional District of Comox-Strathcona, 1975). The company employs 220 men in this operation.

A forest cover survey conducted by the Department of Lands, Forests, and Water Resources indicated that 88,686 ha (218,979 ac.) of School District 71 were covered by harvestable or potentially harvestalbe timber, 33,255 ha (82,113 ac.) being mature and 55,440 ha (136,686 ac.) immature. Of the remaining area, 26,653 ha (65,760 ac.) were composed of unmarketable stands (Regional District of Comox-Strathcona, 1972).

Hemlock and balsam account for approximately 70% of the logs harvested from tree farm licences in the study area. Within tree farm licence No. 2, 63% of the logs harvested were hemlock, 10% balsam, 9% fir, 14% cedar, and 4% other species (Regional District of Comox-Strathcona, 1975).

Sawmilling and lumber production are prominent industries within the Courtenay-Comox area. In the Regional District, there is a trend towards total log utilization and greater processing of cut logs, adding impetus to the Comox Valley forest industry.

(a) LOG HANDLING AND STORAGE

In August 1973, the Engineering Division of the B.C. Forest Service, submitted a report concerning Comox Harbour water quality as a result of logging activity within the estuary and watershed. Logging contributes to wood debris on the water surface and harbour floor, accelerated erosion in the hinterland due to road construction, increased particulate matter in the water column, and greater sediment deposition.

The forest industry leases 46.97 ha (116.00 ac.) of the Comox Harbour foreshore; however, only half the area is actively used for log booming and storage.

Lot 169 (see Figure 10.3), has been leased by Crown Zellerbach Limited and its predecessor company for log handling purposes since the early 1900's. About 24.3 ha (60 ac.) have not been used since 1953, and only residual debris is present in this area.

Foreshore lots 258 and 346 are leased to Field Sawmills Limited for log storage. Previously, they were used for log dumping.

Field Sawmills Limited also has an agreement with the Federal Government to collect and store logs for a limited period of time on the north side of Goose Spit.

Logs are delivered to Field Sawmills in booms or by trucks. The mill receives about 3.70×10^5 m^3 (13.0×10^6 $ft.^3$) of logs in booms annually while another 4.8×10^5 m^3 (17×10^6 $ft.^3$) are trucked in and dumped directly in the mill pond (B.C. Dept. Recreation and Conservation, 1974b).

2. POWER DEVELOPMENT

The following section is based primarily on a feasibility study prepared by Acres Consulting Services Limited (1973) on the proposed Puntledge River salmon hatchery.

On April 18, 1911, Canadian Collieries (Dunsmuir) Limited were granted two water licences authorizing diversion of a total of 28.3 m^3/s (1000 cfs.) of water. Hydro-electric power development began in 1913. An impounding dam was built at the outlet of Comox Lake and a diversion dam erected 4.0 km (2.5 mi.) further downstream (Figure 10.5). A canal and pipeline were built to divert about 9.40 m^3/s (330 cfs.) of water to the powerhouse located on the right bank of the Puntledge River, 1.61 km (1.0 mi.) upstream from Courtenay. Two 7,000 kilowatt (4,700 h.p.) turbines were installed to generate 25 H_z (25 cycle) power.

The British Columbia Hydro and Power Authority (formerly British Columbia Power Commission) purchased the hydro-electric development in 1953. Reconstruction of the powerhouse, and intake penstock commenced the same year to take advantage of the maximum flow allowed under the water licences.

The new Puntledge powerhouse was built slightly upstream to house a vertical Francis turbine with a capacity of 27,000

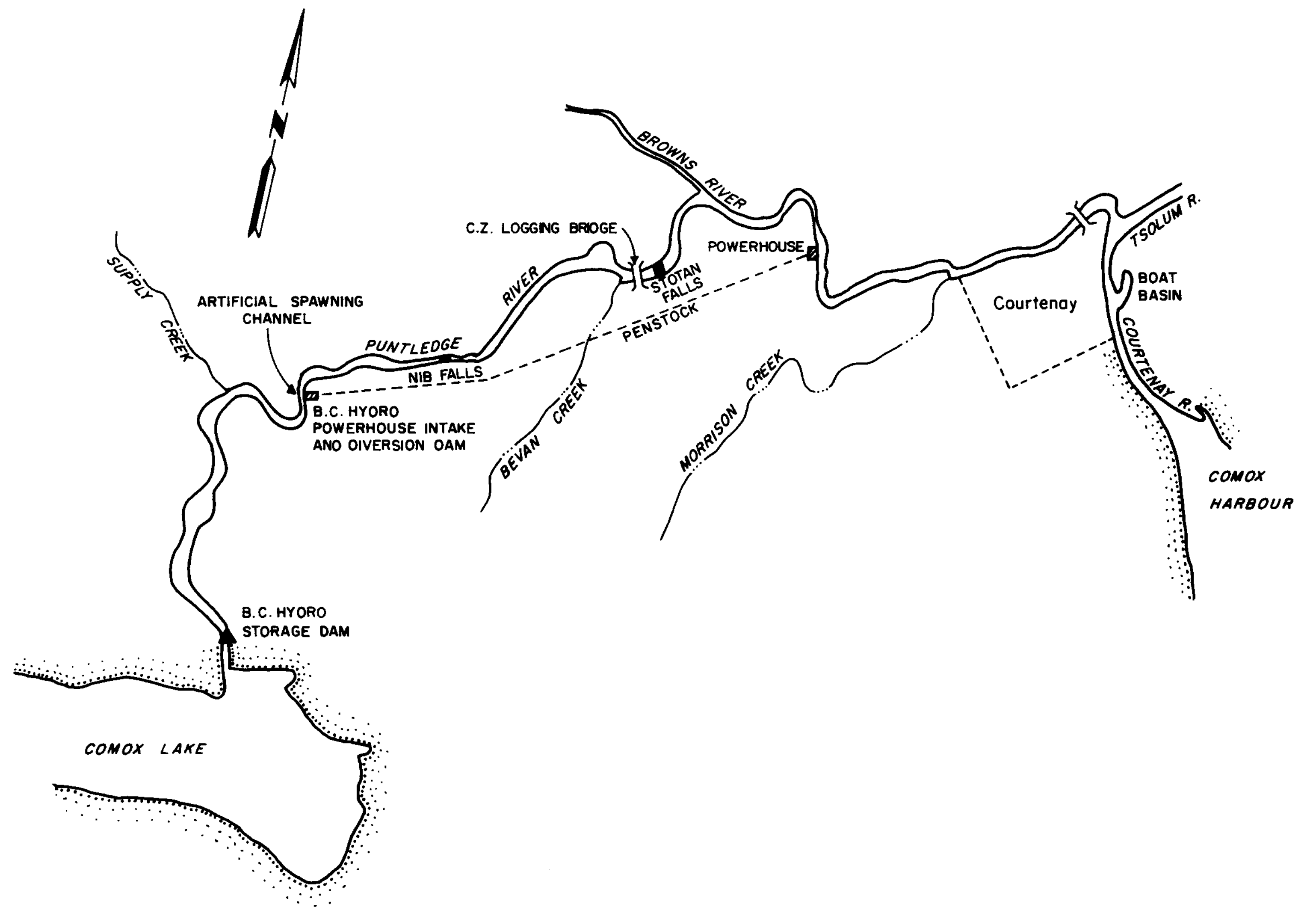


Figure 10·5 Hydro - Electric Development and Spawning Channel on the Puntledge River.

kilowatts (35,000 h.p.) developed from a head of 103 m (340 ft.). The powerhouse is operated as a base-load plant, owing to the penstock length and to the limited storage capacities of Comox Lake and the headpond (located between the diversion and impounding dams). This arrangement facilitated maximum energy production from a restricted water supply. Power flows vary in accordance with runoff and snowpack conditions.

Diversion dam modifications occurred in 1954. The approach channel was deepened and widened and construction of a new intake structure for a second penstock in the future was undertaken. However, B.C. Hydro has no plans to increase the generating capacity in the forseeable future.

During 1955, the original canal and pipeline were replaced by a penstock. The impounding dam was rebuilt between 1957 and 1958, and a new sluice way with two vertical lift gates was installed to increase the discharge and storage capacity of the dam. The effective storage capacity of the new impounding dam is 2,110.5 m^3 (74,500 $ft.^3$), approximately 708.2 m^3 (25,000 $ft.^3$) more than available prior to reconstruction.

In September, 1965, the Water Rights Branch granted fisheries permission to divert 2.83 m^3/s (100 cfs.) under water licence No. 1919 to operate a spawning channel constructed near the diversion dam. Water required for operation of the spawning channel is obtained from above the diversion dam, and the used water is discharged downstream of the dam.

3. MINING

Coal mining was a major industry, providing the early impetus to the social, economic and regional growth of the Comox Valley. When the Tsable River mine closed in 1966, about 20.5 million tons of coal had been removed from the Cumberland region. This figure represented nearly 20% of the entire production of Vancouver Island.

Between 1966 and 1967, Mount Washington Mine, located 29.2 km (18.0 mi.) northwest of Courtenay, employed about 80 people in the extraction and processing of copper ore.

Sand and gravel represent the current mineral resources of the area. Commercial extraction has been discussed in Geology and Soils.

4. AGRICULTURE

The primary Vancouver Island agricultural belt is located on the eastern coastal plain between Fanny Bay and the Oyster River basin. Agricultural districts within the study area are shown in Figure 10.6. There are about 170 farm units covering a total of 8,947 ha (2,222 ac.) and ranging in size from one to several hundred hectares (Statistics Canada, 1976).

In 1975, 290 persons in the Comox Valley were directly employed in agriculture. For further information regarding general agricultural activities and living standards, one is referred to the recent socio-economic survey of the Vancouver Island area (Verner and Dickinson, 1971).

Local agricultural practices are reflected in regional production statistics. Dairying is the primary source of agricultural revenue, followed by livestock raising, vegetable production, and poultry products (Regional District of Comox-Strathcona, 1972). Livestock such as beef cattle, swine and sheep, is generally raised in mixed farming with dairy cattle or vegetables.

In 1973, dairy cattle represented 47% of the regional cattle population. In total, they produced about 23 million

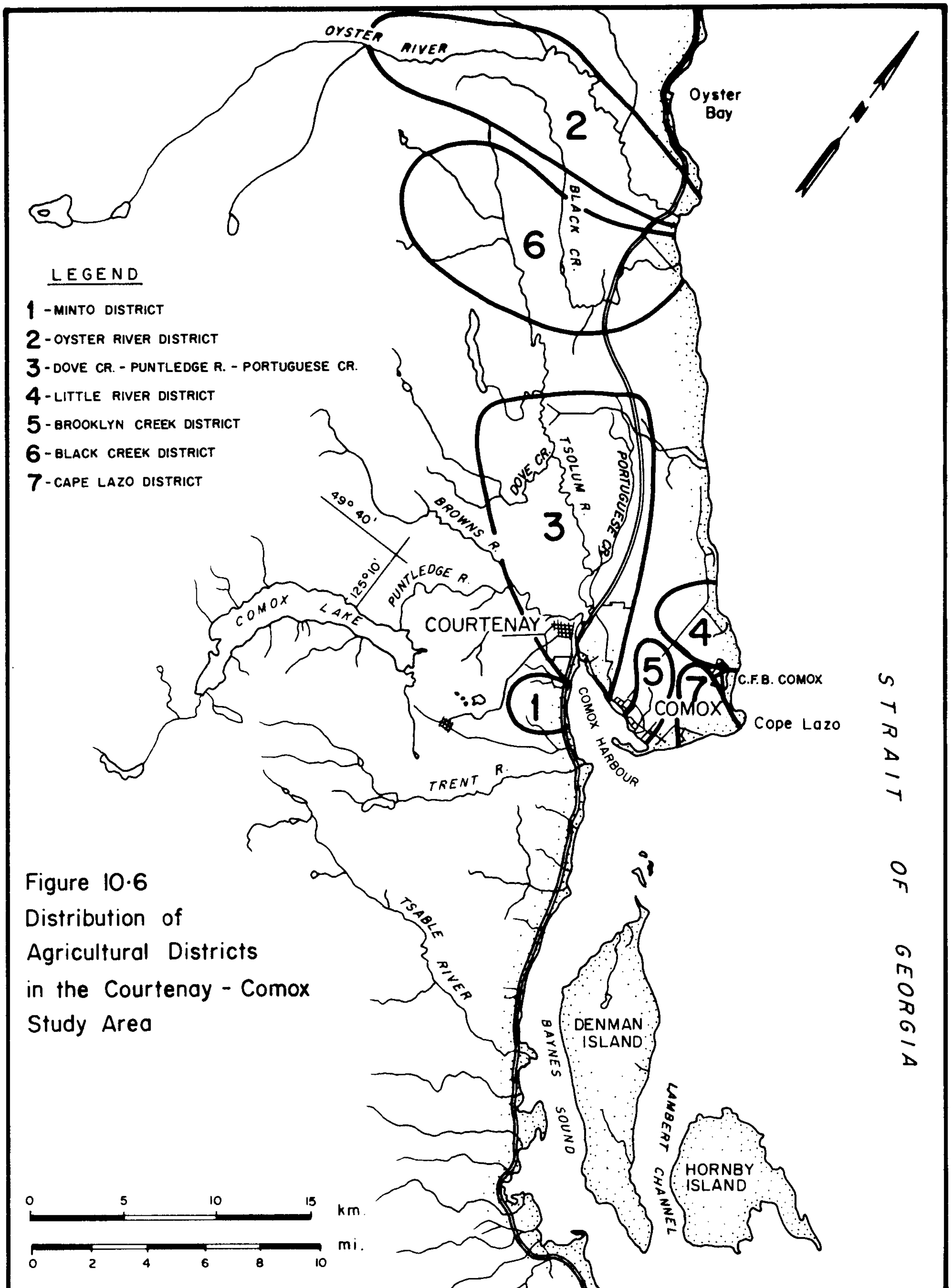


Figure 10·6
Distribution of
Agricultural Districts
in the Courtenay - Comox
Study Area

pounds of raw milk, valued at 1.9 million dollars. All milk produced within the study area is purchased by and marketed through the Fraser Valley Milk Producers Association. Homogenized and two-percent milk are processed within the area for local consumption.

Of the total area cropped in the Comox Valley, about 2,052 ha (5,067 ac.) are utilized for growing wheat, oats, and hay. Another 122 ha (301 ac.) are devoted to vegetable production. Small fruit and berry operations occupy a further 20 ha (50 ac.). The remaining 275 ha (678 ac.) are under miscellaneous cultivation. Root crops such as potatoes, onions, and carrots are marketed through the Island Vegetable Co-operative, in Courtenay. With Co-op consent, vegetable growers can sell produce directly to consumers; such direct sales are presently valued at about $50,000 annually.

10 (vi) REGIONAL AND MUNICIPAL SERVICES

1. WATER SUPPLY

The water supply systems in the Comox Valley are supervised at both the regional and municipal levels.

The water supply system, under the management of the Regional District of Comox-Strathcona, was incorporated on February 17, 1967 by Supplementary Letters Patent. The new district formed, included the Corporation of the Town of Courtenay, the Village of Cumberland, and the Back Road unspecified area.

Surveys of existing water supply systems in the Comox Valley and evaluations of future requirements were conducted by the Water Investigations Branch, B.C. Department of Lands, Forests, and Water Resources (Anthony and Leslie, 1966) and by Associated

Engineering Services Ltd. (AESL, 1965, 1970, 1975).

Prior to the incorporation of the regional supply system, Courtenay obtained its water from a dam built on the Browns River with a main leading to a settling pond north of Courtenay. A further main connected the pond to a 2,272,500 litre (5,000,000 gal.) storage tank from which water flowed through yet another main to Courtenay (AESL, 1965; Anthony and Leslie, 1966).

Both the report completed by AESL (1965) for Courtenay and Anthony and Leslie (1966) concluded that the municipal water supply system in the Comox area was inadequate. Livingston (1962) concluded that good wells could be dug near Anderton and Hilton Springs, but that wells in other areas would be of limited capacity.

Both AESL (1965) and Anthony and Leslie (1966) recommended that a regional water district be established and additional water for the area be obtained from the B.C. Hydro penstock. The most economical method was to tap the penstock upstream from the pumphouse. Water would then flow to a 4,546 m^3 (1 Mgal.) reservoir west of Courtenay; from there, mains would direct water to both Courtenay and to a proposed reservoir northwest of Comox. By 1970, both reservoirs were constructed; a pump station was built outside Courtenay to force water into the Courtenay reservoir, and a main from the Comox reservoir was constructed to carry water to Comox.

Subsequent to the AESL (1965) survey, a report was prepared for the Regional District of Comox-Strathcona (AESL, 1970) for the expansion of the regional water supply area. Recommendations included: (1) addition of pumps to the booster stations to increase the water supply to Comox and Courtenay; and (2) provision of preferred routes for mains to the Arden and Sandwick districts, so that these areas could be incorporated into the Regional District.

A further expansion of the Regional District to include all the Improvement and Waterworks districts and Specified areas in the Courtenay-Comox region was proposed by AESL (1975). Further expansions were suggested to deal with any proposed expansions of the regional water district. In a study of the groundwater in the area, Livingston (1974) concluded, on the basis of drilling, that some areas possess medium-to-high capacity sources of groundwater. Potentially good sources are likely to be found in the area between Courtenay and Black Creek. Hurley (pers. comm., 1978) stated that both Arden and Little River Improvement districts have been recently incoporated into the Regional District water supply system. Sandwick Improvement District, Cumberland and Royston still have independent water supply and distribution systems.

2. SEWAGE TREATMENT

Courtenay, Comox, CFB Comox and Cumberland have organized sewage systems. All other areas have septic tanks.

An organized sewage system for the City of Courtenay was first proposed by AESL (1951). The firm recommended routes for collector and trunk mains which would discharge into a sewage lagoon. A sewage lagoon consists of a shallow pond(s) in which bacteria decompose dissolved and suspended organic materials in the sewage in the presence of oxygen supplied by algae. When the pond is frozen, algae production slows down or ceases and little decomposition of the suspended solids occurs. The larger particles settle out as in septic tanks.

The area was surveyed by AESL (1959), and it was again recommended that sewage be treated using a sewage lagoon and that the effluent from the treated sewage be discharged into the Courtenay River. In 1962, the City of Courtenay adopted this recommendation and a 6.8 ha (17 ac.) sewage lagoon, with a capacity to serve 5,000 people was built on the foreshore of the Courtenay River (Figure 10.3).

An increase in the population resulted in an overloading of the lagoon and a need to expand the treatment facilities. AESL (1967) recommended that the most inexpensive method would be to install aerators in the lagoon. In 1968, five earators were added.

AESL (1961) was asked by the Town of Comox to suggest a method for disposing of sewage. They recommended that collection and trunk mains merge at a pump station which would pump sewage through a force main, to an outfall off Goose Spit. Waldichuk (unpublished) measured currents and other oceanographic characteristics in Comox Harbour and northern Baynes Sound and concluded that a 361 m (1,200 ft.) outfall discharging at a depth of 22 m (72 ft.), be built to ensure that no raw sewage entered Comox Harbour (see Oceanography Section).

In 1953, CFB Comox constructed a series of collector and trunk mains leading to a treatment plant (Dayton and Knight, 1974). The plant is a package type Chicago Pump Aerator-Clarifer. The effluent is aerated and chlorinated, and then flows in an open ditch to Point Holmes. As runoff was seeping into the collector mains, and the treatment plant was both over-loaded and mechanically unsound, Dayton and Knight (1974) were asked for suggestions to update the system. None of the schemes the firm proposed were adopted because the proposals were too expensive, and therefore no changes have been made to the sewage system.

In 1936, Canadian Collieries built a combined sewer and storm trunk main from Cumberland to the Trent River (Figure 10.1). After surveying the sewage system in 1965, AESL recommended that the village build a system of collector mains from the areas not on the combined system, and that the trunk mains from the systems empty into a sewage lagoon. In 1968, Cumberland built a 2.6 ha (6.4 ac.) lagoon about one mile from the village centre; an additional 0.9 ha (2.2 ac.) pond was built in 1970. To further enlarge the capacity of this lagoon, AESL (1971) suggested that the most economical method would be to add aerators. Three were installed in 1972.

Plans to separate the combined sewage-storm drain mains to reduce the discharge of effluent to the treatment lagoon and to confine the treatment to sewage only, were proposed by AESL, (1973). Cumberland is currently altering the combined system.

3. TRANSPORTATION

The Courtenay-Comox area has a well developed transportation system. The area is served by road, ferry, railway, air transport and port facilities.

Highway 19 connects Courtenay and Comox with other Vancouver Island east coast communities. There is direct road access between Cumberland and Courtenay and several routes exist between Courtenay and Comox. A new inland route between Courtenay and Campbell River has recently been proposed, as has a second crossing of the Courtenay River (Regional District of Comox-Strathcona, 1977, 1978).

Ferry service in the study area is maintained by the B.C. Ministry of Highways. The Comox-to-Powell River service operates several times daily as an extension to the provincial highway system. Vehicular and passenger ferry service is available between Denman Island and Hornby Island and Buckley Bay on Vancouver Island.

The Esquimalt and Nanaimo (E and N) Railway, a subsidiary of the Canadian Pacific Railway, facilitated resource development in the Comox Valley (Regional District of Comox-Strathcona, 1975). The E and N Railway still supplies freight service weekly between Courtenay and Victoria.

There are two controlled airports in the Courtenay-Comox area. A gravelled landing strip at Courtenay is 600 m (2,000 ft.) long, and is primarily used by private and chartered flights. Commercial carriers have permission to land at CFB Comox, where the Department of National Defence maintains a 3,040 m (10,000 ft.) runway. Comox also has float plane services; Airwest and Pacific Western Airlines Limited make several daily scheduled flights to Vancouver, Powell River, Nanaimo and Campbell River.

Comox is classified as a port of entry with a Canadian Customs Office (Canadian Hydrographic Service, pers., comm., 1978). The Department of National Defence maintains a wharf 30.5 m (100 ft.) long with a depth alongside of 8.8 m (29 ft.) at low water. There are two public wharves in the harbour, as well as an aircraft float operated by the Department of Transport. The port also has a fuel barge dispensing diesel oil and gasoline.

11. WATER QUALITY AND POLLUTION

Water pollution control is administered primarily by the federal Fisheries Act, section 33, and by the provincial Pollution Control Act, S.B.C. 1967c. 34. The federal Canada Shipping Act controls pollution from ships, particularly by oil. The dumping of all materials for the purposes of disposal, including dredge spoils, into the sea, is regulated under the Ocean Dumping Control Act. Other federal and provincial legislation and municipal by-laws controlling specific aspects of environmental pollution are listed in Appendix 11.1.

Resources maps of Comox Harbour and contiguous waters have been prepared by the Environmental Emergency Branch of the Environmental Protection Service (EPS) as part of the oil and chemical spill counter measures series (Canada Dept. Environ., 1976). These maps inventory some of the existing resource information to aid in initial decision making and contingency planning in the event of an emergency.

Under the Pollution Control Act, the Pollution Control Board was set up to set standards for the emission of solid, liquid and gaseous pollutants by: food processing industries; agriculturally-oriented and miscellaneous industries; mining; mine-milling and smelting industries; chemical and petroleum industries; forest product industries and municipal wastes.

Monitoring of the effluent quality and quantity is usually stipulated when the B.C. Pollution Control Branch (PCB) issues effluent permits to ensure that the discharge is within the standards set by the Pollution Control Board. Results of testing by both the permittee and PCB personnel, as well as the permit listings, are stored in the computer bank EQUIS (Clark and Ellis, 1975). Information is available on request from the PCB head office in Victoria. Permit listings for the study area are summarized in Appendix 11.2 .

Fresh, estuarine and marine waters are also analysed by PCB personnel to determine if effluents are causing a deterioration in water quality (Figure 11.1). Results of the parameters analysed at sample sites in the study area are also stored in the computer bank. A list of the parameters measured at each site is given in Appendix 11.3.

11. (i) GENERAL WATER QUALITY DATA

General analyses of the water draining into Comox Harbour have been carried out by Canada Dept. Fish. and Environ. (1958) Acres (1973), and PCB (1974b). Canada Dept. Fish. (1958) found that temperature, dissolved oxygen concentration, pH, turbidity and the relative concentrations of diatoms in Comox, Willemar and Forbush lakes were acceptable for rearing salmon.

An analysis of Comox Lake and Puntledge and Browns rivers by Acres (1973) showed no chemicals in concentrations large enough to affect fish in a hatchery proposed for the for the Puntledge River. High turbidity was observed in the Browns River during peak runoff periods, however. During periods of low flow, extremes in temperatures between 0^{o} and $23^{o}C$ (32^{o} and $74^{o}F$) were measured in the Puntledge River.

An analysis of water in the Trent and Courtenay rivers, between February and December 1973 by PCB (1974, Figure 11.1), showed no unusual values except for phosphate, where concentrations at the mouth of both rivers exceeded the recommended algae growth contaminant level (0.01 mg/l). The source of contamination was unknown.

In Comox Harbour itself, water quality studies were carried out by Waldichuk (MS, 1962) and Waldichuk, *et al.* (1968) and PCB (1974c). The vertical distribution of temperature salinity and dissolved oxygen in Comox Harbour was measu-

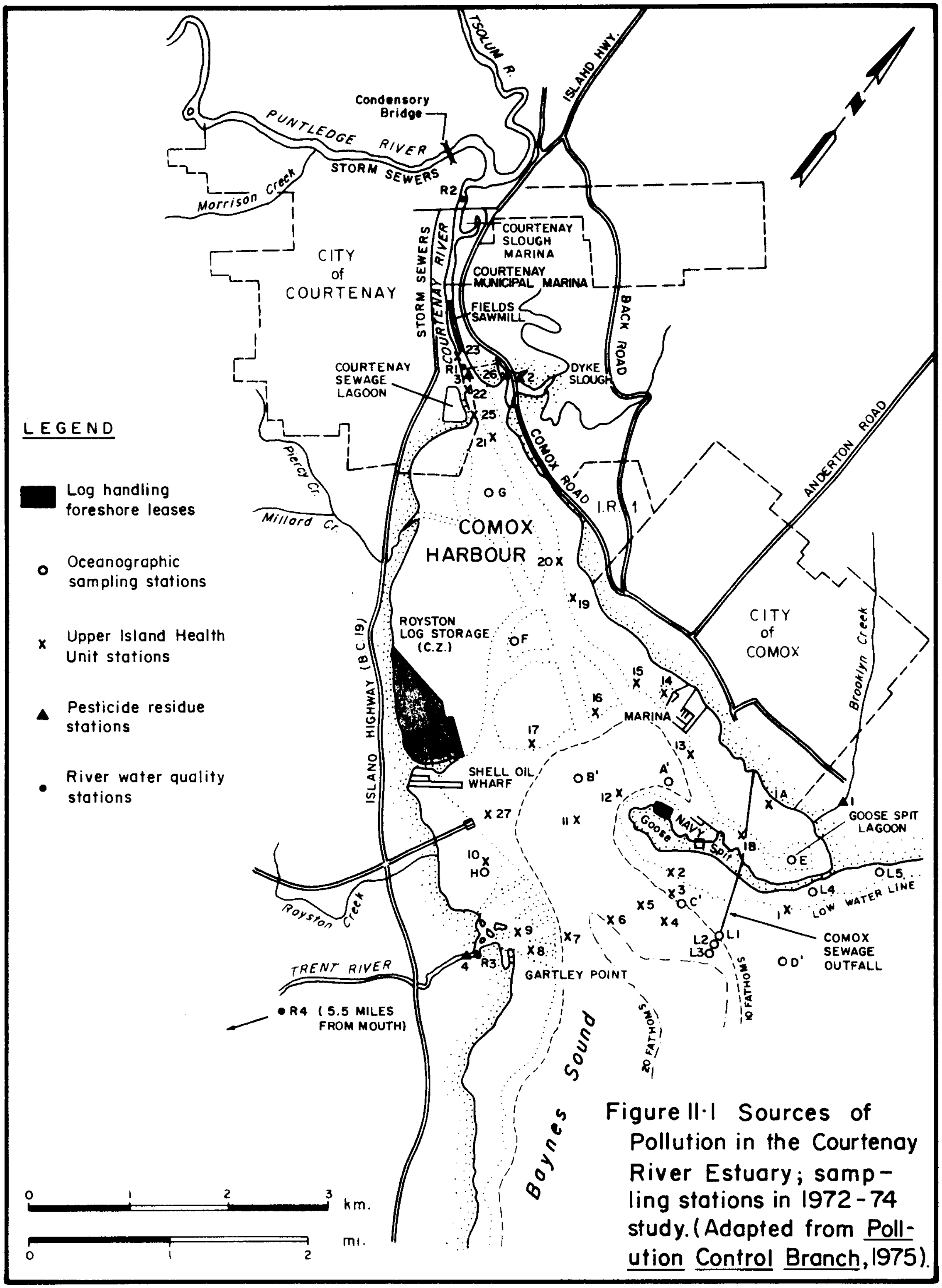


Figure II·1 Sources of Pollution in the Courtenay River Estuary; sampling stations in 1972-74 study. (Adapted from Pollution Control Branch, 1975).

red by Waldichuk (MS, 1962) in January, 1958. Waldichuk, *et al.*, (1968) collected data on the temperature, salinity dissolved oxygen concentration, pH and alkalinity of the water in Comox Harbour from January 28 to February 1, 1958, May 24 to May 27, 1961 and August 7 to August 8, 1962 (See Oceanography Section).

Physical and chemical parameters determined at 13 sites (Figure 11.1) in Comox Harbour on April 23, July 11 and October 16 - 17, 1973, showed that nitrate and phosphate levels were not excessively high, dissolved oxygen was generally near saturation and TOC, oil and grease, colour and tubidity showed consistently low values, (PCB, 1974c). Coliform values however, exceeded the values safe for shellfish harvesting (see Domestic Sewage section).

11. (ii) POLLUTION

The major sources of pollution are domestic sewage and log handling and storage. Minor sources of pollution originate from boating, mining, ocean dumping, industrial wastes and pesticide use.

1. DOMESTIC SEWAGE

Domestic sewage discharge introduces bacteria, coliforms and organic nutrients into the aquatic environment. Coliform counts are measured as the Most Probable Number (MPN) of bacteria /100 ml of water (Waldichuk, MS, 1962). The maximum acceptable fecal coliform counts in water for edible oysters are 14 MPN/100 ml with 10% of the samples not exceeding 43 MPN/100 ml. Swimming may not be permitted when the fecal coliform counts exceed 240 MPN/100 ml (Appendix 11.4).

Prior to 1962, raw sewage was discharged into Comox Harbour from a variety of sources (Waldichuk, MS, 1962). The "100 homes outfall" from Comox pumped 90.9 cu. m/day

(20,000 gpd) of raw sewage into the harbour. Raw sewage from septic tanks located behind Goose Spit, along the coastline at Comox and in Courtenay, also entered the harbour. Sewage from Courtenay septic tanks flowed into storm drains that emptied into the Puntledge and Courtenay rivers. The total coliform counts, in the areas where raw sewage entered the harbour, ranged from 350 to 2,000 MPN/ 100 ml. These values exceeded those stipulated to be safe for harvesting oysters (total coliform counts less than 70 MPN/100 ml) and swimming (total coliform counts less than 1000 MPN/100 ml).

Sewage treatment at Courtenay and Cumberland now consists of comminution and retention in an aeration lagoon followed by the discharge of treated effluent into the Courtenay and Trent rivers, respectively. The treatment of sewage by the lagoons was thought to reduce the amount of BOD, volatile suspended solids, suspended solids, and total solids emptying into the harbour by <85%, 93%, 93% and 97%, respectively (Stewart, pers. comm., 1978). When the results of analysis of the chemicals in the effluent from Courtenay and Cumberland sewage lagoons were compared to those from a "typical" sewage outfall, the effluent from each of the sewage lagoons was considered to be weak (PCB, 1974a). Only phosphate (PO_4) and total organic carbon (TOC) were found in appreciable amounts (Table 11.1).

Despite the predicted 99% reduction in fecal coliforms from each of the two lagoons, Waldichuk (1974) concluded that 10,000 MPN/100 ml total coliforms were still entering the harbour from the Courtenay sewage system alone. The lagoon was considered to be less effecient in reducing coliform counts than the Comox sewage disposal system, which discharged an average of 0.29 to 0.45 mgpd (Dayton and Knight, 1976) of raw sewage into Baynes Sound (Waldichuk, 1974).

Table 11.1 Municipal Sewage Treatment Plant Effluent Characteristics for Courtenay and Cumberland (condensed from PCB permit monitoring data from January 1972 to June 1977, Victoria, B.C.)

	BOD (mg/1.)	V.S.S. (mg/1.)	S.S. (mg/1.)	T.S.S. (mg/1.)	Mean Flow (gpd)	Fecal Coliforms MPN
COURTENAY						
Max.	255.0	60.0	188.9	306.0	936.0	240,000
Min.	18.0	11.0	188.9	200.0	318.0	1,700
Mean	39.9	30.8	188.9	242.8	576.2	65,000
CUMBERLAND						
Max.	28.0	34,000.0	129.3	234.0	-	54,000
Min.	<10.0	3.0	129.3	104.0	-	<200
Mean	15.4	2,019.1	129.3	138.3	-	11,450

Other sources of pollution affecting fecal coliform counts in the harbour were investigated by the Upper Island Health Unit (U.I.H.U.), 1974, unpublished), Kay and Tevendale (1974b) and Patten (unpublished). Aside from the Courtenay sewage lagoon, effluent from leaky shoreline septic tanks, effluent from leaky septic tanks and feces from farm animals seeping into rivers flowing into the harbour, have also influenced fecal coliform counts. Leaky septic tanks were found behind Goose Spit, the Indian Reserve in Comox, the Millard Creek mouth area and throughout the Royston District. Bacterial counts exceeding 14 MPN/100 ml were found in Roy, Brooklyn and Willemar creeks, the Indian Reserve and Courtenay River mouth throughout the year, Trent River in the fall and Tsolum River in the winter. High coliform counts were prevalent throughout most of Comox Harbour during the winter (U.I.H.U., 1974).

In a comprehensive survey of fecal coliform counts in Comox Harbour during the summer, Kay and Tevendale (1974b) concluded that the marine water samples were generally of acceptable quality. Shellfish were thought to become dangerously contaminated during low tide, when the dilution of sewage effluent was limited. Pollution from the Comox pumphouse, Roy Creek and Trent River had resulted in some localized marine samples showing fecal coliform counts exceeding 14 MPN/100 ml. Closure of Comox Harbour and further surveys of coliform counts during the winter were recommended.

Patten (unpublished), surveyed the harbour in the summer of 1975 and found high coliform counts at the mouth of the Courtenay River, off Royston and behind Goose Spit.

As Baynes Sound is one of the richest oyster-producing areas in B.C., the area is constantly being monitored for fecal contamination. Kay and Tevendale (1974a) concluded that, in general, the waters were of acceptable quality, except near Waterloo Creek where agricultural runoff caused high fecal coliform counts. During heavy rainfall, the foreshore waters near Union Bay were subject to contamination which may result in temporarily excessive fecal coliform counts. Derkson and Tevendale (1974) surveyed Denman Island and found no unacceptable values, although during periods of rain, agricultural runoff is thought to increase fecal coliform counts in some of the leased oyster growing areas. E.P.S. (unpublished) conducted a survey of Henry Bay, Denman Island, and found that the fecal bacteria count was too high to permit the harvesting of oysters. The source of pollution was unknown.

2. LOGGING, LOG HANDLING AND STORAGE

The removal of streambank flora by loggers contributes to a less stable flow regime. Streambank erosion and sediment deposition on the bottom of rivers can adversely affect fish production by smothering or dislodging incubating eggs or fry, by disrupting benthic invertebrate (fish food) habitats, and by decreasing organic detritus and some nutrients essential for fish production (Burns, unpublished). Hooton unpublished), Pacific Northwest Pollution Council (PNPPC) (1971), and Canada Dept. Environ. (1973) also noted that the removal of shade trees resulted in summer water temperatures lethal to roe, fry and adult salmonids.

Logging has occurred in the Courtenay River watershed since the 1900's; most of the area has now been reforested. Logging in the watershed now centres at the headwaters of the Puntledge, Browns and Tsolum rivers (Gibson, pers. comm., 1978).

The impact of past logging practices on the watershed was investigated by the B.C. Forest Service (1974). They found that increased sediment loads in the Browns, Tsolum and Trent rivers were caused by road construction and debris from logging, e.g. a major slide from the washout of a road too close to the Browns River resulted in 1,070 cu. m (1,400 cu. yd.) of sediment entering the river. Streambank erosion on the Tsolum River is also due, to a large extent, from clearing for agriculture (Burns, unpublished). Log jams on the Trent River diverted water into the streambank, increasing erosion (B.C. Forest Service, 1974).

A lack of streambank flora in parts of the Tsolum River, coupled with the diversion of water for irrigation, resulted in an average flow of 0.62 m^3/s (22 cfs) for August and an average flow of 1.27 m^3/s (45 cfs) for September between 1968 and 1977. Some of the tributaries were dry (B.C. Fish and Wildlife Branch, unpublished). Low flows are thought to be a major factor causing the high mortality of adult salmonids by inhibiting upstream migration (Walker and McLeod, undated).

Hatten (memo to H. De Beck, 1974), noted that as a result of low flows, temperatures in the Tsolum River were

10°F higher than any river between Parksville and the Oyster River. Maximum temperatures ranged between 23.8° and 25.5°C (75° and 78°F) and resulted in a high mortality of pink salmon fry.

Logging has progressed up the Oyster River over the last 50 years; currently both Crown Zellerback and MacMillan Bloedel are logging in the headwaters (Venus, pers. comm., 1978).

On the Oyster River, clear-cut logging on steep terrain has also led to an altered pattern of runnoff. Flooding has occurred frequently in the last twenty years and is considered to be the major cause of the decline of pink and chum salmon. Flash floods have displaced much of the gravel used for spawning, so that there is little hope for an increase in the fish population through natural events (Brown, *et al.*, 1977). Following the flood in 1975, an estimated 90% of the pink and chum salmon eggs were lost.

In addition, the lack of or damage to streambank flora has resulted in poor soil cohesion. Several major slides have occurred because logging roads were built too close to the river and were washed out during heavy rainfall. A small slide was reported to have occurred in 1971 (Wilcocks, memo to T. Bird, 1971) and 49,679 cu. m (65,000 cu. yd.) of sediment, in two separate slides, washed into the Oyster River in 1974 (Burns, memo to G. Reid, 1974). Heavy siltation may have cemented gravel in some sections of the Oyster River rendering them unsuitable for cutthroat spawning (B.C. Fish and Wildlife Branch, unpublished). Declines in pink and chum salmon may be due, in part, to egg loss from siltation.

The dumping, sorting and transporting of logs in water is considered by the PNPPC (1971) to be detrimental to aquatic ecosystems as toxic leachates, chip and bark debris and non-organic debris combine to increase BOD and smother benthos.

Surveys by Okano (1974) and Maxwell and Speers (1975) on Comox, Wolf and Willemar lakes showed an extensive build-up of debris from dumping, sorting and transporting logs. Thirty-four thousand eight hundred twenty-one cubic metres (12,300 cunits) were found to have accumulated around Comox Lake. One quarter of that had collected on the flats at the mouth of the upper Puntledge River. Sunken logs and bark debris on the bottom of Comox Lake were covered with a layer of silt; no flora was seen. Around Wolf Lake, 11,880 cu. m (4,200 cunits) of debris were found while 3,397 cu. m (1,200 cunits) were seen at Willemar Lake. Crown Zellerbach no longer dumps or sorts logs in Comox Lake. They sort logs on dry land, which greatly reduces the accumulation of debris, and trucks the logs to the Campbell River area.

Accumulations of log debris in Comox Harbour have resulted from present activities in Field Sawmill's foreshore leases and past activities on several of the lots in the harbour. Kennedy and Waters (unpublished) noted that in 1974, Field Sawmill was using 0.7 ha (1.8 ac.) to de-water logs (Figure 11.1). The lot was dredged 2 to 3 times a year (Conlan, unpublished).

Until early 1978, Crown Zellerbach dumped logs on 9.3 ha (23 ac.) of foreshore at Royston (Hall, pers. comm., 1978; Kennedy and Waters, unpublished). In 1974, 0.03 to 1.4 x 10^6 cu. m (1.0 to 4.9 x 10^6 cu. ft.) of logs were dumped into Comox Harbour per year. The area was dredged once every 3 to 4 years to remove the 15.2 - 60.9 cm (6 - 24 in.) of bark and wood chips that had accumulated (Conlan, unpublished). Only a little debris is present now and the lot is being used by Field Sawmill for log storage (Figure 11.1).

Scattered logs, bark and delapidated piles were found in Dyke Slough while logs, straps, piles, bark, hardware, etc. were found in an abandoned forshore near Field Sawmill (B.C.

Fish and Wildlife Branch, 1974; B.C. Forest Service, 1974). Logs and other wood debris can still be seen along the shoreline of the harbour.

Chemical analyses of samples of water from an area of Comox Harbour where large deposits of debris had accumulated, showed the presence of hydrogen sulfide (H_2S) gas (Werner, 1968; Werner and Angotti, 1973). Hydrogen sulfide is created as a waste product by anaerobic bacteria (those able to function in an environment without oxygen) during the decomposition of wood wastes (Werner, pers. comm., 1978). In these areas, all the oxygen has been consumed by aerobic bacteria. Dredging of sediments rich in wood wastes releases H_2S into the surrounding water. While H_2S is highly toxic to salmonids, no fish kills resulting from the presence of H_2S have been reported in the harbour.

Conlan (unpublished) surveyed the Royston dump site and found euphausids, isopods, dead crabs and needlefish. No other fish were seen. The abundance of fauna was greater in a nearby storage area where clams, mussels, horse clams, jellyfish, salmon fry and seals were common. The more extensive deposits at the boom site accounted for the difference in the diversity of fauna.

3. STREAM CHANNELIZATION

Erosion in the Oyster River from a flood in November, 1975, resulted in a substantial loss of property along the river banks (Brown, 1976). The River-bank Protection Act provides means whereby owners of property bordering a river bank can apply to the provincial government to construct works to prevent the deterioration of the river banks (Ince, 1976). Following the application for channelization, construction began in the lower portions of the Oyster River. The effects of the bank stabilization and channelization on the river fauna are unknown, as the construction was just completed in 1976.

4. BOATING

Fifteen thousand recreational boats per year have been estimated to use the five marinas located in Comox Harbour (B.C. Fish and Wildlife Branch (1974). McKelvey (unpublished) noted that boat-hull anti-fouling agents, as well as gas and oil resulting from flushed bilges, the operation of marine motors (outboards in particular) and spillage, are introduced into the surrounding marine waters.

While no studies have been carried out to assess the impact of any of the marinas on the biota in Comox Harbour, the Canadian Fisheries and Marine Service is currently surveying Courtenay Slough, located in an area where very little flushing occurs, to determine the impact of the pollutants on the fauna and flora, water quality, etc. of the immediate area (Bell-Irving, pers. comm., 1978).

No studies have been carried out to determine how well pollutants from the Oyster River marina are flushed out of the marina basin or what effects these pollutants have on the estuarine or marine biota.

5. MINING

Coal mining was very active in the Cumberland area between 1904 and 1921 (see Geology Section). In 1966, the last mine on the Tsable River closed. Probable sources of pollutants from these old mines are sulfuric acid and sodium sulfate, which could leach into a river affecting the pH of the water (Hallam, pers. comm., 1978).

Contamination from the Mount Washington Copper mine tailings has been reported. Thornton (pers. comm., 1978) suggested that arsenic in the Tsolum River, possibly from these mine tailings, had resulted in fish kills. Coho fry introduced into Bevan Creek, a tributary of the Puntledge River, were thought to have died from unspecified pollution from mine tailings (Marshall, 1973). The ore in the copper tailings within the Puntledge river drainage area does not have sufficient alkalinity to prevent oxidation by the bacteria *Thiobacillus ferrooxidans*. This means that some leaching of copper into the Puntledge River could occur (Jackson, pers. comm., 1978). Further details are unavailable, as the report by B.C. Research on copper tailings in the study area is confidential.

6. OCEAN DUMPING

In a study of existing and historical dump sites in B.C., Wards, (1976) noted that two sites in the Comox Harbour area have been used to dump log debris and sediment under wharves. No studies have been carried out to assess the impact of the material dumped near the harbour.

7. OTHER POLLUTANTS

(a) In an analysis of the Sixth and First Street storm drains in Courtenay, PCB (1974a) concluded that the effluent from the Sixth Street drain was comparable to moderate concentrations of the chemicals found in the effluent from "typical domestic sewage outfall", while the First Street drain was comparable to weak concentrations of sewage. The major effluents discharged through the Sixth Street storm drain are wash-water from the Dairyland and Island Ready-Mix plants and a fungicide (pentachlorophenol) from Fields Sawmill.

(b) Effluent from Veloso's Fish Market empties directly into Comox Harbour on the east side of the Courtenay River.

(c) To determine the extent to which pesticides are used in an area, EPS has developed a computer program to store information from all the permit applications made (Wilson, pers. comm., 1978). The study area falls into watershed 8HB. Neilson (memo to Reidel, 1972) compiled a list of all the insecticides, fungicides and herbicides used in the Courtenay - Comox area. Only organo-chlorine insecticides are known to persist in soil and water. A list of all the fertilizers and pesticides used by farmers in the Courtenay area is given by the B.C. Department of Agriculture (1974).

PCB (1974d) noted that the major pesticide users in the Courtenay area are Canadian Pacific Railway, B.C. Hydro and Power Authority and Crown Zellerbach. In a survey of Comox Harbour, pentachlorophenol was found in some of the water samples. None of the other pesticides tested for was present. PCB (1974d) noted, however, that any of the pesticides used could occur periodically in the harbour from freshwater sources.

12. EFFECTS OF DEVELOPMENT

Some changes to the physical and biological features of the study area have occurred as a result of man's activities.

In the watersheds of the Courtenay and Oyster rivers, the drastic decline of fish populations has been caused by the expansion of the Puntledge River dam, logging and irrigation. Even though good habitat exists, the expansion of the diversion dam has prevented salmonids from utilizing the upper watershed. The decline of fish since the expansion of the Puntledge dam is seen in Appendix 6.3. To increase native populations, a spawning channel was constructed adjacent to the dam (MacKinnon *et al.*, unpublished; Marshall, 1973). Incubation, propagation and rearing ponds were added in 1972. As no increases in native anadromous salmon populations occurred, the emphasis shifted to hatchery propagation. The proposed hatchery to be built near the old powerhouse, will have the capacity for 130,000 chinook smolts, 75,000 coho smolts and 7,500 steelhead. About 0.085 million chinook could be harvested offshore leaving an escapement of 17,000 adults. Assuming a local catch of 4,250 chinook, about 12,750 chinook spawners could be expected. With increases in coho and steelhead production, considerably more salmonids could be available to both commercial and recreational fishermen.

Both irrigation and clearcutting have caused very low flows in the Tsolum River, resulting in a decline of pink and chum salmon populations. A dam and control works were built by Fisheries at Wolf Lake in 1964 to increase the flow and reduce the temperature of water in the river. Hybrid pink salmon have been re-introduced in the Tsolum River, and their numbers have now climaxed at 10,000 (Walker and McLeod, unpublished; Bams, 1976). As increasing amounts of water are being diverted from the Tsolum River, AESL (1976) proposed that the Wolf Lake dam be enlarged to maintain sufficient flow for both salmon and irrigation.

By the Oyster River, clearcut logging is thought to have encouraged peak flows following heavy precipitation. Flooding washed away many gravel deposits used for spawning and caused substantial losses of streambank soil, which cemented gravel deposits and made streambank stabilization and channelization inevitable. The effect of channelization on fisheries has yet to be assessed.

In the estuary, changes in the biota have resulted from logging, marina and wharf construction, foreshore development and sewage.

Only a small area of Comox Harbour was actively being used for log dumping and sorting. Although no fish kills have occurred owing to high BOD_5, a decline in both the number of species and the number of individual invertebrates and fish occurred in log booming areas, and to a lesser extent, in log storage areas (Conlan, unpublished). Egan, (pers. comm., 1978) stated that although log booming no longer occurs in the harbour, Fields Sawmill is using approximately 80 acres of Comox Harbour foreshore (at Royston and in-transit storage at Goose Spit) for log storage.

Marina and wharf construction have a significant impact, as dredging must be undertaken to provide navigational access. Vegetation is uprooted, the basin is reshaped and the substrate is often altered. The ecological impact of these modifications has not been determined.

Construction on the foreshore has resulted in a considerable amount of landfill. Valuable tidal marshes have been filled in by the sewage lagoon, Northguard Holdings Limited (housing development), Fields Sawmill and a small amount associated with wharf construction (Burns, 1976). As a result, migratory bird habitat and fish nursery areas have been reduced (Kennedy and Waters, unpublished). They felt that a great deal of consideration should be given to proposed developments needing landfill, as it generally eliminates the ecological utilization of the estuarine foreshore permanently.

As a considerable number of foreshore leases have expired, a committee was set up by the Land Management Branch in Courtenay to analyse development on the foreshore and to formulate a plan to direct future growth (Alley pers. comm., 1978).

The effects of sewage pollution have been the introduction of large concentrations of coliforms into Comox Harbour. Shellfish in Comox Harbour became contaminated by fecal coliforms, because the bacteria are injested along with other food. As a result, the harbour is now closed to shellfish harvesting.

AESL (unpublished), noted that the Courtenay, Comox and CFB Comox sewage systems are now deteriorating. Infiltration of run-off into the collector mains of the Courtenay sewage system has caused an increase in the volume of sewage processed and the amount of suspended solids in the harbour. The PCB permit, which expired in late 1977, has not been renewed. Sewage is also reported to be leaking from the Comox pumphouse and from holes in the outfall (AESL, unpublished). The maximum discharge permitted for the Comox sewage system is also being exceeded. Canadian Forces Base Comox sewage treatment plant has chronic maintenance problems and is processing a far greater volume of sewage than it is capable of treating (Dayton and Knight, 1976; AESL, unpublished).

Both Dayton and Knight (1976) and AESL (unpublished) have proposed plans for the regionalization of sewage disposal between Courtenay, Comox and Canadian Forces Base Comox, with sewage being discharged through a common outfall. The municipalities have agreed to have an outfall constructed off Cape Lazo but have not yet decided if the sewage will be treated.

With the removal of the Courtenay sewage outfall, Comox outfall and pumphouse, the coliform counts in Comox Harbour should show a significant decline. If so, the ban on shellfish harvesting in Comox Harbour could be lifted.

Other developments slated for the harbour include:-

(1) A new bridge is being proposed by the City of Courtenay to connect Courtenay and Comox.

(2) Comox Marine Industries (Jazbec) is currently dredging an area to increase the number of floats in their marina. They began dredging in mid February, 1979.

(3) The Small Craft Harbours Branch, on the east side of the Federal-Civic Marina, want to put in additional floats. Their request is currently under review.

(4) General commercial development is being considered for an area of foreshore land on the northeast side of Comox Harbour; however, no formal application has been made (Bell-Irving, pers. comm., 1979).

CONCLUSIONS

Developments, both existing and proposed, in the Courtenay River estuary have prompted investigations into the natural renewable resources and into the potential environmental impacts of these developments on the area. Based on the existing environmental knowedge compiled in this report, the following conclusions are drawn:

1. Municipal wastes are the principal sources of pollution in the area. Sewage pollution from the discharge of effluents from the Courtenay and Cumberland sewage lagoons, septic tanks and other minor sources, causes the high concentrations of fecal coliforms found on Comox Harbour. Shellfish harvesting has been banned in the harbour to prevent the transmittal of disease by the consumption of raw or partially cooked shellfish, contaminated by pathogenic bacteria and viruses.

2. Wood debris, and other particulate matter, accumulate on the bottom in areas of log storage, sorting and loading and unloading.

3. Waterborne pollutants in the surface layer are gradually flushed from Comox Harbour by tides, wind-driven currents and river runoff. Pollutants in Baynes Sound are only slowly dissipated, because there is a limited exchange of water over Comox Bar and through the southern entrance to the sound. The addition of large quantities of industrial and domestic wastewaters into Comox Harbour and Baynes Sound could produce substantial degradation in water quality.

4. A decline in the abundance and diversity of fauna in the Royston dump area and a reduction in the variety

of fauna in the log storage areas have been observed; however, no quantitative studies have been conducted to substantiate this.

5. Landfilling in the foreshore of the estuary has resulted in the elimination of valuable tidal marshland, which is very important bird and fish habitat.

6. Sedge beds, characteristic of tidal marshes, extend along the shoreline from Millard Creek to the Indian Reserve. These sedge beds make an important contribution to the primary productivity in the estuary.

7. Thousands of waterbirds utilizing the estuary are attracted in part by tidal marshes, emphasizing the importance of these marshes as a direct or indirect food source, particularly during the winter when freshwater habitats can freeze or become covered with snow.

   Eelgrass, another important source of food for waterbirds, is fairly extensive throughout Comox Harbour. There is some evidence that eelgrass is increasing throughout the harbour.

8. Shellfish, particularly the Pacific oyster and various clam species, are abundant on the shores of Baynes Sound. Butter clams are also found in the Sandy Island - Seal Islets area, north of Denman Island. Between Cape Lazo and Point Holmes is a major geoduck bed. These species are vulnerable to both waterborne pollution and to disturbances of the bottom, such as dredging and land filling.

9. Escapements of Pacific salmon to the Courtenay River declined following the development of hydro-electric facilities on the Puntledge River. Restoration of these stocks to their former abundance is anticipated through the use of salmonid enhancement measures, thereby augmenting the quantities of fish available for commercial and recreational fisheries. Further in-

vestigations are needed to determine the extent to which adult and juvenile salmonids utilize freshwater and estuarine habitats in the study area. Recent surveys suggest that the estuary may be an important rearing and nursery area for juveniles, but the extent to which it is utilized is still unknown.

10. A proposal has been made to relocate some of the major foreshore industries in the Courtenay River estuary considered to be potentially deleterious to the estuarine environment.

11. Recreational opportunites, dependent upon environmental quality, abound in the Courtenay - Comox region. The Regional District of Comox - Strathcona formulated a comprehensive plan in 1977, to guide future residential, commercial and industrial growth, as well as transportation, recreational development and environmental preservation. The objective of this plan was to retain the basic environmental and aesthetic integrity of the Courtenay River estuary, considered by some, to be one of the finest in Canada.

APPENDIX 1.1:

Sources of Information

1. Canada Department of Fisheries and the Environment

   Environmental Protection Service, Pacific Region
   (West Vancouver, B.C.)
   Environmental Protection Branch
   Environmental Services Branch

   Fisheries and Marine Service, Pacific Region
   (Vancouver, B.C.)
   Fisheries Management
   Economics Branch Directorate
   Field Services Directorate
   Habitat Protection Directorate
   Research and Resource Services Directorate
   Pacific Biological Station (Nanaimo, B.C.)
   Pacific Environment Institute (West Vancouver, B.C.)
   Ocean and Aquatic Sciences Institute of Ocean Sciences
   (Patricia Bay, B.C.)
   Canadian Hydrographic Service

   Environmental Management Service (Vancouver, B.C.)
   Canadian Forestry Service
   Pacific Forest Research Centre (Victoria, B.C.)
   Western Forest Products Laboratory (Vancouver, B.C.)
   Canadian Wildlife Service (Delta, B.C.)
   Inland Waters Directorate
   Lands Directorate

   Atmospheric Environment Service (Vancouver, Richmond)

2. Canada Department of Energy, Mines and Resources

   Geological Survey of Canada (Coastal and Terrain Sciences)
   Surveys and Mapping Branch (Vancouver, B.C.)

3. Statistics Canada

   User Advisory Service (Vancouver, B.C.)

4. Province of British Columbia

   Ministry of Environment (Victoria, B.C.)
   Fish and Wildlife Branch (Victoria, Nanaimo, Courtney, B.C.)
   Marine Resources Branch
   Environment and Land Use Committee Secretariat

Appendix 1.1 (cont'd)

Resource Analysis Branch
Pollution Control Branch
Water Rights Branch
Surveys and Mapping Branch
Map and Production Division
Water Investigations Branch

Ministry of Provincial Secretary and Government Services (Victoria, B.C.)
Provincial Museum

Ministry of Lands, Parks and Housing (Victoria, B.C.)
Parks Branch
Land Management Branch (Victoria, Courtenay, B.C.)

Ministry of Forests (Victoria, B.C.)
British Columbia Forest Service
Research Division

Ministry of Economic Development (Victoria, B.C.)

Ministry of Agriculture (Surrey, Courtenay, B.C.)

Ministry of Energy, Mines and Petroleum Resources (Victoria, B.C.)

Ministry of Health (Courtenay, B.C.)

5. District of Courtenay

District Planning Department
Office of Assistant Clerk

6. District of Comox

Office of Clerk Administrator

7. District of Cumberland

Office of Clerk Administrator

8. Regional District of Comox-Strathcona (Courtenay, B.C.)

9. Crown Zellerbach of Canada Ltd. (Vancouver, Courtenay, B.C.)

10. MacMillan Bloedel Ltd. (Nanaimo, Campbell River, B.C.)

11. Weldwood of Canada (Vancouver, B.C.)

Appendix 1.1 (cont'd)

12. Non-governmental Environmentalists

Comox-Strathcona Natural History Society (Courtenay, B.C.)
National Second Century Fund (Vancouver, B.C.)
Steelhead Society of British Columbia (Courtenay, B.C.)
Tyee Club of British Columbia (Courtenay, B.C.)
Vancouver Peoples Law School (Vancouver, B.C.)
West Coast Environmental Law Association (Vancouver, B.C.)

13. Environmental and Engineering Consultants (see author index for mention of their work)

Acres Consulting Services Ltd.
Associated Engineering Services Ltd.
A.V.G. Management Science Ltd.
Burns, J.E.
Dayton and Knight Ltd.
Ecosign Ltd.
EPEC Consulting Western Ltd.
Howard Paish and Associates Ltd.
Pollutech Pollution Advisory Services
Stanley Associates Engineering Ltd.
Underwood McLellan and Associates Ltd.
Western Canada Hydraulic Laboratories Ltd.

14. University of British Columbia

Departments of Botany, Geography, Geographical Sciences, Soil Science, Zoology
Faculty of Forestry
Institute of Animal Resource Ecology
Institute of Oceanography

15. University of Victoria

Department of Zoology

16. British Columbia Hydro and Power Authority (Vancouver, Nanaimo, B.C.)

17. Libraries

City of Vancouver and Municipal Libraries
Federal and Provincial Government Department Libraries
University Libraries and Reading Rooms

APPENDIX 1.2:

Research in progress in the Courtenay River estuary and area

Associated Engineering Services Ltd. Proposed sewage treatment for outfall for the Courtenay sewage system. Also proposed an alternate regional sewage disposal system involving Courtenay, Comox and C.F.B. Comox, Vancouver, B.C.

Bams, R.A. (PBS) Evaluation of Japanese salmonid culture method utilizing chum and coho salmon. Project situated at Rosewall Creek. Fish. Mar. Serv., Pacific Biological Station, Nanaimo, B.C.

Bell-Irving, R. (Fish. Mar. Serv.) Environmental overview of six Vancouver Island marinas including Courtenay marina. Sampled: current speed and direction, fecal coliforms, sediments (particle size, trace metals, PCB's etc), benthic fauna, zooplankton, eelgrass mapping, fish presence and utilization of area. Purpose: to identify environmental concerns, to identify parameters requiring further study and to set up guidelines for future marina development, Pacific Region, Vancouver, B.C.

Bilton, T. (PBS) Time and size at release: three releases of three major size categories of juvenile coho salmon from Rosewall Creek. Fish. Mar. Serv., Pacific Biological Station, Nanaimo, B.C.

Borne, N. (PBS) Continuation of studies of the population dynamics of the horse clam (*Tresus capax*) located on Seal Islets. The studies were initiated by Dr. D. Quayle in the 1930's. Fish. Mar. Serv., Pacific Biological Station, Nanaimo, B.C.

Cox, R. (Mar. Res. Br.) Estimation of the amount of harvestable geoducks in the Comox area. Sampled: size and weight of geoducks found. Ministry of the Environment, Victoria, B.C.

Dayton and Knight Ltd. Proposed outfall for C.F.B. Comox sewage system. Also proposing an alternate proposal for a regional sewage disposal system involving Courtenay, Comox and C.F.B. Comox. West Vancovuer, B.C.

Dobrocky-Seatech Ltd. Oceanographis study of the area between Pt. Holmes and Hornby Island for Dayton and Knight Ltd., West Vancouver, B.C. Sampling: current speed and direction, sea-bed soundings, temperature, salinity, benthic fauna. Purpose: to determine an ideal location for a sewage outfall. Victoria, B.C.

Appendix 1.2 (cont'd.)

Egan, J. Chairman of the "Comox Estuary Management Study Committee". Purpose: to develop a resource plan for the foreshore crown land on the estuary. The resulting recommendations will be forwarded to the Regional District of Comox-Strathcona for incorporation into the official settlement plan for the Courtenay-Comox area. Ministry of Lands, Forests and Water Resources, Management Branch, Courtenay, B.C.

Hale, P. (McMaster University) Study in nearshore waters between Parksville and Comox on the current and wave regime in relation to sediment transportation and sedimentation. Ph.D. thesis in progress. Dept. of Geography, Hamilton, Ont.

Harbo, R. and I. Birtwell (Fish. Mar. Serv.) Continuation of studies to determine the concentration of zinc in marine organisms from coastal waters in southern British Columbia, Pacific Region, Vancouver, B.C.

Kennedy, K. (U.B.C.) Plant communities and productivities of estuaries on the east coast of Vancouver Island. M.Sc. in progress. Botany Dept., Vancouver, B.C.

Kennedy, O.D. (PBS) To monitor changes in the population of phytoplankton in Baynes Sound. Purpose: to alert the Rosewall Creek hatchery operator of the time when there is a peak plankton standing crop so salmon fry can be released to take advantage of this abundant food source. Fish. Mar. Serv., Pacific Biological Station, Nanaimo, B.C.

Klinka, K. and F. Nuszdorfer (B.C. Forest Service) Biogeoclimatic zonation of central and southern Vancouver Island, Vancouver Island.

McKelvey, R. (Simon Fraser University) Feeding ecology of the Trumpeter Swan (*Olor buccinator*) in Comox Harbour. M.Sc. Thesis in progress. Biology Dept., Burnaby, B.C.

Sir William Halcrow and Partners. Proposed sewage treatment and disposal of sewage for the Mount Washington Ski Resort in Courtenay, B.C. North Vancouver, B.C.

Upper Island Health Unit. Routine coliform surveys on the Regional District of Comox-Strathcona. Ministry of Health, Victoria, B.C.

APPENDIX 1.3:

Metric Conversion Factors

EXISTING UNIT X	CONVERSION FACTOR =	SI UNIT
acre	0.405	hectare
acre foot	1,233.48	cubic metre
board foot	0.00236	cubic metre
cubic foot per second	0.0283	cubic metre per second
cubic yard	0.7646	cubic metre
cunit (100 cubic feet)	2.831	cubic metre (solid timber)
degrees Fahrenheit (^{o}F)	5/9(F-32)	degrees Celsius
fathom (6 feet)	1.8288*	metre
foot	0.3048*	metre
foot per second	30.480*	centimetre per second
gallon (Imp.)	0.004546	cubic metre
gallon (U.S.)	0.003785	cubic metre
grain per standard cubic foot (68 F, 1 ATM)	55.044	milligram per mole
inch	2.54*	centimetre
inch of mercury	3.386	kilopascal (kPa)
knot (nautical miles per hour)	51.444	centimetre per second
mile	1.609	kilometre
nautical mile (Int.)	1.852*	kilometre
parts per million	1.0	milligrams per litre
pound	0.4536	kilogram
pounds per cunit	0.1602	kilograms per cubic metre (solid wood)
pounds per short ton	0.5*	kilograms per tonne
square miles	259	hectares
standard cubic foot per minute (air pollution)	0.0196	moles per second
cubic foot per minute	0.00047	cubic metre per second
ton (2,000 lbs); ADT	0.90717	tonne (1,000 kg); ADT

* *exact conversion factor*

Appendix 1.3 (cont'd)

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.

References:

British Columbia Department of Environment. 1976. The international system of units (SI), metric practice guide. Water Resources Service, Victoria, B.C. 9 p.

Canadian Standards Association. 1973. Metric practice guide. National Standard of Canada. CAN-3-001-73 CSA 7234.1-1973. 43 p.

Gabour, J.A.M. 1968. Conversion factors and tables. P.O. Box 24, Station "B", Montreal 110, Quebec, Canada. 71 p.

Rennie, P.J. 1967. Measure for measure. Canada Department of Forestry and Rural Development, Forestry Branch, Dept. Publ. No. 1195. 31 p.

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
Palaeozoic	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
Archaean	Temiskaming Keewatin	2,000 to 4,800

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

Appendix 4.1

Streamflow Data for the Study Area (*Canada Dept. Environ.* 1976)

STATION NO.	LATITUDE AND LONGITUDE	RIVER OR STREAM	DRAINAGE AREA	PERIOD OF RECORD
08HD002	49°52'08"N 125°07'25"W	Oyster River near Campbell River	18,130 ha (70 sq. mi.)	1914-1917
08HD011	49°53'38" 125°14'18"	Oyster River below Woodhus Creek	29,785 ha (115 sq. mi.)	1973-continuing
08HD008	49°49'53" 125°07'27"	Black Creek near Miracle Beach Park	7,278 ha (28.1 sq. mi.)	1968
08HB011	49°42'26" 125°00'41"	Tsolum River near Courtenay	25,822 ha (99.7 sq. mi.)	1912-1917 1955-1957 1964-continuing
08HB025	49°41'33" 125°05'07"	Browns River near Courtenay	8,598 ha (33.2 sq. mi.)	1913-1915 1960-1972

Appendix 4.1 (cont'd.)

STATION	LATITUDE AND LONGITUDE	RIVER OR STREAM	DRAINAGE AREA	PERIOD OF RECORD
08HB006	49°41'17"N 125°01'57'W	Puntledge River at Courtenay	58,275 ha (225 sq. mi.)	1914-1921 1955-1957 1964-continuing
08HB024	49°31'03" 124°50'30"	Tsable River near Fanny Bay	11,266 ha (43.5 sq. mi.)	1913 1960-continuing
08HB007	49°39'50" 125°05'35"	Puntledge River near Cumberland	45,325 ha (175 sq. mi.)	1914-1953
08HB037	49°27'46" 124°46'22"	Rosewall Creek at the mouth	4,325 ha (16.7 sq. mi.)	1968-continuing
08HB044	49°38'22" 124°55'50"	Trent River near Royston	7,200 ha (27.8 sq. mi.)	1971-continuing
08HB045	49°30'24" 124°43'52"	Graham Creek at the mouth	336 ha (1.3 sq. mi.)	1971-continuing

APPENDIX 6.1.

List of fish species found in and near the Courtenay and Oyster River estuaries (Goodman, 1974 and Beamish, *et al.*, 1976).

1.	*Agonus acipenserinus*	(sturgeon poacher)
2.	*Anoplopoma fimbria*	(sablefish)
3.	*Apristurus brunneus*	(brown cat shark)
4.	*Aprodon cortezianus*	(bigfin eelpout)
5.	*Asterotheca pentacanthus*	(bigeye poacher)
6.	*Atheresthes stomias*	(arrowtooth flounder)
7.	*Citharichthys stigmaeus*	(speckled sanddab)
8.	*Clupea harengus pallasi*	(Pacific herring)
9.	*Cottus aleuticus*	(coastrange sculpin)
10.	*C. asper*	(prickly sculpin)
11.	*Culaea inconstans*	(brook stickleback)
12.	*Cymatogaster aggregata*	(shiner perch)
13.	*Dasycottus setiger*	(spinyhead sculpin)
14.	*Gadus macrocephalus*	(Pacific or grey cod)
15.	*Gasterosteus aculeatus*	(threespine stickleback)
16.	*Glyptocephalus zachirus*	(rex sole)
17.	*Hippoglossoides elassodon*	(flathead sole)
18.	*Hippoglossus stenolepis*	(Pacific halibut)
19.	*Hydrolagus colliei*	(ratfish)
20.	*Icelinus tenuis*	(spotfin sculpin)
21.	*Isopsetta isolepis*	(butter sole)
22.	*Lampetra tridentatus*	(Pacific lamprey)
23.	*Lepidopsetta bilineata*	(rock sole)
24.	*Leptocottus armatus*	(Pacific staghorn sculpin)
25.	*Lumpenus sagitta*	(Pacific snake prickleback)
26.	*Lycodopsis pacifica*	(blackbelly eelpout)
27.	*Lyopsetta exilus*	(slender sole)
28.	*Malacottus kincaidi*	(blackfin sculpin)
29.	*Merluccius productus*	(Pacific hake)
30.	*Microgadus proximus*	(Pacific tomcod)

Appendix 6.1. - cont'd

31. *Microstomau pacificus* (Dover sole)
32. *Oncorhynchus gorbuscha* (pink or humpback salmon)
33. *O. keta* (chum or dog salmon)
34. *O. kisutch* (coho or silver salmon)
35. *O. nerka* (sockeye or red salmon)
36. *O. n. keenerlyi* (kokanee)
37. *O. tshawytscha* (chinook, king, tyee or spring salmon)
38. *Ophiodon elongatus* (lingcod)
39. *Parophrys vetulus* (English sole)
40. *Platichthys stellatus* (starry flounder)
41. *Porichthys notatus* (plainfin medshipman)
42. *Psettichthys melanostictus* (sand sole)
43. *Raja kincaidi* (black skate)
44. *R. rhina* (longnose skate)
45. *Rhacochilus vacca* (pile perch)
46. *Salmo clarki clarki* (coastal cuttthoat trout)
47. *S. gairdneri* (rainbow or steelhead trout)
48. *Salvelinus malma* (Dolly Varden char)
49. *Sebastes caurinus* (copper rockfish)
50. *S. diploproa* (splitnose rockfish)
51. *S. elongatus* (greenstriped rockfish)
52. *S. maliger* (quillback rockfish)
53. *S. pinniger* (canary rockfish)
54. *S.* spp. (unidentified rockfish)
55. *Squalus acnthias* (spiny dogfish)
56. *Thaleichthys pacificus* (eulachon)
57. *Theragra chalcogramma* (walleye pollock)
58. *Triglops macellas* (roughspine sculpin)

APPENDIX 6.2

Sources of information describing the fish habitats of the Courtenay and Oyster river systems.

REGION	INFORMATION YIELD	PERIOD OF STUDY	REFERENCE
Statistical Area 14	-summary of fisheries officers' activities and observations in the marine and fresh-water environment: pollution; preditors; fishing; development; obstructions.	perennial	Canada Dept. Environ., (Annual)
Puntledge River	-complete discussion of salmonid uses of the lower Puntledge River, with emphasis on chinook. Contains biological data and detailed information regarding habitats and the impact of hydroelectric develop-ment.	1954-1974	Marshall (1973, 1974)
Puntledge River	-review of impact of hydroelectric development; effect of turbine intakes on juvenile mortality; history of salmonid use of the river; descriptions of flow regime.	1953-1957	Canada Dept. Fish., (1958)
all streams, lakes and most of their tributaries.	- stream survey re-ports of variable content; describe physical and biotic feature of the fresh-water network.	recent	B.C. Fish and Wildlife Branch files, Nanaimo, B.C.
Courtenay River estuary	-land use problems with respect to ecology of the estu-ary; some comments on the ecology of the drainage system	1975-1976	Burns (1976)

APPENDIX 6.2. - cont'd.

REGION	INFORMATION YIELD	PERIOD OF STUDY	REFERENCE
Comox Lake and area	-multiple resource use with respect to water quality of Comox Lake and its related streams.	1969-1970	Regional District of Comox-Strathcona (1970)
Oyster River	-physical description of the Oyster River.	1976	Wright (1976)
Wolf Lake, upper Tsolum River	-hydrological study to balance water needs for agriculture and for fisheries.	1975-1976	Associated Engineering Services Ltd., (1976)
entire area (Horne Lake to Campbell River)	-overview of environmental conditions that could be put at risk by coal mining.	1974-1975	EPEC Western Ltd., (1975)
Puntledge River	-summary of fisheries problems created by hydroelectrie development.	1953-1962	Canada Dept. Fish., (1962)
entire area	-assessment of the impact of a proposed gas pipeline constructed along the east coast of Vancouver Island.	1973-1974	Paish, H. and Associates (1974)
Puntledge River	-development of the Puntledge River Salmon Hatchery	recent	Sinclair (pers. comm.)
Black Creek, Courtenay and	-detailed diaries re steelhead and cutthroat runs and habitats	last couple of decades	Thornton

APPENDIX 6.3.

Spawning escapement data for the Puntledge River. Reproduced from Walker and McLeod (undated).

YEAR	SOCKEYE	CHINOOK	COHO	CHUM	PINK	STEELHEAD
1947		3500	3500	75000	1500	
48		3500	1500	35000	750	
49		7500	3500	15000	7500	
50		7500	1500	15000	7500	
51		7500	3500	75000	100,000	
52		3500	3500	15000	15000	1500
53		3500	7500	35000	7500	3500
54		15000	7500	35000	15000	3500
55	25	7500	3500	35000	15000	3500
56	25	1500	3500	15000	7500	3500
57	200	3500	7500	35000	15000	1500
58	400	7500	7500	35000	35000	1500
59	25	3500	1500	35000	3500	1500
60	25	3500	3500	35000	3500	1500
61	25	1500	3500	15000	7500	1500
62	25	1500	3500	35000	3500	1500
63		1500	7500	75000	7500	1500
64	25	750	15000	35000	750	1500
65		1500	1500	1500	1500	1500
66		1500	3500	35000	1500	u.d.*
67		840	1500	20000	1200	u.d.
68		720	1100	55000	2100	u.d.
69		200	1400	27500	100	u.d.
70		250	2500	34000	1000	u.d.
71		150	4000	14500	300	u.d.
72		250	1500	60000	2500	u.d.
73		500	1500	55000	700	u.d.
74		564	7000	45000	850	u.d.
75		354 400	2500	27500	400	u.d.
76		278 327	1000	35000	350	u.d.
77		500 600	5000	47000	4000	u.d.
78		600 300	2500	68000	1600	u.d.

*u.d. - undetermined

APPENDIX 6.4.

Spawning escapement data for the Tsolum River. Reproduced from Walker and McLeod (undated). The escapement to the Courtenay River is the sum of the escapements to the Puntledge and Tsolum rivers. Spawning escapement to the Brown's River is insignificant.

YEAR	SOCKEYE	CHINOOK	COHO	CHUM	PINK	STEELHEAD
1947			7500	750	75000	
48			3500	750	15000	
49			7500	1500	15000	
50			7500	750	15000	750
51			7500	400	100,000+	1500
52			15000	400	100,000+	1500
53			7500	1500	35000	1500
54			7500	1500	75000	3500
55			3500	200	35000	1500
56			7500	75	15000	1500
57			7500	750	75000	750
58	25		7500	25	75000	1500
59			15000	400	15000	1500
60			7500		7500	
61			7500	200	7500	1500
62	3		7500	200	3500	1500
63			7500	750	7500	1500
64			15000	750	1500	u.d.*
65			3500	75	3500	u.d.
66			15000		7500	u.d.
67			3000	200	3000	u.d.
68			3800	5000	5525	u.d.
69	few		2500	500	200	u.d.
70	few		12000	200	6880	u.d.
71	few		10000		800	u.d.
72			2500		10000	u.d.
73			3000		3368	u.d.
74	few		5000	50	10100	u.d.
75			3000	200	10000	u.d.
76			1000	75	10000	u.d.
77			2300	500	3800	u.d.
78			2500	150	1500	u.d.

*u.d. - undetermined

APPENDIX 6.5.

Spawning escapement data for the Oyster River. Reproduced from Walker and McLeod (undated).

YEAR	SOCKEYE	CHINOOK	COHO	CHUM	PINK	STEELHEAD
1947		25	7500	7500	7500	
48			3500	1500	75000	
49		25	3500	3500	15000	
50		75	3500	3500	100,000+	1500
51		25	7500	3500	3500	1500
52		25	35000	7500	100,000+	750
53		200	15000	7500	15000	1500
54		25	15000	15000	100,000+	1500
55			15000	3500	3500	1500
56		25	7500	750	35000	750
57		25	7500	3500	3500	750
58			15000	7500	75000	1500
59		25	15000	750	1500	750
60			7500	400	3500	750
61			7500	400	1500	750
62			7500	1500	750	750
63		25	7500	750	3500	750
64			15000	400	200	u.d.*
65			15000	75	750	u.d.
66			15000	200	3500	u.d.
67			4000	50	1200	u.d.
68			5500	800	2150	u.d.
69			3000	250	200	u.d.
70			6000	200	1600	u.d.
71			8000	100	1400	u.d.
72			3500	850	1100	u.d.
73			3500	250	1200	u.d.
74			5000	500	850	u.d.
75			3500	450	900	u.d.
76			1500	450	800	u.d.
77			3700	75	200	u.d.
78			3200	1300	400	u.d.

*u.d. - undetermined

APPENDIX 6.6.

The value of commercial landings from Statistical Area 14, in $000, from 1968-1977, compiled from Fisheries and Marine Service 1A Worksheets. Less than $1,000:*. Data unavailable:θ. ("Groundfish includes skate, English sole, rockfish, Pacific cod, sablefish, flounder and halibut).

YEAR	SALMON $000	CATCH kg. (lb.)	GROUND-FISH $000	CATCH kg. (lb.)	LINGCOD $000	CATCH kg. (lb.)	PERCH $000	CATCH kg. (lb.)	HERRING $000	CATCH kg. (lb.)
1977	852	34,564 (76,300)	70+	18,392 (40,600)	25	2,491 (5,500)	1	906 (2,000)	3,928	1,016,713 (2,244,400)
1976	1,052	57,259 (126,400)	50	14,541 (32,100)	6	951 (2,100)	1	906 (2,000)	1,258	425,775 (939,900)
1975	905	49,468 (109,200)	33	10,827 (23,900)	10	1,178 (2,600)	1	453 (1,000)	152	89,694 (198,000)
1974	521	35,062 (77,400)	33	10,600 (23,400)	9	1,178 (2,600)	1	1,359 (3,000)	25	21,744 (48,000)
1973	1,469	109,309 (241,300)	36	11,869 (26,200)	4	680 (1,500)	*	453 (1,000)	152	223,782 (494,000)
1972	544	83,896 (185,200)	31	13,092 (28,900)	11	19,479 (43,000)	*	906 (2,000)	1	1,812 (4,000)
1971	258	309,172 (682,500)	23	109,264 (241,200)	11	249,150 (550,000)	1	2,356 (5,200)	θ	θ
1970	330	262,423 (579,300)	19	112,389 (248,000)	10	328,425 (725,000)	*	1,042 (2,300)	8	116,104 (256,300)
1969	107	81,087 (197,000)	16	105,549 (233,000)	15	62,786 (138,600)	1	2,627 (5,800)	θ	θ
1968	148	151,166 (333,700)	12	92,865 (205,000)	12	53,092 (117,200)	*	1,042 (2,300)	1	10,464 (23,100)

+ incomplete estimate

APPENDIX 6.7.

Estimated sport catch in pieces (first number) and effort (second number - in angler-days) for the steelhead fishery in the rivers that drain into Comox Harbour. Data abstracted from the annual "Steelhead Harvest Analysis" reports of the B.C. Fish and Wildlife Branch, Victoria, B.C. Data unavailable: θ.

SEASON	PUNTLEDGE R.	TSOLUM R.	BROWNS R.	COURTENAY R.	TRENT R.
1975-6	177; 1253	103; 1982	15; 177	0; 5	5; 109
1974-5	747; 1389	139; 385	27; 64	0; 6	32; 234
1973-4	147; 1637	93; 741	20; 82	0; 0	42; 234
1972-3	325; 4297	228; 994	θ	0; 18	42; 413
1971-2	193; 1989	108; 379	θ	0; 1	86; 414
1970-1	132; 2503	122; 1150	θ	0; 41	105; 566
1969-70	360; 4458	346; 1667	θ	0; 27	209; 652
1968-9	489; 3234	262; 1115	θ	0; 4	259; 704
1967-8	509; 4527	393; 2130	θ	7; 32	148; 385
1966-7	1177; 3288	654; 1654	θ	15; 19	181; 319

APPENDIX 6.8.

Estimated sport catch and effort data for the steelhead fishery of the Oyster River (1966-1976), abstracted from the annual "Steelhead Harvest Analysis" reports of the B.C. Fish and Wildlife Branch, Victoria, B.C. Data unavailable:θ.

SEASON	EFFORT (DAYS FISHED)	NUMBER OF ANGLERS	CATCH (PIECES)	NO. FISH RELEASED	SUCCESS (CATCH/DAY)
1975-6	1357	401	261	95	.193
1974-5	1389	156	747	481	.537
1973-4	1637	232	147	91	.090
1972-3	2611	491	521	296	.199
1971-2	1281	399	351	207	.278
1970-1	2326	498	396	239	.167
1969-70	2646	539	408	θ	.151
1968-9	1130	455	275	θ	.247
1967-8	2351	724	425	θ	.181
1966-7	1546	681	838	θ	.54

APPENDIX 6.9.

Sport catch of Pacific salmon in federal Statistical Area 14 (1953-1976), reported in pieces. Data from Canada Department of the Environment, (annual reports). Data unavailable: θ.

YEAR	SPRINGS AND JACKS	COHO	SPRING GRILSE	COHO GRILSE	PINKS	SOCKEYE AND CHUMS	TOTAL	EFFORT (TOTAL BOAT DAYS)	CATCH/ BOAT/DAY
1976	33721	59267	25740	24429	760	62	143,979	88999	1.6
75	19240	42563	12909	16131	1455		91469	66053	1.4
74	17540	86944	11790	31041	1305		148,621	80161	1.9
73	8923	33405	3143	15487	1198		62156	59705	1.0
72	22618	24737	7593	13954	708		69610	66361	1.0
71	10974	107,120	5405	31926	1503		156,928	75057	2.1
70	7225	52975	3400	24050	425		88075	49575	1.8
69	5275	25450	2400	8550	450		42125	39525	1.1
68	5240	32670	13860		360		52130	43460	1.2
67	4475	22550	13600		575		41200	44500	0.9
66	9825	60600	19050		275		89750	54775	1.6
65	2525	22600	8450		325	θ	33900	θ	θ
64	3225	21450	18600		250	θ	43525	θ	θ
63	4075	21900	24600		1600	θ	52175	θ	θ
62	5495	27950	24050		125	θ	57620	θ	θ
61	4100	21975	21000		425	θ	47500	θ	θ
60	7650	47400	45350		275	θ	100,675	θ	θ
59	10825	37200	32150		575	θ	79750	θ	θ
58	14875	36150	48600		1600	θ	101,225	θ	θ
57	18275	58375	32500		725	θ	109,875	θ	θ
56									
55	4000	14550	12700		θ	θ	31250	θ	θ
54	2950	6400	11000		θ	θ	20350	θ	θ
53	2650	8000	4000		θ	θ	15250	θ	θ

APPENDIX 7.1

List of macroinvertebrate species found within rectangular areas scattered in the intertidal zone between Gartley Point and Millard Creek and between Brooklyn Creek and Goose Spit in June 1973. Data from a report by the B.C. Pollution Branch (1974). Spellings according to Kozloff, (1973).

PORIFERA

1.	(unidentified sponge)	

ECHINODERMATA

2.	*Dendraster excentricus*	Sand Dollar
3.	*Leptosynapta afficans*	Sea Cucumber
4.	*Pisaster* spp.	Starfish

ANNELIDA

5.	(unidentified nereid)	Pile Worm
6.	(unidentified sedentarian)	Thin Mud Worm

PELECYPODA

7.	*Clinocardium nuttalii*	Cockle
8.	*Crassostrea gigas*	Pacific Oyster
9.	*Macoma* spp.	Clam
10.	*Mya arenaria*	Mud Clam
11.	*Mytilus edulis*	Edible Mussel
12.	*Protothaca staminea*	Little-neck Clam
13.	*Saxidomus giganteus*	Butter Clam
14.	*Venerupis japonica*	Japanese Little-neck Clam

Appendix 7.1 (cont'd.)

GASTROPODA

15. *Acmaea digitalis*	Limpet
16. *Acmaea pelta*	Limpet
17. *Batillaria zonalis*	Tall-spired Snail
18. *Littorina* spp.	Periwinkle
19. *Policices* spp.	Moon Snail
20. *Thais lamellosa*	Wrinkled purple Whelk
21. (unidentified dovid)	Nudibranch

ISOPODA

22. *Idotea* spp.	Isopod

CIRRIPEDIA

23. *Balanus balanus*	Barnacle

DECAPODA

24. *Hemigrapsus nudus*	Shore Crab
25. *Cancer magister*	Edible Crab
26. *Callianassa californiensis*	Mud Shrimp
27. (unidentified pagurid)	Hermit Crab

APPENDIX 8.1

List of vascular plant species found in the Courtenay River estuary during July 1974. Prepared by Kennedy (M.Sc., in progress, University of British Columbia, Vancouver).

TREE

Alnus rubra	Red Alder
Populus trichocarpa	Cottonwood
Pyrus fusca	Pacific Crabapple
Picea sitchensis	Sitka Spruce
Sorbus scopulina	Mountain-ash
Cornus stolonifera	Red-osier Dogwood

SHRUBS

Rosa nutkana	Nootka Rose
Lonicera involucrata	Black Twin-berry
Myrica gale	Sweet gale
Physocarpus capitatus	Ninebark
Salix spp.	Willow
Rubus ursinus	Pacific Blackberry
Rosa gymnocarpa	Little Wild Rose
Spiraea douglasii	Hardhack
Rubus spectabilis	Salmonberry
Cytisus scoparius	Broom
Symphoricarpos albus	Snowberry

FORBS

Aster hesperius	Marsh Aster
Sium suave	Water-parsnip
Mentha arvensis	Field Mint
Heracleum lanatum	Cow-parsnip

Appendix 8.1 (Cont'd.)

FORBS (Cont'd.)

Oenanthe sarmentosa	Water-parsley
Atriplex patula	Saltbush
Symphytum asperum	Rough Comfrey
Myosotis scorpioides	Common Forget-me-not
Epilobium watsonii	Watson's Willow-herb
Cicuta douglasii	Water-hemlock
Habenaria dilatata	Bog-candle
Lactuca biennis	Tall Blue Lettuce
Plantago lanceolata	Ribgrass
Vicia gigantea	Giant Vetch
Cirsium arvense	Canada Thistle
Montia parvifolia	Miner's Lettuce
Galium asperrimum	Rough Bedstraw
Lathyrus palustris	Marsh Pea
Sidalcea hendersonii	Henderson's Checker-mallow
Melilotus alba	White Sweet Clover
Anaphalis margaritacea	Pearly-everlasting
Mimulus guttatus	Yellow Monkey-flower
Trifolium repens	White Clover
Prunella vulgaris	Self-heal
Ranunculus repens	Creeping Buttercup
Trifolium pratense	Red Clover
Heliopsis helianthoides	Ox-eye Daisy
Potentilla pacifica	Cinquefoil
Mentha spicata	Spearmint
Hypericum formosum	St. John's-wort
Hypochaeris radicata	Hairy Cat's-ear
Pteridium aquilinum	Bracken
Achillea millefolium	Yarrow
Camassia quamash	Camas
Dodecatheon pulchellum	Shooting-star

Appendix 8.1 (Cont'd.)

FORBS (Cont'd.)

Lilium columbianum	Columbia Lily
Plantago major	Common Plantain
Galium aparine	Bedstraw
Montia sibirica	Siberian Miner's Lettuce
Epilobium angustifolium	Fireweed
Lupinus sp.	Lupine
Lilaeopsis occidentalis	Lilaeopsis
Grindelia integrifolia	Gumweed
Plantago macrocarpa	Plantain
Sisbyrinchium angustifolium	Blue-eyed Grass
Castilleja levisecta	Golden Indian-paintbrush
Triglochin maritimum	Arrow-grass
Spergularia marina	Saltmarsh Sandspurry
Glaux maritima	Sea-milkwort
Lemna minor	Duckweed
Plantago maritima	Seaside Plantain
Trifolium wormskjoldii	Springbank Clover
Erigeron philadelphicus	Philadelphia Fleabane
Sonchus arvensis	Milk-thistle
Convolvulus sepium	Morning-glory
Equisetum arvense	Common Horsetail
Rumex crispus	Curly Dock
Typha latifolia	Cat-tail
Rumex salicifolius	Willow Dock
Stachys cooleyae	Cooley's Hedge-nettle
Trifolium dubium	Least Hop Clover

GRASSES

Deschampsia cespitosa	Tufted Hairgrass
Distichlis spicata	Saltgrass

Appendix 8.1 (Cont'd.)

GRASSES (Cont'd.)

Dactylis glomerata	Orchard-grass
Elymus mollis	Wildrye
Phalaris arundinacea	Reed Canarygrass
Phleum pratense	Timothy
Glyceria occidentalis	Western Mannagrass
Holcus lanatus	Velvet-grass
Festuca pratensis	Meadow Fescue
Agrostis tenuis	Colonial Bentgrass
Agropyron repens	Couch Grass
Hordeum brachyantherum	Meadow Barley

SEDGES

Carex lyngbyei	Lyngby's sedge
Scirpus microcarpus	Small-fruit bulrush
Scirpus validus	Bulrush
Eleocharis palustris	Spike-rush
Scirpus americanus	Three-square Bulrush

RUSHES

Juncus balticus	Baltic Rush
Juncus effusus	Common Rush
Juncus acuminatus	Tapered Rush

APPENDIX 8.2

List of vascular plant species found in the Oyster River estuary during September, 1976. Kennedy,(M.Sc., in progress, University of British Columbia, Vancouver).

TREES

Pseudotsuga menziesii	Douglas fir
Picea sitchensis	Sitka Spruce
Pyrus fusca	Pacific Crabapple
Thuja plicata	Western Red Cedar
Tsuga heterophylla	Western Hemlock
Acer macrophllum	Common Maple

SHRUBS

Rosa nutkana	Nootka Rose
Physocarpus capitatus	Ninebark
Lonicera involucrata	Black Twin-berry
Symphoricarpos albus	Snowberry
Berberis nervosa	Oregon Grape
Sonchus arvensis	Milk-thistle
Achillea millefolium	Yarrow
Grindelia integrifolia	Gumweed
Plantago lanceolata	Ribgrass
Maianthemum dilatatum	False Lily-of-the-Valley
Plantago maritima	Seaside Plantain
Potentilla pacifica	Cinquefoil
Lilaeopsis occidentalis	Lilaeopsis
Pteridium aquilinum	Bracken
Luthyrus palustris	Marsh Pea
Polystichum munitum	Sword-fern
Tiarella trifoliata	Foamflower
Lactuca muralis	Wall Lettuce

Appendix 8.2 (Cont'd.)

FORBS (Cont'd.)

Lumex crispus	Curly Dock
Vicia gigantea	Giant Vetch
Chenopodium album	Pigweed
Atriplex patula	Saltbush
Elymus mollis	Wildrye
Distichlis spicata	Saltgrass
Poa pratensis	Kentucky Bluegrass
Agrostis alba	Bentgrass
Hordeum brachyantherum	Meadow Barley
Deschampsia cespitosa	Tufted Hairgrass

SEDGE

Carex lyngbyei	Lyngby's Sedge

RUSH

Juncus balticus	Baltic Rush

APPENDIX 9.1

List of birds reported from the study area. Sources of information for the following list are Dawe (unpublished); Henderson and Capes (undated); McKelvey (unpublished); Provincial Museum bird siting and nesting records (contributions from amateur ornithologists); Smith and Smith (1971.) Nomenclature is based on Godfrey (1966) except where recent taxonomic revisions take precedence (American Ornithologists Union (A.O.U., 1973, 1976). Entries follow the accepted A.O.U. order. The letter "P" signifies that the species is protected under federal law (Canada Dept. Fish. Environ., 1978).

Definition of areas utilized are as follows:

1. Courtenay River estuary
2. Oyster River estuary
3. Other

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Gavia immer	X	X	X	P	Common Loon	
Gavia adamsii	X			P	Yellow-billed Loon	
Gavia arctica	X	X	X	P	Arctic Loon	
Gavia stellata	X		X	P	Red-throated Loon	X
Podiceps grisegena	X	X	X	P	Red-necked Grebe	
Podiceps auritus	X	X	X	P	Horned Grebe	
Podiceps nigricollis	X	X	X	P	Eared Grebe	
Aechmophorus occidentalis	X	X	X	P	Western Grebe	
Podilymbus podiceps	X			P	Pied-billed Grebe	
Phalacrocorax auritus	X				Double-crested Cormorant	
Phalacrocorax penicillatus	X				Brandt's Cormorant	
Phalacrocorax pelagicus					Pelagic Cormorant	
Ardea herodias	X	X	X	P	Great Blue Heron	
Bubulcus ibis	X			P	Cattle Egret	
Olor columbianus			X	P	Whistling Swan	
Olor buccinator	X		X	P	Trumpeter Swan	

Appendix 9.1 (cont'd.)

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Branta canadensis	X			P	Canada Goose	X
Branta bernicla	X	X	X	P	Brant	
Anser albifrons	X			P	Greater White-fronted Goose	
Anser caerulescens	X			P	Snow Goose	
Anas platyrhynchos	X		X	P	Mallard	X
Anas strepera	X			P	Gadwall	X
Anas acuta	X		X	P	Common Pintail	
Anas carolinensis	X		X	P	Green-winged Teal	X
Anas discors	X		X	P	Blue-winged Teal	X
Anas cyanoptera	X			P	Cinnamon Teal	X
Anas penelope	X			P	European Wigeon	
Anas americana	X	X	X	P	American Wigeon	X
Anas clypeata	X			P	Northern Shoveler	X
Aix sponsa	X			P	Wood Duck	X
Aythya collaris			X	P	Ring-necked Duck	X
Aythya valisineria	X		X	P	Canvasback	
Aythya marila	X	X	X	P	Greater Scaup	X
Aythya affinis	X	X	X	P	Lesser Scaup	X
Bucephala clangula	X	X	X	P	Common Goldeneye	X
Bucephala islandica	X		X	P	Barrow's Goldeneye	
Bucephala albeola	X	X	X	P	Bufflehead	X
Clangula hyemalis	X	X	X	P	Oldsquaw	
Histrionicus histrionicus	X	X	X	P	Harlequin Duck	
Melanitta deglandi	X	X	X	P	White-winged Scoter	
Melanitta perspicillata	X	X	X	P	Surf Scoter	X
Melanitta nigra	X	X	X	P	Black Scoter	
Oxyura jamaicensis	X			P	Ruddy Duck	
Lophodytes cucullatus	X	X	X	P	Hooded Merganser	X
Mergus merganser	X	X	X	P	Common Merganser	X
Mergus serrator	X	X	X	P	Red-brested Merganser	
Cathartes aura	X		X		Turkey Vulture	

Appendix 9.1 (cont'd.)

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Calidris alpina	X		X	P	Dunlin	
Limnodromus griseus	X		X	P	Short-billed Dowitcher	
Limnodromus scolopaceus	X		X	P	Long-billed Dowitcher	
Micropalama himantopus	X			P	Stilt Sandpiper	
Calidris mauri	X		X	P	Western Sandpiper	
Calidris alba	X			P	Sanderling	
Larus hyperboreus	X			P	Glaucous Gull	
Larus glaucescens	X	X	X	P	Glaucous-winged Gull	
Larus argentatus	X	X		P	Herring Gull	
Larus thayeri	X		X	P	Thayer's Gull	
Larus californicus	X		X	P	California Gull	
Larus delawarensis				P	Ring-billed Gull	
Larus canus	X	X	X	P	Mew Gull	
Larus pipixcan	X			P	Franklin's Gull	
Larus philadephia			X	P	Bonaparte's Gull	
Sterna hirundo			X	P	Common Tern	
Uria aalge		X	X	P	Common Murre	
Cepphus columba	X	X	X	P	Pigeon Guillemot	
Brachyramphus marmoratus	X	X	X	P	Marbled Murrelet	
Columba fasciata	X		X	P	Band-tailed Pigeon	X
Columba livia	X	X			Rock Dove	
Zenaida macroura	X			P	Mourning Dove	X
Tyto alba					Barn Owl	
Otus asio					Screech Owl	
Bubo virginianus	X				Great-horned Owl	
Nyctea scandiaca	X				Snowy Owl	
Glaucidium gnoma					Pygmy Owl	
Asio flammeus					Short-eared Owl	
Aegolius acadicus	X				Saw-Whet Owl	X
Chordeiles minor	X			P	Common Nighthawk	X

Appendix 9.1 (cont'd.)

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Accipiter gentilis	X				Goshawk	
Accipiter striatus	X				Sharp-skinned Hawk	
Accipiter cooperii	X				Cooper's Hawk	
Buteo jamaicensis	X		X		Red-tailed Hawk	
Haliaeetus leucocephalus	X	X	X		Bald Eagle	X
Circus cyaneus	X				Marsh Hawk	
Pandion haliaetus	X	X			Osprey	
Falco pergrinus	X				Peregrine Falcon	
Falco columbarius	X				Pigeon Hawk (Merlin)	
Falco sparverius			X		Sparrow Hawk (American Kestrel)	
Dendragapus obscurus			X		Blue Grouse	X
Bonasa umbellus	X		X		Ruffed Grouse	X
Lagopus leucurus			X		White-tailed Ptarmigan	
Lophortyx californicus	X				California Quail	
Phasianus colchicus	X				Ring-necked Pheasant	
Grus canadensis	X			P	Sandhill Crane	
Fulica americana	X		X	P	American Coot	
Charadrius semipalmatus	X			P	Semipalmated Plover	
Charadrius vociferus	X	X	X	P	Killdeer	X
Pluvialis dominica	X			P	American Golden Plover	
Pluvialis squatarola	X			P	Black-bellied Plover	
Arenaria melanocephala	X	X	X	P	Black Turnstone	
Capella gallinago	X		X	P	Common Snipe	
Numenius phaeopus	X			P	Whimbrel	
Actitis macularia	X			P	Spotted Sandpiper	
Tringa melanoleuca	X		X	P	Greater Yellowlegs	
Tringa flavipes	X		X	P	Lesser Yellowlegs	
Calidris melanotos	X			P	Pectoral Sandpiper	
Calidris minutilla	X		X	P	Least Sandpiper	

Appendix 9.1 (cont'd.)

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Sitta canadensis			X	P	Red-breasted Nuthatch	
Certhia familiaris	X		X	P	Brown Creeper	
Cinclus mexicannus	X			P	American Dipper	
Troglodytes aedon			X	P	House Wren	X
Troglodytes troglodytes	X		X	P	Winter Wren	X
Thryomanes bewickii	X		X	P	Bewick's Wren	X
Cistothorus palustris	X			P	Long-billed Marsh Wren	
Turdus migratorius	X	X	X	P	American Robin	X
Ixoreus naevius	X		X	P	Varied Thrush	X
Catharus guttatus			X	P	Hermit Thrush	X
Catharus ustulata	X		X	P	Swainson's Thrush	X
Sialia mexicana	X			P	Western Bluebird	X
Sialia currocoides			X	P	Mountain Bluebird	
Myadestes townsendi			X	P	Townsend's Solitaire	
Regulus satrapa	X		X	P	Golden-crowned Kinglet	
Regulus calendula	X		X	P	Ruby-crowned Kinglet	
Anthus spinoletta			X	P	Water Pipit	
Bombycilla cedrorum	X		X	P	Cedar Waxwing	X
Lanius excubitor	X			P	Northern Shrike	
Sturnus vulgaris	X	X	X		Common Starling	X
Vireo huttoni			X	P	Hutton's Vireo	
Vireo solitarius			X	P	Solitary Vireo	
Vireo olivacius			X	P	Red-eyed Vireo	
Vireo gilvus			X	P	Warbling Vireo	X
Vermivora celata	X		X	P	Orange-crowned Warbler	X
Dendroica petechia	X			P	Yellow Warbler	X
Dendroica coronata			X	P	Yellow-rumped Warbler	X
Dendroica nigrescens			X	P	Black-throated Grey Warbler	
Dendroica townsendii			X	P	Townsend's Warbler	
Oporornis tolmiei			X	P	MacGillvray's Warbler	X

Appendix 9.1 (cont'd.)

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Cypseloides niger			X	P	Black Swift	
Chaetura vauxi			X	P	Vaux's Swift	
Calypte anna	X			P	Anna's Hummingbird	
Selasphorus rufus	X		X	P	Rufous Hummingbird	
Megaceryle alcyon	X	X	X	P	Belted Kingfisher	
Colaptes auratus	X	X	X	P	Common Flicker	
Dryocopus pileatus	X		X	P	Pileated Woodpecker	
Sphyrapicus varius			X	P	Yellow-bellied Sapsucker	
Picoides villosus	X		X	P	Hairy Woodpecker	
Picoides pubescens	X		X	P	Downy Woodpecker	X
Picoides tridactylus			X	P	Northern Three-toed Woodpecker	X
Tyrannus tyrannus			X	P	Eastern Kingbird	
Empidonax traillii			X	P	Willow Flycatcher	
Empidonax hammondii			X	P	Hammond's Flycatcher	
Empidonax difficilis	X		X	P	Western Flycatcher	X
Contopus sordidulus			X	P	Western Wood Peewee	
Nuttallornis borealis			X	P	Olive-sided Flycatcher	X
Eremophila alpestris			X	P	Horned Lark	
Tachycineta thalassina	X		X	P	Violet-Green Swallow	X
Iridoprocne bicolor	X		X	P	Tree Swallow	X
Stelgidopteryx ruficollis	X		X	P	Rough-winged Swallow	X
Hirundo rustica	X		X	P	Barn Swallow	X
Petrochelidon pyrrhonota	X			P	Cliff Swallow	X
Progne subis			X	P	Purple Martin	
Perisoreus canadensis			X		Gray Jay	X
Cyanocitta stelleri	X		X		Steller's Jay	
Corvus corax	X	X	X		Common Raven	
Corvus caurinus	X	X	X		Northwestern Crow	X
Parus rufescens	X		X	P	Chestnut-backed Chickadee	X
Psaltriparus minimus	X		X	P	Bushtit	

Appendix 9.1 (cont'd.)

SPECIES	Area Utilized 1	2	3		COMMON NAME	Breeding near Comox Harbour
Geothlypis trichas	X		X	P	Common Yellowthroat	
Wilsonia pusilla			X	P	Wilson's Warbler	X
Passer domesticus	X				House Sparrow	X
Sturnella neglecta	X			P	Western Meadowlark	X
Agelaius pheoniceus	X		X		Red-winged Blackbird	X
Euphagus carolinus			X		Rusty Blackbird	
Eupagus cyanocephalus	X		X		Brewer's Blackbird	X
Molothrus ater	X		X		Brown-headed Cowbird	
Piranga ludoviciana	X			P	Western Tananger	X
Pheucticus melanocephalus	X			P	Black-headed Grosbeak	X
Hesperiphona vespertina	X			P	Evening Grosbeak	
Carpodacus purpurcus	X		X	P	Purple Finch	X
Carpodacus mexicannus	X	X	X	P	House Finch	
Pinicola enucleator			X	P	Pine Grosbeak	
Leucosticte tephrocotis			X	P	Grey-crowned Rosy Finch	
Carduelis pinus	X		X	P	Pine Siskin	X
Carduelis tristis	X		X	P	American Goldfinch	X
Loxia curvirostra			X	P	Red Crossbill	
Pipilo erythrophthalmus	X		X	P	Rufous-sided Towhee	X
Passerculus sandwichensis	X		X	P	Savannah Sparrow	
Junco hyemalis	X			P	Dark-eyed Junco	X
Spizella passerina			X	P	Chipping Sparrow	X
Zonotrichia querula	X			P	Harris' Sparrow	
Zonotrichia leucophrys	X		X	P	White-crowned Sparrow	
Zonotrichia atricapilla	X		X	P	Golden-crowned Sparrow	
Passerella iliaca	X		X	P	Fox Sparrow	X
Melospiza lincolnii			X	P	Lincoln's Sparrow	
Melospiza melodia	X	X	X	P	Song Sparrow	X

APPENDIX 9.2

List of the mammals seen or likely to be found in the study area, (Henderson and Capes, undated; Cowan and Guiguet, 1956; Guiguet, pers. comm., 1978). Taxonomic authority: Banfield (1974).

Order Insectivora	
Sorex vagrans isolatus	Wandering Shrew
Sorex vagrans vancouverensis	Dusky Shrew
*Sorex palustris brooksi**	Water or Navigator Shrew
Order Chiroptera	
Myotis lucifugus	Little Brown Myotis
Myotis yumanensis	Yuma Myotis
Myotis keenii	Keen's Myotis
Myotis evotis	Long-eared Myotis
Myotis californicus	California Myotis
Lasionycteris noctivagans	Silver-haired Bat
Plecotus townsendi	Western Big-eared Bat
Eptesicus fuscus	Big Brown Bat
Order Rodentia	
Marmota vancouverensis	Vancouver Island Marmot
Tamiasciurus hudsonicus	Red Squirrel
Castor canadensis	Beaver
Peromyscus maniculatus angustus	White-footed Mouse
Peromyscus maniculatus interdictus	" " "
Ondatra zibethicus	Muskrat
Microtus townsendii tetramerus	Townsend's Vole
Microtus townsendii laingi	" "
Rattus norvegicus[1]	Norway Rat
Mus musculus[1]	House Mouse

Appendix 9.2 - (cont'd.)

Order Cetacea

Orcinus orca	Killer Whale
Phocoena phocoena	Harbour Porpoise
Phocoenoides dalli	Dall's Porpoise
Balaenoptera acutorostrata	Pike Whale
Megaptera novaeangliae	Humpback Whale

Order Carnivora

*Canis lupus crassodon**	Wolf
Vulpes fulva[1]	Red Fox
*Ursus americanus vancouveri**	Black Bear
Procyon lotor	Raccoon
Martes americana	Marten
Mustela erminea	Short-tailed Weasel
*Mustela vison evagor**	Mink
*Gulo luscus vancouverensis**	Wolverine
Lontra canadensis	River Otter
Enhydra lutris	Sea Otter
*Felis concolor vancouverensis**	Cougar

Order Pinnipedia

Eumetopias jubata	Northern Sea Lion
Callorhinus ursinus	Northern Fur Seal
Phoca vitulina	Harbour Seal

Order Artiodactyla

Odocoileus hemionus	Black-tailed Deer
*Cervus canadensis roosevelti**	Roosevelt Elk

* mammals native to Vancouver Island.
[1] introduced species.

APPENDIX 10.1

Estimated Participation in Recreational Boating by Courtenay-Comox Residents in 1973 (adapted from Mos and Harrison, 1974).

No. of households	7,272
No. of households owning one or more boats	2,637
Percent of households owning one or more boats	36.3%
No. of primary boats	2,637
No. of secondary boats	783
Total No. of boats	3,420
Percent primary boat type:	
sail	3.1%
outboard	78.1%
inboard-outboard	6.3%
rowboat, canoe and other	12.5%
Average value of primary boats	$1,520
No. of days of saltwater use by primary boats	62,101
No. of person-days of saltwater use by primary boats	155,253
Average proportion of primary boat use in saltwater (%)	68.0%
Percent primary boat activity:	
fishing	92.5%
cruising	3.8%
other	3.8%
Average No. of days spent on boat outings	23.6
Average No. of persons on board	2.5
Average No. of salmon taken on board primary boat	24.5

APPENDIX 10.2

Maps, Charts and aerial photographs of the Courtenay and Oyster River 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
Comox, B.C.	92F/10	1:50,000
Forbidden Plateau, B.C.	92F/11	1:50,000
Great Central Lake, B.C.	92F/6	1:50,000
Horne Lake, B.C.	92F/7	1:50,000
Oyster River, B.C.	92F/14	1:50,000
Powell River, B.C.	92F/15	1:50,000

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

MISCELLANEOUS MAPS

1. Forest Cover Maps	Map No.	Scale
a. Duncan Bay Tree Farm Licence No. 2	1-12, 14-15	1 cm = 12 m (1 in. = 1,000 ft.)
b. Cumberland Tree Farm Licence No. 39		1 cm = 150 m (1 in. = 1,250 ft.)
c. Oyster River	92F/115	20 chain (1 in. = ¼ mi.) (1 cm = 158 m)
d. Wowo Lake	92F/144	20 chain (1 in. = ¼ mi.) (1 cm = 158 m)

Available from: (a) Crown Zellerbach of Canada Ltd., Ladysmith, B.C.

Appendix 10.2 (cont'd)

(b) Weldwood of Canada Ltd., Vancouver, B.C.

(c) and (d) MacMillan Bloedel Ltd., Nanaimo, B.C. or or the Forest Inventory Division, British Columbia Forest Service, Victoria, B.C.

	Scale
2. The biogeoclimatic subzones of Vancouver Island and adjacent mainland based on climax vegetation (third approximation)	1 cm = 3.8 km (1 in. = 6 mi.)

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

3. Seabird colonies of the Vancouver Island area (compiled by W. Campbell)	1 cm = 5 km (1 in. = 8 mi.)

Available from: Provincial Museum, Birds and Mammals Section, Victoria, B.C.

4. Wildlife distribution mapping, big game series-

a. Deer	1:2,000,000
b. Elk	1:2,000,000

5. Southern British Columbia coastal wildlife resoures map

Available from: British Columbia Fish and Wildlife Branch, Victoria, B.C.

6. Algal vegetation maps (Austin and Adams, 1972)

a. Elma Bay to Shelter Bay	1 cm = 200 m (1 in. = 1,675 ft.)
b. Little River to William's Beach coast	1 cm = 200 m (1 in. = 1,675 ft.)
c. Northeast coast of Denman Island	1 cm = 200 m (1 in. = 1,675 ft.)
d. Willemar Bluff/ Little River coast	1 cm = 200 m (1 in. = 1,675 ft.)

7. Oil and chemical spill counter measures series

a. Physical base, land status, land and water use

Appendix 10.2 (cont'd)

	Map No.	Scale
Comox , B.C.	N.T.S. 92F/10 E & W (portion only)	1:50,000
Oyster River, B.C.	N.T.S. 92F/14 E & W	1:50,000

b. Biological resources

Comox, B.C.	N.T.S. 92F/10 E & W (portion only)	1:50,000
Oyster River, B.C.	N.T.S. 92F/14 E & W	1:50,000

c. West coast offshore environment maps

Marine-associated birds	Map No. 1	1:1,000,000
Marine mammals	Map No. 2	1:1,000,000
Commercial salmon fisheries	Map No. 3	1:1,000,000
Groundfish and herring resources	Map No. 4	1:1,000,000
Shellfish	Map No. 5	1:1,000,000
Parks, ecological reserves and sports fisheries	Map No. 6	1:1,000,000
Shoreline geomorph-ology and marine vegetation	Map No. 7	1:1,000,000
Ocean currents	Map No. 8	1:1,000,000
Winds	Map No. 9	1:1,000,000

Available from: Canada Department of Fisheries and the Environment, Environmental Protection Service, Kapilano 100, Park Royal, West Vancouver, B.C.

8. Departmental reference maps
(Foreshore leases, timber leases, survey lots and sections)

Denman Island - Hornby Island	R 92F/NE	1 in. = 1 mi. (1 cm = 63.4 m)
Oyster River - Miracle Beach	R 92F/14-E½	1 in. = ½ mi. (1 cm = 31.7 m)

Appendix 10.2 (cont'd)

	Sheet No.	Scale
Park - Kitty Coleman Beach Park - Merville - Wolf Lake - Headquarters		
Hornby Island - Denman Island - Baynes Sound - Fanny Bay - Union Bay - Comox Harbour - Goose Spit - Cape Lazo - Kye Bay - Comox - Courtenay - Tsable River - Cumberland - Puntledge River - Tsolum River - Browns River - Comox Lake - Strathcona Provincial Park	R 92F/10 & 11 E½	1 in. = ½ mi. (1 cm = 31.7 m)
Oyster River watershed - Forbidden Plateau - Strathcona Provincial Park	R 92F/NW	1 in. = 1 mi. (1 cm = 63.4 m)
Cruikshank River - Browns River - Strathcona Provincial Park	R 92F/SW-E½	1 in. = ½ mi. (1 cm = 31.7 m)
Denman Island - Hornby Island - Deep Bay - Fanny Bay - Rosewall Creek	R 92F/SE-W	1 in. = ½ mi. (1 cm = 31.7 m)

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

9. Canada Land Inventory, land capability maps

a. Agriculture

Comox, B.C.	92F/10-W	1:50,000
Forbidden Plateau	92F/11-W	1:50,000

b. Recreation

Buttle Lake, B.C.	92F/NW	1:126,720
Port Alberni, B.C.	92F/SE	1:126,720
Powell River, B.C.	92F/NE	1:126,720

Appendix 10.2 (cont'd)

	Sheet No.	Scale
c. Ungulates		
Buttle Lake, B.C.	92F/NW	1:125,000
Powell River, B.C.	92F/NE	1:125,000
d. Waterfowl		
Alberni, B.C.	92F/SE	1:125,000
Buttle Lake, B.C.	92F/NW	1:125,000
Comox, B.C.	92F/10	1:50,000
Forbidden Plateau, B.C.	92F/11	1:50,000
Oyster River, B.C.	92F/14	1:50,000
Powell River, B.C.	92F/15 92F/NE	1:50,000 1:125,000

10. Land use maps, ARDA present land use project, 1968

Comox, B.C.	92F/10	1:50,000
Forbidden Plateau, B.C.	92F/11	1:50,000
Great Central Lake, B.C.	92F/7	1:50,000
Horne Lake, B.C.	92F/6	1:50,000
Oyster River, B.C.	92F/14	1:50,000
Powell River, B.C.	92F/15	1:50,000

Canada Land Inventory and ARDA Present Land Use Project Maps available from: Map Librarian, Resource Analysis Unit, ELUC Secretariat, Parliament Buildings, Victoria, B.C.

Appendix 10.2 (cont'd)

		Sheet No.	Scale
11.	Regional District of Comox-Strathcona		
	Comox Valley - electoral areas a, b and c		1 cm = 357 m (1 in. = 3000 ft.)
	Town of Comox, B.C.		1 cm = 720 m (1 in. = 6000 ft.)
	Regional District of Comox-Strathcona-Zoning Maps		1 cm = 48 m (1 in. - 400 ft.)
	Baynes Sound zoning map-Electoral area "A"		1 cm = 240 m (1 in. = 2000 ft.)
	Regional District of Comox-Strathcona		1 cm = approx. 4 km (1 in. = 8 mi.)
	Lower Puntledge River area	92F11/E41	1 cm = 48 m (1 in. = 400 ft.)
		92F11/E50	1 cm = 48 m (1 in. = 400 ft.)

Available from: Regional District of Comox-Strathcona, Planning Department, Courtenay, B.C.

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

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

		Scale
13.	Shellfish resources status of southern British Columbia waters	1:525,000

Available from: British Columbia Department of Recreation and Conservation, Marine Resources Branch, Victoria, B.C.

Appendix 10.2 (cont'd)

	Published By	Scale
14. Recreation Guide Maps		
Strathcona Provincial Park	Provincial Parks Branch	1 cm = 1.4 km (1 in. = 2.3 mi.)
Provincial Parks on Vancouver Island	Ministry of Recreation and Conservation	1 cm = 6.2 km (1 in. = 10 mi.)
Forbidden Plateau visitor's guide and road map	Crown Zellerbach, Coast Wood Supply	
Comox Valley and Forbidden Plateau	Doris Stastny Maps, Box 5277 Postal Station B, Victoria, B.C.	1 cm = 0.8 km (1 in. = 1.3 mi)

HYDROGRAPHIC CHARTS

	Map No.	
Baynes Sound and Approaches, B.C.	3532	1:40,000
Comox Harbour, B.C.	3599	1:10,000
Vancouver Island, B.C.	3001	1:525,000

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

GEOLOGICAL MAPS

Cumberland-Tsable River (Comox) coalfield, Vancouver Island (J.E. Muller and M.E. Atchinson, 1971)	1 cm = 0.63 km (1 in. = 1 mi.)
Oyster River area, east coast of Vancouver Island, B.C. (S.F. Leaming, 1966)	1 cm = 0.6 km (1 in. = 1.6 mi.)
Horne Lake area, east coast of Vancouver Island, B.C. (S.F. Leaming, 1966)	1 cm = 0.6 km (1 in. = 1.6 mi.)

Appendix 10.2 (cont'd)

GEOLOGICAL MAPS (cont'd)

	Map No.	Scale
Courtenay area, east coast of Vancouver Island, B.C. (S.F. Leaming), 1966)		1 cm = 0.6 km (1 in. = 1.6 mi.)
Geology of Vancouver Island (J.E. Muller, 1977-3 sheets)		1:250,000
Surficial geology of Courtenay, Comox, Nelson, Nanaimo and Newcastle Districts, Vancouver Island, B.C. (J.G. Fyles, 1956-1957)	32 - 1960	1:63,360
Comox Lake area, B.C. (J.E. Muller, 1964)	2 - 1965	1:126,720
Surficial geology, Oyster River Map area, Comox, Nanaimo, and Sayward Districts (J.G. Fyles, 1956-1957)	49 - 1959	1:63,360
Surficial geology, Horne Lake Map area (J.G. Fyles, 1963)	1111A	1:63,360
Soil maps of Vancouver Island - Report No. 6 of the British Columbia soil survey (J.H. Day, L. Farstad and D.G. Laird, 1959)		
Qualicum - Alberni sheet		1:63,360
Courtenay - Campbell sheet		1:63,000

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

AERIAL PHOTOGRAPHS (B.C. GOVERNMENT)

	Date	Flight Line	Scale
Courtenay/Comox	June, 1964	BC 5097	40 chain (1 in. = ½ mi.)
Comox Lake	July, 1964	BC 5101	40 chain
Puntledge River Watershed	July, 1966	BC 5201	40 chain

Appendix 10.2 (cont'd)

AERIAL PHOTOGRAPHS (B.C. GOVERNMENT) (cont'd)

	Date	Flight Line	Scale
Oyster River Watershed/Wolf Lake	Aug., 1972	BC 5496	80 chain (1 in. = 1 mi.)
Courtenay/Comox/ Baynes Sound	Aug., 1972	BC 5498	80 chain
Comox/Baynes Sound	July, 1975	BC 7761	20 chain (1 in. = ¼ mi.)
Trent River/ Puntledge River Watershed	July, 1975	BC 7766	20 chain
Hart Creek/Tsable River/ Puntledge River	July, 1975	BC 7767	20 chain

The photograph numbers and index maps showing the locations of all flight lines may be obtained from:

Ministry of Environment
Map Productions Branch
Map and Air Photo Sales
Parliment Buildings
Victoria, B.C. V8V 1X5

SPECIAL AERIAL PHOTOGRAPHY

Oyster River estuary, Comox Harbour, Baynes Sound, Fanny, Mud and Deep bays are included in a special project.

Lines Flown: March 23, 1973

Photo scale: 1 cm - 48 m
(1 in. = 400 ft.)

Negative Numbers:

Deep Bay; Mud Bay	67228B - 67239B
Tsable River; Fanny Bay	67240B - 67262B
Comox Harbour	67263B - 67295B
Oyster River	67296B - 67303B

Available from: Pacific Survey Corporation Limited, 1409 West Pender St., Vancouver, B.C.

APPENDIX 11.1 :

Environmental Law

Canada's legal system, at all three levels of government, has exercised some form of control over pollution for decades. Only in the last 20 years did the field of environmental law become a discrete branch of the legal system.

As understood from various pieces of literature prepared for laymen by lawyers (Rounthwaite, 1975; Ince, 1976; Vancouver People's Law School, 1976), there are two kinds of environmental law in British Columbia: legislation, a written law which has been accepted by either the federal or provincial legislatures and clearly defines the crime and punishment, and common law, which permits a judge in civil court to determine the guilt of an offender, based on the decisions of judges hearing similar cases in the past rather than specific laws embodied in preconceived legislation.

Legislation is a more promising avenue for the development of a legal system permitting human society to live within the laws of nature than common law, because it permits society to define an act of pollution before the fact*, either through writing details into the wording of a statute, or by providing a designated agency with the power to design regulations. For example, the federal Environmental Contaminants Act contains no enforceable provisions, yet it does give the Minister of Environment the ability to present regulations to Cabinet for their approval, whereupon they become Orders-in-Council controlling the manufacture, importation, sale and emission of specified contaminants (Vancouver People's Law School, 1976). The B.C. Pollution Control Act of 1967 established a Pollution Control Board which is charged with a similar function within the provincial Ministry of the Environment. By-laws at the

---

*i.e. make pollution *per se* a crime (rather than drawing on non-pollution law) municipal level can be enacted to control litter and dumping, e.g. within municipal district boundaries.

Unlike common law, legislated law has a very recent history in Canada. The federal Northern Inland Waters Act, Canada Water Act, Arctic Water Pollution Prevention Act, Weather Modification Information Act and Clear Air Act, were not passed through Canada's Parliament until 1970 and 1971. The federal government established the Department of the Environment, (now Fisheries and Environment Canada), only seven years ago (1971), at which time one of its new branches, the Environmental Protection Service was formed. The oldest environmental act in Canada, the Fisheries Act, has been amended to make it more effective in controlling environmental problems (Information Branch, 1978). As late as July 1976, the Environmental Contaminants Act was without regulations that would make it effective.

It is a credit to Canadian society that, despite the social, economic and technological complexity of ecological problems, many gaseous and liquid emissions in British Columbia have been placed under permit by the B.C. Pollution Control Board, that the dumping of waste at sea has similarly been regulated to some extent by the federal Environmental Protection Service, and that applications for foreshore leases in Comox Harbour are being passed to federal and provincial environmental agencies by the B.C. Lands Branch for advice concerning the impact that use of those leases will have on the estuarine ecosystem.

The following are partial lists of federal and provincial statutes that can be employed to cope with environmental problems in estuaries on Canada's Pacific coast. It must be remembered that under some definitions, the "environment" of an estuary can be taken to include human activities remote from the immediate vicinity of the estuary, conceivably invoking any of 114 federal and B.C. Acts listed by Ince (1976). See also Appendix 1.1 for a useful checklist of the governmental agencies that administer environmental legislation with respect to B.C. estuaries.

Partial list of federal and provincial legislation designed, at least in part, to control abuse of the natural environment (from Rounthwaite, 1975; Ince, 1976; and Vancouver People's Law School, 1976).

A. FEDERAL (CANADA)

(1) Fisheries Act. R.S.C. 1970c. F-14 c. 17 as amended (various amendments).

The oldest piece of environmental legislation in Canada, the Fisheries Act permits control of environmental abuse on showing proof that an action is or might be detrimental to the health of, or habitat of fish (McLaren, 1976; (Information Branch, 1978); applies in part, to all waters in Canada.

(2) Ocean Dumping Control Act. S.C. 1974-75c. 55.

Applies only to intentional disposal in marine waters. Permits issued to allow dumping under controlled conditions. Violation of the Act can be penalized by fines up to $100,000. Administered by the Environmental Protection Service, supported by the Regional Ocean Dumping Advisory Committee, with representation from EPS and Fisheries and Marine Service.

(3) Canada Water Act R.S.C. 1970c. 5(1st supp.) as amended.

Offers a mechanism to create an organized management system for water resources, with special attention to pollution problems. Permits federal-provincial cooperation.

(4) Canada Shipping Act T.C.S. 1970c. S-9 as amended.

The Shipping Act controls oil pollution and garbage dumping from ships (vessels not propelled by oars) and lists other substances controlled by regulations. The act's provisions concern civil consequences arising from pollution by ships.

(5) Navigable Waters Protection Act R.S.C. 1970c. N-19

Although not concerned directly with pollution, it is possible to use the Act to prevent dumping fill or dredge spoil, constructing causeways, or otherwise disturbing the environment - if it can be proven that such disturbance interferes with navigation.

(6) Migratory Birds Convention Act R.S.C. 1970c. M-12 as amended.

This Act protects migratory bird habitats (see Appendix 9.1).

(7) Environmental Contaminants Act.

Enables the Minister of the Environment to assemble information regarding contaminants, and grants cabinet the power to formulate regulations controlling the emission, sale and manufacture of such substances.

(8) Clean Air Act S.C. 1970-71-72c. 47.

Enables the Minister to monitor and control the emission of contaminants into the air, where they would endanger health or violate international agreement.

(9) Pesticide Control Act S.B.C. 1977c. 59.

Controls the usage of specific pesticides on crown land, municipal land, regional district land and any body of water.

A. <u>PROVINCIAL (BRITISH COLUMBIA)</u>

(1) <u>Pollution Control Act</u> 1967 S.B.C. 1967c. 34 as amended.

Established the Pollution Control Board, which sets standards for the discharge of pollutants. These standards are used as guides in issuing permits to specific industrial establishments which privileges them to discharge substances to the environment. Violators are subject to fines up to $10,000.

(2) <u>Water Act</u> R.S.C.B. 1960c. 405 as amended.

Applies mainly to water consumption. Requires that water use must be licenced. Some water quality provisions.

(3) <u>Health Act</u> R.S.B.C. 1960c. 170 as amended.

The Health Act gives the B.C. Cabinet wide powers in regulating threats to the public health but is rarely used to control pollution, although it does have potential. The Act authorizes private prosecutions. Section 6(L) applies to stream pollution.

(4) <u>Fisheries Act</u> R.S.B.C. 1960c. 150 as amended.

The federal government has constitutional jurisdiction over the fish resource while it is in the water, but the provinces have limited powers owing to their proprietary ownership of parts of the estuary, which stems from their jurisdiction over the foreshore. Of most interest in this Act are the sections preventing stream and river obstructions.

(5) <u>Environment and Land Use Act</u> S.B.C. 1971c. 17.

The most potentially powerful environmental statute in force in British Columbia. Established the Environment and Land

Use Committee. Can be applied to environmental problems with implications too general for the application of other Acts in the Statutes of British Columbia. Useful for emergency situations like oil spills.

(6) Municipal Act R.S.B.C. 1960c. 225 as amended.

Through the Municipal Act, local governments are able to establish resolutions or by-laws which control a wide variety of pollution problems within their boundaries.

(7) Department of Recreation and Conservation Act. R.S.B.C. 1960.

(b) Partial list of provincial legislation (British Columbia) relevant to land and water use.

1. Park Act S.B.C. 1965. C31 as amended.

The primary statute controlling parks in the province. The Act lists five purposes for which a park can be established: (1) to preserve the environment or ecology; (2) to preserve features of a scientific, historic or scenic nature; (3) enjoyment of the travelling public; (4) recreational opportunity for a specific community; and (5) recreational opporturnity of a specific nature. The Park Act is subject to the Environment and Land Use Act and the Pollution Control Act, but no others.

Activity in provincial parks is regulated by a variety of statutes, examples being:

(a) Mineral Act R.S.B.C. 1960c. 244 as amended - prohibits the exploration or development of minerals within a provincial park unless authorized by the Cabinet.

(b) Forest Act R.S.B.C. 1960c. 153 as amended - prohibits hunting and shooting in certain provincial parks and places restrictions on the removal of wildlife.

(c) Department of Recreation and Conservation Act, R.S.B.C. 1960 - controls the landing of aircraft and the use of firearms and powerboats in provincial parks.

2. Ecological Reserves Act S.B.C. 1971c. 16.

The purpose of this Act is to reserve Crown land for ecological purposes, including:

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

(b) areas that are representative examples of natural ecosystems within the Province;

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

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

(e) areas that contain unique and rare examples of botanical, zoological, or geologcial phenomena.

3. Archaeological and Historic Sites Protection Act R.S.B.C. 1972c. 15.

Enacted to authorize the Minister of Recreation and Tourism to designate land and objects as archaelogical or historic sites or objects. The moving, excavating, or altering in any way any such site or object except by permit is prohibited.

4. Land Commission Act S.B.C. 1973c. 46.

This Act established the British Columbia Land Commission which is responsible for specific facets of land use in the province, including the preservation of agricultural greenbelt and park lands.

APPENDIX 11.2:

List of B.C. Pollution Control Branch permits, issued to and applied for by industries operating in the Courtenay River and Oyster River watershed and nearby marine waters (Baynes Sound). The permits have been grouped into (1) watershed and (2) estuary in order to indiciate where the pollution occurs. Each entry provides PCB identification no. (first letter P: permit issued, first letter A: application in process); name of permittee; location of pollution; type of pollution (gas, liquid, solid); and specific source of discharge. Entries marked with an asterisk (*) are those for which monitoring data exists: see Appendix 11.3. Longitude-latitude positions are only accurate to within 05 minute (30").

Permit No.	Permittee	Approx. Discharge Location	Discharge Type	Discharge Source
1. OYSTER RIVER WATERSHED				
AE 0512301	Mt. Washington Ski Resort Limited	Piggot Creek	Outfall	Sewage
PR 0240101	Campbell River Townsite Dump	49°53'00" 125°18'00"	Refuse	Incorporated Discharge
2. COURTENAY RIVER WATERSHED				
AE 0518901	Johnston Corp.	49°45'00" 125°15'00" (Ground water)	Outfall	Sewage
3. COURTENAY RIVER ESTUARY				
PA 0296001	Island Redi-Mix, Courtenay.	49°38'40" 125°00'50" (Atmosphere)	Gaseous	Redi-Mix Plant (Silo)
PA 0301401	Tayco Paving, Courtenay	49°47'40" 125°05'30" (Atmosphere)	"	Asphalt plant

Appendix 11.2 (cont'd.)

Permit No.	Permittee	Approx. Discharge Location	Discharge Type	Discharge Source
PA 0301402	Tayco Paving, Courtenay.	$49^{\circ}47'40''$ $125^{\circ}05'30''$ (Atmosphere)	Gaseous	Asphalt plant
PA 0301403	Tayco Paving, Courtenay.	$49^{\circ}47'40''$ $125^{\circ}05'30''$ (Atmosphere)	"	"
*PA 0395601	Tayco Paving, Cumberland.	$49^{\circ}38'46''$ $125^{\circ}01'05''$ (Atmosphere)	"	"
PA 0395602	Tayco Paving, Cumberland.	$49^{\circ}38'46''$ $125^{\circ}01'05''$ (Atmosphere)	"	"
AE 0520801	Mission Mobile Home Park.	$49^{\circ}43'02''$ $125^{\circ}59'35''$ (Ground water)	Outfall	Mobile Home Park
AE 0522601	Comox Seafoods, Comox.	$49^{\circ}40'00''$ $124^{\circ}58'00''$ (Marine)	"	Fish Cannery
PA 0301404	Tayco Paving, Victoria.	$49^{\circ}47'40''$ $125^{\circ}05'30''$ (Ground water)	"	Asphalt plant
*PE 0011101	Comox, R.S. Pump Station.	$49^{\circ}40'22''$ $124^{\circ}55'33''$ (Comox Harbour)	"	Town

Appendix 11.2 (cont'd.)

Permit No.	Permittee	Approx. Discharge Location	Discharge Type	Discharge Source
*PE 0019701	Cumberland, Village Site	49°47'10" 125°00'59" (Trent River)	Outfall	Village (sewage)
*PE 0025801	Courtenay, City Site	49°40'37" 124°58'34" (Comox Harbour)	"	City (treated sewage)
PE 0193101	Veloso Courtenay	49°40'50" 124°57'50" (Misc. marine)	"	Fish Cannery
PE 0217801	Island Redi-Mix, Courtenay	49°38'40" 125°00'50" (Ground water)	"	Gravel Plant (screening)
PE 0217802	Island Redi-Mix, Courtenay	49°38'40" 125°00'50" (Ground water)	"	Redi-Mix Plant (truck washout)
PE 0262501	Talson Trailer, Comox	49°42'00" 124°52'30" (Ground water)	"	Mobile Home Park
PE 0433201	Woods Trucking, Cumberland	49°38'34" 125°00'34" (Ground water)	"	Gravel Plant (washing)
PR 0413001	Davis, Courtenay	49°43'55" 125°04'05"	Refuse	Sawmills (yard wastes)
PR 0486501	Gregory MFG, Courtenay	49°38'10" 125°02'03" (Ground water)	"	Sawmills (yard wastes)
PR 0505001	Comox-Strathcona, Cumberland	49°38'17" 125°02'55" (Ground water)	"	Regional District (garbage dump)

APPENDIX 11.3 List of Air and Water Stations in the Courtenay-Comox Harbour area for which monitoring data exists in the B.C. Pollution Control Branch "Environmental Data Base".

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE0154006	outfall	Comox Outfall 6 (49°39'30"; 124°54'54")	pH, resins-(unfilt.) resins-(fixed-unfilt.), silica, sulphate, coliforms, resins-(vol. unfilt.), spec. conduct., ammonia, NO_2/NO_3, nitrite, nitrate, org. nitrog., total nitrog., ortho phosph., total phosph.
PE0154007	"	Comox Outfall C-7 (49°39'30"; 124°55'00")	oil & grease, pH, resins, spec. conduct., temp., diss. oxy., turbidity, organic carbon, ammonia, NO_2/NO_3, nitrate, nitrite, org. nitrog., nitrog. kjel., total nitrog., COD, ortho. phosph., silica, sulphate, coliforms.
PE0154008	"	Comox Outfall C-7A (49°39'0"; 124°54'30")	oil & grease, pH, resins, spec. conduct., ammonia, NO_2/NO_3, nitrate, nitrite, org. nitrog., nitrog. kjel., total nitrog., ortho. phosph., total phosph., silica, sulphate, fecal coliforms.
PE0154009	"	Comox Outfall C-7B	pH, spec. conduct., ammonia, nitrate, resins, ortho. phosph., total phosph., silica, nitrite, NO_2/NO_3, total nitrog., nitrog. kjel., org. nitrog., sulfate, coliforms.
PE0154010	"	Comox Outfall C-8 (49°39'25"; 125°01'05")	" "

APPENDIX 11.3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE 0011101	outfall	Comox, R.S., Pump Station	oil & grease, pH, resins, temp., spec. conduct., diss. oxy., organic carbon, BOD., ortho. phosph., colour, turbidity, nitrate, coliforms.
PE 0025801	"	Courtenay, City Site	pH, resins, spec. conduct.,temp., diss. oxy., turbidity, flow, organic carbon, nitrate, BOD., ortho. phosph., coliforms, colour, oil & grease, NO_2/NO_3.
PE 0019701	"	Cumberland, Village Site (49°37'10"; 125°00'59")	pH, resins, spec. conduct., temp., diss. oxy., turbidity, org. carbon, nitrate, BOD., ortho. phosph., coli-forms, colour, oil and grease, NO_2/NO_3, nitrites, total phosp.
PE 0120860	stream	Courtenay R., Stn. 1 (49°40'52"; 124°58'40")	coliforms
PE 0120861	"	Courtenay R., Stn. 2 (49°40'50"; 124°58'40")	"
PE 0120862	"	Courtenay R., Stn. 3 (49°40'46"; 124°58'32")	"
PE 0120420	"	Brown's River (49°41'33"; 125°05'07")	colour, pH, resins, spec. conduct., temp., diss. oxy., turbidity, TAX, hardness, NO_2/NO_3, nitrate, nitrite, total nitrog., nitrog. kjel., COD, ortho. phosph., total phosph., silica, sulphate, surfacan, tannins & lignins, diss. calcium, total

APPENDIX 11.3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE 0120420	(continued)		calcium, diss. & total copper, diss. & total iron, diss. & total lead, diss. magnesium, total magnesium, mercury, diss. sodium, zinc, coliforms, ammonia, org. nitrog.
PE 0125581	stream	Oyster R., above Camp. (49°53'35"; 125°13'30")	colour, pH, resins, spec. conduct., temp., diss. oxy., turbidity, alkalinity, hardness, fluoride, NO_2/NO_3, nitrate, nitrite, COD, ortho. phosph., silica sulphate, diss. & total iron, diss. & total calcium, lead, copper, diss. & total magnesium, diss. manganese, mercury, diss. sodium, zinc, coliforms.
PE 0125980	"	Puntledge River (49°41'17"; 125°01'57")	colour, pH, resins, spec. conduct., temp., diss. oxy., tubidity, TAC, hardness, NO_2/NO_3, nitrate, nitrite, total nitrog., nitrog. kjel., COD, ortho. phosph., total phosp., silica, sulphate, surfacan, tannins & lignins, diss. & total calcium, diss. & total copper, diss. & total lead, diss. & total iron, mercury, diss. & total magnesium, diss. sodium, diss. & total zinc, coliforms, ammonia, org. nitrog.
PE 0127620	"	Tsolum River (50°46'00"; 125°06'30")	colour, pH, resins, spec. conduct., temp., diss. oxy., turbidity, TAC, hardness, ammonia, NO_2/NO_3, nitrate, nitrite, organic nitrog., nitrog. kjel., total nitrog., COD, ortho.

APPENDIX 11.3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE 0127620	(continued)		phosph., total phosph., silica, sulphate, surfacan, tannins & liginins, diss. & tot. calcium, diss. & tot. copper, tot. iron, diss. & tot. lead, diss. & tot. magnesium, tot. manganese, tot. mercury, diss. sodium, diss. & tot. zinc, tot. and fecal coliforms.
PE 0127580	stream	Trent R. Stn. 1 (49°38'30"; 124°56'00")	colour, pH, resins, spec. conduct., temp., diss. oxy., turbidity, TAC, organic carbon, hardness, NO_2/NO_3, nitrate, nitrite, total nitrog., nitrog. kjel., COD, ortho. phosph., total phosph., silica, sulphate, surfacan, tannins & lignins, diss.& total calcium, diss. & total copper, diss. & total iron, diss. & total lead, diss. & total magnesium, manganese, mercury, diss. & total zinc, oil & grease, coliforms, flow, ammonia, org. nitrog.
PE 0127581	"	Trent R. Stn. 2 (49°39'00"; 124°56'00")	colour, pH, resins, temp., diss. oxy., turbidity, org. carbon, hardness, nitrate, nitrite, COD, ortho. phosph., total phosp., sulphate, surfacan, tannins & lignins, diss. calcium, total copper, total iron, total lead, diss. magnesium, mercury, zinc, coliforms, oil & grease, spec. conduct.

APPENDIX 11.3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE 0127600	stream	Tsable River (49°31'00"; 124°50'30")	colour, pH, resins, spec. conduct., temp., diss. oxy., TAC, hardness, NO_2/NO_3, COD, nitrate, nitrite, nitrog. kjel., total nitrog., ortho. phosp., total phosph., silica, sulphate, surfacan, tannins & lignins, diss. & total calcium, diss. & total copper, diss. & total iron, diss. & total lead, diss. & total magnesium, manganese, mercury, diss. & total zinc, coliforms, turbidity, ammonia, org. nitrog.
PE 0130160	lake	Comox Lake (49°38'00"; 125°05'03")	colour, pH, resins, spec. conduct., temp., diss. oxy., turbidity, TAC, hardness, NO_2/NO_3, nitrate, nitrite, nitrog. kjel, total nitrog., COD, ortho. phosph., total phosph., silica, sulphate, surfacan, tannins & lignins, diss. & total calcium, diss. & total copper, diss. & total lead, diss. & total iron, diss. & total magnesium, manganese, diss. & total mercury, sodium, diss. & total zinc, coliforms, ammonia, org. nitrog.
PE 0154000	marine	Pt. Holmes, Comox C-1 (49°41'41"; 124°52'00")	fecal coliforms

Appendix 11.3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE0154001	marine	Pt. Holmes, Comox C-2 (49°41'30"; 124°62'18")	fecal coliforms
PE0154002	"	Pt. Holmes, Comox-C (49°41'42"; 124°52'06")	" "
PE0154003	"	Pt. Holmes, Comox C-3 (49°41'30"; 124°52'06")	" "
PE0154004	"	Radford's, Comox Study C-4 (49°41'06"; 124°53'00")	" "
PE0154005	"	Balmoral, Comox Study C-5 (49°40'30"; 124°54'24")	" "
PE0154025	"	Comox Harbour C-21 (49°38'17"; 124°53'55")	coliforms
PE0154026	"	Comox Harbour C-22 (49°38'18"; 124°52'00")	"
PE0154027	"	Comox Harbour C-23 (49°36'00"; 124°51'12")	"
PE0154028	"	Comox Harbour C-24 (49°35'12"; 124°51'10")	"
PE0154029	"	Comox Harbour C-25 (49°39'35"; 124°51'00")	"
PE0154030	"	Comox Harbour C-26 (49°33'22"; 124°51'12")	"

Appendix 11.3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE0154031	marine	Comox Harbour C-27 (49°33'15"; 124°51'12")	pH, resins, spec. conduct., ammonia, NO_2/NO_3, nitrate, nitrite, org. nitrog., nitrog. kjel., total nitrog., ortho. phosph., total phosph., silica, sulfate, coliforms.
PE0154032	"	Comox Harbour C-28 (49°33'15"; 124°50'42")	coliforms.
PE0154033	"	Comox Harbour C-29 (49°41'35"; 124°50'10")	pH, resins, spec. conduct., ammonia, NO_2/NO_3, nitrate, nitrite, org. nitro., nitrog. kjel., total nitrog., ortho. phosph., total phosph., silica, sulfate, coliforms.
PE0154034	"	Comox Harbour C-30 (49°42'55"; 124°50'35")	
PE0154035	"	Comox Harbour C-31 (49°43'50"; 124°51'45")	
PE0154011	"	Goose Spit, Comox C-9 (49°39'54"; 124°54'30")	oil & grease, temp., diss. oxy., coliforms.
PE0154012	"	Goose Spit, Comox C-10 (49°39'48"; 124°55'00")	"
PE0154013	"	Goose Spit, Comox C-11 (49°39'30"; 124°55'18")	"
PE0154014	"	Goose Spit, Comox C-12 (49°39'42"; 124°55'20")	"

Appendix 11. 3 (cont'd.)

SITE NO.	TYPE OF SITE	LOCATION	PARAMETERS MEASURED
PE0154015	marine	Comox Harbour C-13 (49°39'12"; 124°56'54")	coliforms
PE0154016	"	Comox Harbour C-14 (49°38'42"; 124°55'54")	"
PE0154017	"	Comox Harbour C-15 (49°39'06"; 124°56'30")	"
PE0154018	"	Comox Harbour C-16 (49°39'25"; 124°56'06")	"
PE0154019	"	Comox Harbour C-17A (49°40'12"; 124°	fecal coliforms
PE0154020	"	Comox Harbour C-17B (49°40'00"; 124°55'06")	"
PE0154021	"	Comox Harbour C-18 (49°40'09"; 124°54'30")	"
PE0154022	"	Comox Harbour C-19 (49°38'48"; 124°56'55")	coliforms, pH, resins, spec. conduct., ammonia, NO_2/NO_3, nitrate, nitrite, org. nitrog., nitrog. kjel., total nitrog. ortho. phosph., total phosph., silica, sulphate.
PE0154023	"	Comox Harbour C-20 (49°40'55"; 124°58'18")	coliforms
PE0154024	"	Comox Harbour at PE-111 (49°40'10"; 124°55'25")	"

APPENDIX 11.4

Standard Water Quality Criteria for Drinking Water, Oysters and Beach Sites

	Coliforms (MPN)	
	Total[2]	Fecal
Drinking Water[1]	90% of the samples must be negative	all the sample must be negative
Oysters	where coliforms are from sewage 70/100 ml with not more than 10% of the samples exceeding 230/100 ml[3]	14/100 ml with not more than 10% of the sample exceeding 43/100 ml[4]
Beach Sites	MPN range/100 ml	
Class "A"	0 - 50[5]	240/100 ml[6] maximum
Class "B"	50 - 100	
Class "C"	100 - 500	
Class "D"	500 - 1000	

[1] Upper Island Health Unit, Courtenay, (1973).

[2] total coliform includes various bacterial types from many sources; fecal bacteria originate from sewage

[3] Derkson and Tevendale (1974)

[4] Arney and Kay (1976)

[5] Waldichuk (1962)

[6] Upper Island Health Unit, Courtenay (1973)

GLOSSARY OF SELECTED TERMS

alcid: a member of the family Alcidae which includes auks, murres and puffins. These birds frequent pelagic saltwater, coming ashore only to breed.

alevin: young fish that have hatched but still possess a yolk sac.

algae: a non-taxonomic term for a group of mainly aquatic plants without vascular systems and variously one-celled, colonial, or filamentous, containing chlorophyll and/or other pigments (especially reds and browns), e.g. seaweeds, phytoplankton.

alluvial: 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 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: describes a fish with a life cycle in which maturity is attained in salt water, and the adults enter fresh water to spawn.

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

anoxic: anaerobic, without oxygen.

aqueous: liquid solution where water is the solvent.

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 hydrostatic pressure.

atmospheric pressure: the pressure exerted by the atmosphere as a consequence of gravitational attraction exerted upon the column of air lying directly abouve the point in question. The metric unit of atmospheric pressure adopted by Canada is the kilopascal (1 kPa equals 0.2953 in. of mercury).

avian: 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 science of measurement of the depths of oceans, seas or lakes. Sometimes refers to the bottom topography of marine or lake systems.

bedrock geology: the study of the geology of any solid rock exposed at the surface of the earth or underlain by unconsolidated material.

benthic algae: a group of mainly aquatic plants, variously one-celled, colonial or filamentous, containing chlorophyll and/or other pigments (especially reds and browns), and having no vascular system, which live in or on the bottom sediments of a water body.

benthos: organisms living in or on the bottom sediment of a body of water; can be broken into three size groups - macro (greater than 1.0 mm to 0.5 mm), meio (1.0 mm to 0.5 mm) and micro (less than 0.5 mm).

biochemical oxygen demand (B.O.D.): 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: geological time scale based on dating of fossils.

biogeoclimatic zone: a regional ecosystem characterized by vegetation and soil types that are a product of the macroclimate in which they occur.

biomass: the weight of living or dead organic tissue; e.g. biomass of zooplankton per m^3, or stomach contents biomass.

biota: living organisms, as distinct from abiotic or non-living entities.

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 permantly attached to a material (e.g. sediment or wood) or burrow into it. The class includes clams, mussels and oysters.

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

buffer: (in this case) a modifier of runoff in a river system by acting as a sink e.g. lakes where water from inflowing rivers is held and then released only when the level of the outflowing river is lower than the lake level.

catchment area: same as drainage area ar drainage basin. The area drained by a watercourse or providing water for a reservoir.

channelization: (channeling, channel modification, channel improvement) a term used to descibe realignment, relocation, leveling and deepening of water courses. Flood protection, erosion control and development are commonly sited motives.

chironomid: any of a family of tiny flies (Midges) in the order Diptera; their larvae usually live submerged in freshwater.

chlorophyll: a green pigment found in most plants; a substance which aids in making energy, from available light, for a process called photosynthesis (the manufacturing of a simple sugar, glucose, formed in effect, by carbon dioxide and water).

chytrid: a member of the division - order Chytridiomycota. These fungi are primitive, primarily single-celled and aquatic. They are distinguished by all other fungi because they have motile reproductive cells with a single posterior whiplash flagellum.

cladocera: an order of Crustacea commonly known as "water fleas".

clear cuts: areas from which trees have been completely removed during logging operations.

climatology: the science dealing with climate (the prevailing or average weather conditions of a place) and climatic phenomena.

climax (mature) community: a final self-perpetuating assemblage 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.

cobble: a rock fragment between 64 and 256 mm in diameter, larger than a pebble and smaller than a boulder.

coliform: designating of, or like the aerobic bacillus normally found in the mammalian intestine. A coliform count is designated - Most Probable Number (MPN) of bacteria derived statistically from a series of cultures in different dilutions. It is often used as an indicator of fecal contamination of water supplies.

comminute: to reduce to small, fine particles.

community: a naturally occurring assemblage of organisms inhabiting a common environment and interacting with each other.

conifer: any of an order (Coniferales) of cone-bearing trees and shrubs, mostly evergreens like pine, spruce, fir, cedar, yew, etc.

copepod: any of a large order 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 subpolar climates, living as they do in the plankton and benthos of marine, estuarine and freshwaters.

cretaceous: the third and latest of the mesozoic (geological) era; also the system of homogenous rock formations deposited in the cretaceous period.

crustacean: any of a large class of mostly aquatic creatures having an outer sketeton ("exoskeleton") composed of calcium carbonate and chitin, or of a form of carbohydrate; it includes shrimps, crabs, wood lice, barnacles, cladocerans, amphipods, isopods and mysids.

culture experiments: experiments involving the rearing and breeding of fish in natural or artificial ponds under controlled environmental conditions.

cumacean: any of the order Mysidacea, class Cumacea. These sand and mud dwellers have a distinctively enlarged head and thorax, with a narrow abdomen which terminates in two elongated uropods (modified "tail fin").

dabbling ducks: ducks that usually obtain their food by submerging only the head, while the body remains floating on the water surface, usually in freshwater or estuarine habitats.

decapod: crustaceans having ten legs such as lobsters, crabs and shrimps. Also 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 of all forms of detritus (adjective: detrital).

diatom: one of an algal class (Bacillariophyceae) of microscopic organisms, characterized by thin shells of silica. Commonly abundant in both benthos and plankton of marine, estuarine and fresh waters

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.

dipteran: any of a large order (Diptera - true flies) of insects including the housefly, mosquito, gnat, etc., having one pair of functional membranous wings and usually a vestigial second pair; some species have larval stages that live in freshwater.

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; found in marine, estuarine and fresh water habitats.

dogfish: any of the various small sharks (especially family Squalidae) with a single spine in front of each of the two dorsal fins.

drainage area: the region that drains all the rainwater and snow that falls onto it (apart from that removed by evaporation), into a river or a stream which then carries the water to a sea or lake; its boundary is defined by the ridge beyond which water flows in the opposite direction - away from the basin.

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. Current speed and direction are determined by tracking and timing of the surface buoy.

dyke (dike): in geology, a tabular body of igneous rock that cuts across the structure of adjacent rocks.

ebb tide: outgoing or falling tide.

ecology: that branch of science which attempts to define the biological functions of living organisms and of factors in their environments.

ecosystem: all the organisms and non-living elements of a three-dimensional space which function to support living organisms in that space; e.g. an estuarine ecosystem or a forest ecosystem.

eddy: 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 marine vascular plant that has long narrow leaves, produces seeds and generally grows on a sand or mud substrate in the lower intertidal and upper subtidal zones; e.g., *Zostera marina* in B.C. coastal waters.

effluent: liquid waste material (such as sewage or liquid industrial refuse) discharged into the environment, especially when considered as a pollutant.

effort: the amount of time per hour, day or season spent fishing or hunting.

embayed: sheltered; with regard to the placing of an outfall, an area is considered to be embayed if a line drawn between two points along a coastline is less than four miles long, or the maximum width of sea access by any route is under one mile wide, but may be taken to include other waters if flushing is considered to be inadequate.

emission: in pollution work, usually refers to gaseous or vaporized wastes, as opposed to liquid wastes which are called effluents.

environment: collective term for conditions in which an organism lives.

epifauna: animals living in an aquatic environment on or associated with, the substrate, at depths not exceeding 100 fathoms.

escapement: a statistical term that describes the number of fish that pass unharmed from place to place; indicates the number of salmon adults which survive ocean life and start up a river to the spawning grounds, or the number of juvenile salmon that go to sea after hatching in a stream (usually the former).

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 freshwater derived from land drainage.

eulachon: marine food fish (*Thaleichthys pacificus*) of the north Pacific coast; anadromous; related to the smelt (Osmeridae) and rendered by coast Indians for its oil which remains solid at ordinary temperatures.

euphausid: any pelagic, marine, shrimp-like, usually filter feeding crustacean, approximately one inch in length, belonging to the order Euphausiacea.

fallow: land plowed but not seeded for one or more growing seasons to kill weeds, enrich soil, etc.

fauna: animal life of a specific region or time (microfauna - organisms that pass through a 100 micron mesh; meiofauna - organisms that pass through a 500 micron mesh but are retained by a 100 micron mesh; macrofauna - organisms that are retained by a 500 micron mesh).

fetch: in wave forcasting, the continuous area 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 (*cf.* *fry*).

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.

fluvial: of or pertaining to rivers; produced by river action, as a fluvial plain.

flux: continuous movement or continuous change e.g. tides.

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 operating in a community.

foraminifera: a group of protozoa, mostly marine, which form shells of lime or silica; common in marine benthos.

foreshore: with respect to land use in British Columbia, the land between mean high tide and mean low tide. The foreshore is under the jurisdiction of the B.C. government pursuant to the British North America Act and the B.C. Environment and Land Use Act.

freshet: a sudden increase or rise in the river flow or level because of melting snow and/or heavy rain.

fry: with respect to salmonids , young fish of a year that have absorbed their yolk sacs (cf *fingerling*).

gaff: a large strong hook on a pole or a barbed spear used in the landing of large fish.

game birds: wild birds hunted for sport or food; usually refers to members of the grouse family and to ducks and geese.

gastropod: includes those individuals from subclass Prosobranchia which have gills and anus located at the anterior of the body, all of which is enclosed in a shell shaped like a conical spire; those individuals from subclass Opisthobranchia which display various stages of detorsion. The shell and mantle cavity are either reduced or absent and many members are pelagic or swim. e.g. abalone, whelks, snails, limpets and nudibranchs, etc

gauge station (manual): a location where stage (water levels) and/or discharge rates are obtained by placing a measuring stick in the stream and noting the water depth. At *Automatic gauge stations*, changes in water depth are recorded using a float which rests on the water surface. Variations in height are then traced onto a drum which is connected to the float.

*geohydraulics (*equal, in this case, to *potemology):* potemology is a standard term used to describe the study of rivers and their hydraulics(mechanical properties of water and other liquids in motion), sediment and morphology

gillnet: a net set upright in the water to catch fish by entangling their gills in the mesh of the net.

glacio: a combining form frequently used with other words to denote formation by or relationship to glaciers.

grilse: immature, post-smolt, sea-going chinook or coho salmon.

groundwater: water found underground in porous rock strata and soils, as in a spring.

habitat: the place where an organism or a population lives.

head pond: an accumulation of water to produce a pressure (or force) on a unit area to drive (in this case) the turbines in the powerhouse thereby generating hydro-electric power.

headwaters: the streams and creeks that are the sources of a river or other water body.

hinterland: the land or district behind that bordering on a coast or river.

homogeneous: alike at all parts, consisting of a single phase, chemical composition, physical state, etc. May be a gas, liquid or crystal.

hydrogen sulfide: a chemical compound (H_2S) produced with methane (CH_4) and ammonium (NH_4+) during the decay of lignin and cellulose ($C_nH_nO_nNS$) from wood, a process that consumes oxygen. Hydrogen sulfide has an offensive odour and is toxic to fish and invertebrates.

hydrograph: a graph showing changes in water flow over a period of time.

hydrography: that science which deals with the measurement and description of the physical features of the oceans, seas, lakes, rivers and their adjoining coastal areas, with particular reference to their use for navigational purposes.

igneous rocks: rocks formed by the solidification of hot molten material termed magma.

impounding dam: a barrier built to enclose, gather or hold back flowing water.

infauna: animals found within the substrate e.g. burrowers like clams, ghost shrimp, etc.

intertidal zone: the area of shore bounded by the levels of high and low tide.

invertebrate: an animal not having a backbone (true of most animal species).

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.

jacks: precocious male chinook salmon returing to spawn in their second or third year.

juvenile: not having atained maturity in all respects.

kelt: a steelhead trout (*Salmo gairdneri*) that is migrating back to sea after spawning.

larva: an organism at some pre-adult stage of development, incapable of reproduction and often morphologically and ecologically distinct from the adult stage.

leach: to subject to the action of percolating liquid (such as water) in order to separate the soluble conponents; to dissolve out by the action of a percolating liquid.

littoral drift: organisms drifting or floating with the tides and/or current in waters close to the shoreline.

louvers: metal bars stacked vertically and arranged in a V-like construction to deflect fish away from water intake penstocks.

macrophyte: a large plant; used to describe algal species large enough to be readily apparent to the naked eye (e.g. seaweeds are macrophytic algae).

main: a principal pipe or line in a distributing system for water. *Force mains* are pipes with a smaller diameter than those at either end of it so that flowing water is forced to move through the force main at a faster rate than mains of a larger diameter.

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 through tidal action, and usually produces large amounts of food for fish and birds.

meteorology: the science dealing with the atmosphere and its phenomena, especially as relating to weather.

migratory: to pass, usually periodically, from one region or climate to another for purposes of feeding, breeding, etc.

morphology: the observation of the form of lands; or the study of the form and structure of organisms.

mysid: any of an order (Mysidacea) of small shrimp-like crustaceans with a carapace over most of the thorax and two branched appendages; free-swimming, filter feeders often abundant in marine, estuarine or freshwater habitats.

natural resources: supplies of non-living substances and renewable stocks of plant and animal species considered to be of value to humanity.

nature conservancy area: a roadless area, within a park, retained in a natural condition for the preservation of its ecological environment and scenic features.

needle fish: A group of long pipe-like marine fish of the family Belonidae. They have elongated jaws and many teeth.

normal: perpendicular to the shoreline.

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).

oligochaete: any of a class (Oligochaeta, Annelida) of segmented worms, such as earthworms, which lack a definite head and have relatively few body setae (bristles); common in soil, fresh water and marine benthos.

outfall: the point at which a sewer or land drainage discharges into the sea or a river.

paleontology: the science that deals with the life of past geological ages based on the study of fossil remains of organisms.

parameter: in ecology, a measureable quantity describing some abiotic aspect of the environment; e.g. salinity, temperature, soil depth, light density, etc.

pelagic: of the ocean surface or the open sea, as opposed to coastal waters.

penstock: a pressure pipe supplying water to a water turbine for the purpose of producing electricity.

pH: a symbol for the degree of alkalinity or acidity of a solution, originally expressed as the logarithm of the reciprocal of the hydrogen-ion concentration in gram equivalents per litre of solution, but may have other operational definitions.

phytoplankton: plant life, mostly microscopic algae, found floating or drifting in the oceans or bodies of fresh water; forms the base of some aquatic food chains.

piece: a unit measurement where one piece is equivalent to one fish.

plankton: floating plants and animals that are distributed by currents more than their ability to swim.

pluton: a body of igneous rock that has formed beneath the surface of the earth by consolidation from magma.

plutonic activity: activity associated with the formation of igneous rocks far below the surface of the earth, by intense heat, great pressure and slow cooling.

pollution: (noun) the result of artificially disturbing an ecosystem by introducing a disruptive agent; severity of pollution is commonly judged on the basis of the value placed on the affected organisms by human society.

polychaete: any of an annelid 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 head. Common in marine and estuarine benthos when adult and in zooplankton when in the larval stage.

prevailing wind: the wind, indicated by direction at a certain place or area, that has a higher frequency of occurrence than any other.

primary productivity: the rate at which organic matter is produced from inorganic compounds.

pycnocline: a vertical water density gradient in some layer of a body of water that is greater than the gradients above and below it.

race: equivalent to a sub-species; those that differ from others in the relative frequency of some gene or genes.

raptorial bird: a bird of prey, usually having a strong hooked beak and sharp talons (e.g. eagles, hawks, owls, vultures).

rearing grounds: an area in a river that has a minimal amount of current and a maximal amount of food and shelter. Juvenile fish are normally found in these areas. *Nursery grounds* are similar areas used by alevin and fry.

rhizomes: horizontal underground stems.

roe: fish eggs, especially when still massed in the ovarian membrane.

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 sone of the water which originally sank into the ground and joined 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 matter is completely oxidized.

salmonid: any fish of the family Salmonidae (e.g. salmon or trout).

salt marsh: grassland over which salt water flows at intervals, usually a highly productive ecosystem.

Secchi disc: a disc, 30 cm, in diameter usually painted white. When lowered in the water, the depth at which the disc disappears from view gives an indication of the clarity of the water (measured in metres).

sedge: any of a family (Cyperaceae) of grasslike 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; contributes to habitat and food source of organisms in food chains leading to salmonids.

sedimentary rock: rock formed by the accumulation of sediment in water or from air usually having a characteristic layered structure known as bedding or stratification.

seine net: a large fishing net with floats along the top edge and weights along the bottom edge.

seismic profiling: transmission of sound, generated by an explosive device or some other shock-developing instrument, through sediments. The resulting records show the density and depth of strata.

shorebirds: any of a number of birds that feed (usually by wading) or nest on the shores of oceans, rivers, etc; examples are sandpipers, snipes, dunlin, etc.

shucked: a shellfish removed from its shell.

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.

slackwater: the condition when the speed of tidal current is zero.

slough: a swamp, bog or marsh, especially one that is part of an inlet or backwater.

sluiceway: an artificial channel for water, with or without a flood gate.

smolt: in salmonids, the life stage older than a fry and physiologically adapted to leave fresh water and enter salt water.

spat: the spawn of the oyster, or other bi-valve shellfish; young shellfish larvae.

spawn: (verb) to produce or deposit eggs - usually used in reference to aquatic animals such as fish, crustaceans and oysters. (noun) eggs of fish or invertebrates.

spillway: a passageway or channel to carry off excess water, as around a dam.

stock: in geology, a body of plutonic rock, that covers less than 40 square miles; in fisheries biology, a segment of the population that can be managed as a single unit.

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; e.g. saline stratification in some estuaries.

stratigraphy: the branch of geology relating to the formation, composition, sequence and correlation of the stratified rocks forming part of the earth's crust.

subtidal: below the lowest low tide.

sulfide: a compound of sulfur and some other element or radical.

Supplimentary Letters Patent: a document obtained by the Regional District of Comox-Strathcona from the Ministry of Municipal Affairs giving the Regional District the right to provide functions like water supply, parks, etc. The district must obtain approval from the provincial government as additional functions mean an increase in taxes.

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.

sympatric: of or pertaining to closely related species of organisms occurring in the same area.

tagging: a method by which coho and chinook salmon are identified using a binary coded wire 1/25 inches long, inserted into the nose cartilage of the fish. Upon inspection, the tags reveal information as to where and when the salmon were released (from a hatchery), its size at release, the food it received in the hatchery and what agency released the fish.

tailings: the portions of a washed ore that are regarded as too poor (contain too little of the mineral being mined) to be treated further.

tailrace: the current of water that has passed over the turbines in a powerhouse.

temperature inversion: an increase of temperature with height above the earth's surface, being the reverse of the normal situation 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 body of water.

troll: to fish with a moving line, especially one 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.

tyee: local name used by B.C. sports fishermen to describe chinook salmon (*Onchorhynchus tshawytscha*) that weigh more than 30 pounds (13.6 kg).

ungulates: a non-taxanomic term referring to hoofed mammals; herbiverous, found living in herds, and usually adapted for running on firm, open ground, e.g. deer, elk.

vapour pressure: the pressure exerted in the atmosphere by a substance through its vapourization, 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.

vascular vegetation: those plants having connecting tissues called xylem and phloem.

vector: a straight line representing both direction and magnitude.

visibility: the distance of visual perception, usually through the atmosphere, measured in kilometres; in meteorology, 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).

volcanic rock: the class of igneous rocks that have been poured out or ejected at or near the earth's surface.

waterbirds: birds that live on or near the water; includes loons, grebes, cormorants, swans, geese, ducks, herons, eagles, osprey, cranes, coots, plovers, sandpipers, gulls, terns, auks, murres and kingfishers.

waterfowl: comprised of swans, geese and ducks of the family Anatidae only.

water quality: the totality of physical, chemical, biological and aesthetic characteristics of water; the applicability, based on these characteristics, of water for various uses.

watershed: the summit and dividing line between two catchment areas (drainage areas) from which water flows away in two directions.

weir: a low dam built in a river to back up or divert water; a fence made of two by fours, bushwood or stakes built upstream for catching fish; an obstruction placed in a stream diverting water through a prepared aperture for measuring the rate of flow.

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 in aquatic food chains.

1. INTRODUCTION

Apps, G.E. 1958. Mining. *In:* Comox Valley, its pioneers. Part I. 3 p.

Carthwright, H. 1958. An outline of logging in Comox Valley. *Ibid.* Part II. 9 p.

Haas, M. 1958. Our early pioneers. *Ibid.* Part I. 9 p.

Harding, R. 1958. Comox Valley Indians. *Ibid.* Part III. 9 p.

Hughes, B. 1962. History of the Comox Valley. 1862-1945. Evergreen Press (U.I.) Limited. Nanaimo, B.C. 58 p.

Regional District of Comox-Strathcona. 1975. A report on land use and resources within the region. Regional District of Comox - Strathcona, Planning Department, Courtenay, B.C. 63 p.

Stubbs, D.I. 1975. All about us. A history of the city of Courtenay. Courtenay, B.C. 127 p.

II. GEOLOGY AND SOILS

Armstrong, J.E., D.R. Crandell, D.J. Easterbrook and J.B. Noble. 1965. Late Pleistocene stratigraphy and chronology in southwestern British Columbia and northwestern Washington. Bull. Geol. Soc. Am. 76: 321-330.

Atchison, M.E. 1968. Stratigraphy and depositional environments of the Comox Formation (Upper Cretaceous), Vancouver Island, British Columbia, M. Sc. Thesis, Unpubl., Northwestern University, Evanston, Illinois.

Bell, W.A. 1957. Flora of the upper Cretaceous Nanaimo Group of Vancouver Island, British Columbia. Geol. Surv. Can. Mem. 293.

Bickford, C.L. 1975. Computerized preliminary bibliography of the Nanaimo and Comox coalfields, and partial listing of mines. University of British Columbia, Dept. of Geology. Sciences Ref. Library. 4 p.

Buckman, A.F. 1947. The Nanaimo coalfield. The Canadian Institute of Mining and Metals Transactions. Vol. 50, 1947. p. 460-472.

Canada Department of Agriculture. 1970. The system of soil classification for Canada, 1970. Queen's Printer, Ottawa, Ont. 249 p.

Canada Department of Energy, Mines and Resources. 1975. List of geological reports of British Columbia. Revised 1975. Geol. Surv. Can. Ottawa, Ont., and Vancouver, B.C. 27 p.

Clague, J.J. 1975a. Quaternary geology, northern Strait of Georgia, British Columbia. *In:* Report of activities. Part A. Geol. Surv. Can. Paper 75-1A. p. 397-400.

___. 1975b. Surficial sediments of the northern Strait of Georgia, British Columbia. *In:* Report of activities. Part B. Geol. Surv. Can. Paper 75-1B. p. 151-156.

___. 1976. Sedimentology and geochemistry of marine sediments near Comox, British Columbia. Geol. Surv. Can. Paper 76-21. 21 p.

Clapp, C.H. 1912a. Note on the geology of the Comox and Suquash coalfields. Geol. Surv. Can. Summ. Rept. 1911, p. 105-107.

___. 1912b. Southern Vancouver Island. Geol. Surv. Can. Mem. 13. 208 p.

Cockbain, A.E. 1962. Studies in the marine geology of the continental shelf of British Columbia, Canada. First Nat. Shallow Water Res. Cont., 1961. p. 741-743.

___. 1963a. Distribution of sediments on the continental shelf off the southern British Columbia coast. Institute of Oceanography, University of British Columbia. MS. Rept. No. 15.

___. 1963b. Distribution of foraminifera in Juan de Fuca and Georgia Straits, British Columbia, Canada. Contr. Cushman Foundn. for Foram. Res. 14: 37-57.

Dawson, G.M. 1876. On the surficial geology of British Columbia. Quart. J. Geol. Soc. London. 34: 95.

___. 1887. Report on a geological examination of the northern part of Vancouver Island and adjacent coasts. Geol. and Nat. Hist. Surv. Can., Montreal, P.Q. 107 p. plus appendices.

___. 1890. Notes on the Cretaceous of the British Columbia region. The Nanaimo Group. Am. J. Sci. 39: 180-183.

Day, J.H., L. Farstad and D.G. Laird. 1959. Soil survey of southeast Vancouver Island and Gulf Islands. Rept. No. 6 of the British Columbia Soil Survey, 1959. Research Branch, Canada Department of Agriculture in co-operation with the University of British Columbia and the British Columbia Department of Agriculture. Queen's Printer, Ottawa Ont. 104 p. plus maps.

Dowling, D.B. 1915. Coalfields of Vancouver Island. *In:* Coalfields and coal resources of Canada. Geol. Surv. Can. Mem. 59: 134-142.

EPEC Consulting Western Limited. 1975. Coal resource study of Comox Basin-Nanaimo Series Vancouver Island, British Columbia. Preliminary environmental assessment. Vol. 7. Rept. prepared by EPEC Consulting Western Ltd. for Weldwood of Canada, Vancouver, B.C. 186 p.

Forster, C. and R. Crides. 1975. The environmental geology of Comox Valley. Study prepared for the Planning Director, Regional District of Comox-Strathcona, 10 p.

Fulton, R.J. 1971. Radiocarbon geochronology of southern British Columbia. Geol. Surv. Can. Paper 71-37. 28 p.

Fyles, J.G. 1959a. Geology of the soil parent materials. *In:* Soil survey of southeast Vancouver Island and Gulf Islands, British Columbia by J.H. Day, L. Farstad and D.G. Laird, Canada Dept. Agriculture, B.C. Soil Survey Rept. 6: 23-29.

Fyles, J.G. 1959b. Surficial geology, Oyster River, Comox, Nanaimo and Sayward districts, British Columbia. Geol. Surv. Can. Map 49-1959.

____. 1960. Surficial geology, Courtenay-Comox, Nelson, Nanaimo and Newcastle districts, Vancouver Island, British Columbia. Geol. Surv. Can., Map 32-1960. Note 72.

____. 1963. Surficial geology of Horne Lake and Parksville map-areas, Vancouver Island, British Columbia. 92F/7, 92F/8. Geol. Surv. Can. Mem. 318. Canada Department of Mines and Technical Surveys, Ottawa, Ont. 142 p. plus maps.

Halstead, E.C. and A. Treichel. 1966. Groundwater resources of the coastal lowland and adjacent islands, Nanoose Bay to Campbell River, east coast, Vancouver Island. Geol. Surv. Can. Bull. 144. 42 p. plus maps.

Hardy, G.A. (undated) Geology of Forbidden Plateau. p. B27-B28. *In:* The Natural History of the Forbidden Plateau area. Vancouver Island, British Columbia Provincial Museum Rept. No. B240B63. Victoria, B.C.

Hay, D. and J.P. Secter. 1978. A development case history, Oyster River, B.C. Coastal Zone 78. p. 1419-1431. Preceedings of Symposium on Technical, Environmental, Socio-economic and Regulatory Aspects of Coastal Zone Management, San Francisco, California, 14-16 March 1978. Am. Soc. Civil Eng. New York, N.Y.

Holland, S.S. 1964. Landforms of British Columbia. A physiographic outline. British Columbia Department of Mines and Petroleum Resources. Bull. 48. 138 p.

James, A.R.C. 1969. The coalfields of Vancouver Island. British Columbia Dept. of Mines and Petroleum Resources Victoria, B.C. 39 p. (unpublished report)

Keser, N. and D. St. Pierre. 1973a. Soils of Vancouver Island-a compendium. British Columbia Forest Service, Research Note No. 56. Victoria, B.C.

____. 1973b. System of soil classification for Canada. Appendix B. *In:* Soils of Vancouver Island. British Columbia Forest Service, Research Division, Research Note No. 56. Victoria, B.C. 10 p.

Kulp, J.L. 1961. Geologic time scale. Science. 133: 1111.

Leaming, S.F. 1968. Sand and gravel in the Strait of Georgia area. Geol. Surv. Can. Paper 66-60. 142 p.

Levings, C.D. 1967. Grain size analysis for sediments from the Cape Lazo gully. Data from R. Sheldon. p. 59. *In:* Aspects of the life history of *Lycodopsis pacifica* (Collett) 1879. M. Sc. Thesis, University of British Columbia, Dept. Zoology, Vancouver, B.C. 81 p.

MacKenzie, J.D. 1922. The coal measures of Cumberland and vicinity, Vancouver Island. Trans. Can. Inst. Mining Met. 25: 382-411.

Mathews, W.H., J.G. Fyles and H.W. Nasmith. 1970. Postglacial crustal movements on southwestern British Columbia and adjacent Washington State. Can. J. Earth Sci. 7: 690-702.

McGugan, A. 1962. Upper Cretaceous foraminiferal zones, Vancouver Island, British Columbia, Canada. J. Alta. Soc. Petrol. Geol. II: 585-592.

___. 1964. Upper Cretaceous zone foramnifera, Vancouver Island, British Columbia. J. Paleontal. 38: 933-951.

Muller, J.E. 1965. Geology Comox Lake area, British Columbia. Geol. Surv. Can. Map 2-1965. Scale - 1 in. = 2 mi.

___. 1966. Central Vancouver Island area. Geol. Surv. Can. Paper 66-1. Report of activities May to October, 1965. p. 74-77. Department of Mines and Technical Surveys, Ottawa, Ont.

___. 1977a. Map of geology of Vancouver Island. Scale 1:250, 000 (3 sheets). Geol. Surv. Can. Open File, Vancouver, B.C.

___. 1977b. Geology of Vancouver Island field trip 7: Guide-book for joint annual meeting of the Geological Association of Canada and the Mineralogical Association of Canada held in Vancouver, B.C. April 21-24, 1977 54 p.

___, and M.E. Atchison. 1971. Geology, history and potential of Vancouver Island coal deposits. Geol. Surv. Can. Paper 70-53. 50 p.

___, and D.J.T. Carson. 1969. Geology and mineral deposits of Alberni map area, British Columbia (92F). Geol. Surv. Can. Paper 68-50. 52 p.

___, and J.A. Jeletzky. 1970. Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia. Geol. Surv. Can. Paper 69-25. 77 p.

Newberry, J.S. 1857. Report on the geology of the route of Williamson's survey in California and Oregon. U.S. Pacific Railway Expl. Part. 2. p. 5-68.

Northcote, K.E. 1973. The bedrock geology of Vancouver Island. *In:* Soils of Vancouver Island by N. Keser and D. St. Pierre. British Columbia Forest Service, Research Note No. 56. Victoria, B.C. 6 p.

Richardson, J. 1871. Coalfields Nanaimo, Comox. Geol. Surv. Can. Map 87, Rept. of Progress 1871-1872. Scale, 1 in. = 10 mi.

___. 1872. Coalfields of the east coast of Vancouver Island. Geol. Surv. Can. Rept. of Progress 1871-1872, Part 2: 73-100.

___. 1873. Coalfields of Vancouver Island. Geol. Surv. Can. Rept. of Progress 1872-1873. Part 4: 32-65.

___. 1878. Coalfields of Nanaimo, Comox, Cowichan, Burrard Inlet and Sooke, British Columbia. Geol. Surv. Can. Rept. of Progress 1876-1877. Part 7: 160-192.

Sheldon, R.W. and P.J. Warren. (unpublished manuscript). The distribution of the shrimp *Pandalus jordani* in relation to sediment at Comox, Vancouver Island. Senior author now at Marine Ecology Laboratory, Bedford Institute, Dartmouth, N.S. 18 p.

Tiffin, D.L. 1969. Continuous seismic profiling in the Strait of Georgia, British Columbia. Ph.D. Thesis, University of British Columbia, Vancouver, B.C. 177 p.

Usher, J.L. 1949. The stratigraphy and paleontology of the Upper Cretaceous rocks of Vancouver Island, British Columbia. Ph. D. Thesis, McGill University, Montreal, P.Q.

___. 1952. Ammonite faunas of the Upper Cretaceous rocks of Vancouver Island, British Columbia. Geol. Surv. Can. Bull. 21.

Waldichuk, M. 1953. Oceanography of the Strait of Georgia. III. Character of the bottom. Fish. Res. Board Can. Pacific Progress Rept. No. 95. p. 59-63.

___, J.H. Meikle, and J.R. Markert. 1968. Physical and chemical oceanographic data from the east coast of Vancouver Island 1954-1966. Vol.1. Discovery Passage-Duncan Bay and Baynes Sound-Comox Harbour. Fish. Res. Board Can. MS. Rept. No. 989. 133 p.

Whiteaves, J.F. 1879. On the fossils of the Cretaceous rocks of Vancouver and adjacent islands in the Strait of Georgia. Geol. Surv. Can. Mesozoic Fossils 1: 93-190.

Whiteaves, J.F. 1895. On some fossils from the Nanaimo Group of the Vancouver Cretaceous. Trans. Roy. Soc. Can. Ser. 2. IV: 119-153.

Yole, R.W. 1969. Upper Paleozoic stratigraphy of Vancouver Island, British Columbia. Geol. Assoc. Can. Proc. 20: 30-40.

III. CLIMATOLOGY

Ackerman, E.A. 1941. The Koppen classification of climate in North America. Geog. Rev. 31: 105-111.

Barker, M.L. 1974. Climate - Strait of Georgia. *In:* Water resources and related land uses, Strait of Georgia - Puget Sound basin. Geog. Paper 56. Environment Canada, Lands Directorate, Ottawa, Ont. p. 6-10.

Bell, L.M. and R.J. Kallman. 1976. The Cowichan-Chemainus River estuaries. Status of environmental knowledge to 1975. Special Estuary Series No. 4. Environment Canada, Fisheries and Marine Service, Pacific Environment Institute, West Vancouver, B.C. 324 p.

Brink, V.C. 1953. Climates of British Columbia for agrologists. University of British Columbia. Agronomy Dept. Technical Communication (mimeographed), Vancouver, B.C.

British Columbia Department of Agriculture. 1967. Atlas of climatic resources of British Columbia. Canada Land Inventory, unpublished MS. maps, Victoria, B.C.

___. 1971. Tables of temperature and precipitation. Climatic normals 1941-1970, extremes of record. Publications Branch, Victoria, B.C. 90 p.

___.1972. Climate capability classification for agriculture. Climatology Rept. No. 1. Second edition. British Columbia Land Inventory, Victoria, B.C. 11 p.

___. 1975. Climate of British Columbia. Tables of temperature, precipitation and sunshine. Rept. for 1973. Publications Branch, Victoria, B.C. 59 p.

___. 1976a. Climate of British Columbia. Tables of temperature, precipitation and sunshine. Rept. for 1974. Publications Branch, Victoria. B.C. 83 p.

___. 1976b. Climate of British Columbia. Tables of temperature, precipitation and sunshine. Rept. for 1975. Based on data compiled by Canada Dept. Environment, Atmospheric Environment Service, Vancouver, B.C. Published by the British Columbia Department of Agriculture, Victoria, B.C. 85 p.

British Columbia Department of Lands. 1952. Summary of snow survey measurements in British Columbia 1932-1952. Water Rights Branch, Victoria, B.C.

Canada Department of the Environment. Monthly record of meteorological observations in Canada. Atmospheric Environment Service, Downsview, Ont.

Canada Department of the Environment. 1966. The climates of Canada for agriculture. The Canada Land Inventory. Rept. No. 3. Queen's Printer, Ottawa, Ont.

___. 1971a. Nanaimo River estuary - available weather data. Input to the Estuary Working Group from Atmospheric Environment Service, Pacific Region, Pacific Environment Institute Files, West Vancouver, B.C. 6 p.

___. 1971b. Temperature and precipitation: 1941-1970 (British Columbia). Atmospheric Environment Service, Downsview, Ont. 78 p.

___. 1973. Courtenay River estuary - available weather data. Input to the Estuary Working Group from Atmospheric Environment Service, Pacific Region, Pacific Environment Institute files, West Vancouver, B.C.

___. 1975a. Annual meteorological summary. (annual). Atmospheric Environment Service, Downsview, Ont.

___. 1975b. Canadian normals: Vol. 1, Temperature (1941-1970), Vol. 2, Precipitation (1941-1970), Vol. 3, Wind (1955-1972). *Ibid.*, 139 p.

___. 1976. Climatological station data catalogue, British Columbia. *Ibid.*, 86 p.

Chapman, J.D. 1952. The climate of British Columbia. *In:* Transactions of the 5th British Columbia Natural Res. Conference, Victoria, B.C. p. 8-54

Connor, A.J. 1949. Frost free season in British Columbia. Meteorological Division, Department of Transport, Ottawa, Ont.

Dayton and Knight Limited. 1972. Greater Campbell River Water District, water supply survey, West Vancouver, B.C. Rept. prepared by Dayton and Knight Ltd. for the Regional District of Comox-Strathcona, Courtenay, B.C. 44 p. plus appendicies.

Denike, C.C.E. 1968. A bibliography of climatology for British Columbia, A.L. Farley (ed.) Rept. prepared by University of British Columbia, Dept. Geography, Vancouver, B.C. for the Canada Land Inventory, A.R.D.A., Victoria, B.C. 70 p.

Emslie, J. (pers. comm.), Meteorologist, Scientific Services, Atmospheric Environment Service, Vancouver, B.C.

Farley, A.L. (ed). 1968. A bibliography of climatology, British Columbia. Rept. prepared by A.L. Farley, University of British Columbia, Dept. Geography, For Canada Land Inventory A.R.D.A. Vancouver, B.C. 70 p.

Ferguson, H.L., H.I. Hunter and D.S. Schaefer. 1974. The IHD mountain transects project, Beaufort Range, Vancouver Island, part I and part II. Canadian Meteorological Research Rept. CMRR 3/74 and 1/75. Environment Canada, Atmospheric Environment Service, Downsview, Ont.

Hemmerick, G.M. and G.R. Kendall. 1972. Frost data 1941-1970. Canadian Department of the Environment, Atmospheric Environment Service CL1 5-72. Downsview, Ont. 19 p.

Kendrew, W.G. and D. Kerr. 1955. The climate of British Columbia and the Yukon Territory. Queen's Printer. Ottawa, Ont. 222 p.

Keser, N. and D. St. Pierre. 1973. Climate of Vancouver Island. *In:* Soils of Vancouver Island - a compendium. British Columbia Forest Service Research Note No. 56. Victoria, B.C.

Ministry of the Environment. (annual). British Columbia snow survey bulliten. Published February to June, incl. Uater Investigations Branch, Victoria, B.C.

Nikleva, S. (pers. comm.). Meteorologist. Canada Department of the Environment, Atmospheric Environment Service, Scientific Services, Vancouver, B.C.

Trewartha, G.T. 1943. An introduction to weather and climate. 2nd. Edition. McGraw-Hill Book Company Inc., New York and London. 4th Edition, 1968. 408 p.

Waldichuk, M. MS. 1962. Oceanographic characteristics of Comox Harbour and approaches in relation to sea disposal of sewage. Fish. Res. Board Can. Unpubl. MS. Pacific Biological Station, Nanaimo, B.C. 37 p. plus figures.

Yorke, B.C. and G.R. Kendall. 1972. Daily bright sunshine 1941-1970. Canada Department of the Environment, Atmospheric Environment Services Circ. No. CLI-6-72. Downsview, Ont.

IV. HYDROLOGY

Acres Consulting Services Limited. 1973. Proposed Puntledge salmon hatchery feasibility report. Rept. prepared by Acres Consulting Services Ltd. for Environment Canada, Fisheries and Marine Service, Vancouver, B.C. 45 p.

Associated Engineering Services Limited (AESL). 1975. Regional water study. School District 71. Rept. prepared by AESL, Vancouver, B.C. for the Regional District of Comox-Strathcona, Courtenay, B.C. 92 p.

___. 1976. Wolf Lake study. Rept. prepared by AESL for Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C.

Bams, R. 1973. (memo to W. Crouter). Re: Amount of water required for pink salmon to utilize the Tsolum River. Canada Department of the Environment, Fisheries and Marine Service, Records Section, Tsolum River Stream Obstruction File, Vancouver, B.C.

Bond, K. (pers. comm.). Habitat Protection Technician, Ministry of Environment, Fish and Wildlife Branch, Campbell River, B.C.

British Columbia Hydro and Power Authority. 1977. Operation order manual No. 412. Nanaimo, B.C.

British Columbia Water Resources Service. 1968. Preliminary report on Tsolum River flooding, erosion and irrigation. Department of Lands, Forests and Water Resources, Water Investigations Branch, Water Investigation File No. P73-31. Victoria, B.C.

Canada Department or the Environment. 1972a. Historical streamflow summary of British Columbia to 1970. Water Survey of Canada, Inland Waters Directorate, Ottawa, Ont. 394 p.

___. 1972b. Magnitude of floods in British Columbia. Water Survey of Canada, Inland Waters Directorate, Vancouver, B.C. 367 p.

___. 1973a. Annual narrative report for Comox-Parksville Sub-District, Statistical Area 14. Fisheries and Marine Service, Fisheries Operations Branch. Unpubl. Vancouver, B.C. 22p.

___. 1973b. Courtenay River estuary - available hydrological data. Input to the Estuary Working Group from Water Survey of Canada, Inland Waters Directorate, Pacific Environment Institute Files, West Vancouver, B.C. 5 p.

Canada Department of the Environment. 1973c. Reference Index Canada, 1972. Hydrometric map supplement showing locations of active and discontinued hydrometric stations. Water Survey of Canada, Inland Waters Directorate, Ottawa, Ont. 6 maps including British Columbia.

___. 1974. Historical streamflow summary, British Columbia to 1973. *Ibid.* 694 p.

___. 1975a. Surface water data, British Columbia, 1974. *Ibid.* 338 p.

___. 1975b. Surface water data reference index, Canada. 1975. *Ibid.* 276 p.

___. 1976a. Surface water data, British Columbia. 1975. *Ibid.* 38 p.

___. 1976b. Surface water data, British Columbia. Water Survey of Canada, Inland Waters Directorate, Vancouver, B.C. (Unpubl. data).

Canada Department of Fisheries. 1958. The fisheries problems associated with the power development of the Puntledge River, Vancouver Island, B.C. Canada Department of Fisheries, Vancouver, B.C. 40 p. plus appendices and figures.

DeMong, R. (pers. comm.). District Agriculturalist, Ministry of Agriculture, Courtenay, B.C.

Fuller, R. (pers. comm.). Assistant Planner, Regional District of Comox-Strathcona, Courtenay, B.C.

Johnston, I.L. 1954. Water resources investigation: report on Courtenay-Comox area flooding. British Columbia Department of Lands, Forests and Water Resources, Water Investigations Branch, Rept. No. 155. Reports Library, Victoria, B.C.

___. 1954. *Ibid.* Rept. No. 156. Reports Library, Victoria, B.C.

Kreuder, W.L. (pers. comm.). Inland Waters Directorate, Environment Management Service, Vancouver, B.C.

Marshall, D.E. 1974. Review of minimum fisheries flow requirements for the Puntledge River. Unpubl. memorandum. Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C. 14 p.

Marzocco, E. (pers. comm.). Production Manager, British Columbia Hydro and Power Authority, Nanaimo, B.C.

McKinnon, C. (pers. comm.). Salmon Enhancement Biologist, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

Ministry of Environment. (annual). British Columbia snow survey bulletin. Published February to June, incl. Water Investigations Branch, Victoria, B.C.

Nuttall, J.B. 1957. Puntledge River hydraulic aspects. British Columbia Power Commission, Victoria, B.C.

Pollard, R.A. 1959. Water resources investigation: preliminary report on Comox flooding. British Columbia Department of Lands, Forests and Water Resources, Water Investigations Branch, Rept. No. 172, Reports Library, Victoria, B.C.

Robertson, A.R.D. (unpublished). Preliminary report on Tsolum River flooding, erosion and irrigation investigation. British Columbia Department of Lands, Forests and Water Resources, Water Investigations Branch, Rept. No. 1484. Reports Library, Victoria, B.C. 8 p.

Windsor, J.S. 1954. Report on the fisheries problems of the Puntledge River. British Columbia Power Commission, Planning Committee manuscript, Victoria, B.C. 17 p. plus appendices.

Wright, R. (unpublished). The Oyster River. Regional District of Comox-Strathcona, Planning Division, Courtenay, B.C. 5 p.

V. OCEANOGRAPHY

Anderson, E.P. 1975. The field of motion of water in the vicinity of Cape Lazo. Dobrocky Seatech Limited, Victoria, B.C. Submitted to the Environmental Protection Service, Pacific Region, Environment Canada, Vancouver, B.C. 23 p.

Anderson, L.S. 1960. Toxic shellfish in British Columbia. Am. J. Publ. Health, 50: 71-83.

Berzins, A. (pers comm). Dayton and Knight Limited. Consulting Engineers, 1865 Marine Drive, Box 91247, West Vancovuer, B.C. 272 3N9.

Bowering, R. 1943. Bacteriological and float survey in Comox Harbour, 26 March and 3 September 1943, 12 April 1949. Division of Public Health Engineering, British Columbia Department of Health and Welfare, Victoria, B.C.

Canadian Department of the Environment. 1976. Sailing Directions British Columbia (South Portion). Volume I. Tenth Edition. Hydrographic Chart Distribution Office, Department of the Environment, Ottawa, Canada. 399 p.

Canadian Department of Fisheries and the Environment. 1977. Canadian Tide and Current Tables. Volume 5. Juan de Fuca and Georgia Straits. Fisheries and Marine Service, Canadian Hydrographic Service, Hydrographic Chart Distribution Office, Ottawa, Canada. 95 p.

Clague, J.J. 1976. Sedimentology and geochemistry of marine sediments near Comox, British Columbia. Energy, Mines and Resources Canada, Geological Survey Paper 76-21. 21 p.

Drinnan, R.W., and I. Webster. 1975. Comox Harbour Provincial Interagency Study. Program 3: Tasks 1 and 2. Oceanography and Water Quality. Appendix D *In:* Environment and Land Use Committee Secretariat. Summary Report on Water Quality Evaluation of Comox Harbour and Associated Environs. Pollution Control Branch, British Columbia Water Resources Service, B.C. Department of Lands, Forests and Water Resources, Victoria, B.C.

Giovando, L.F., and H.J. Hollister. 1974. Observations of seawater temperature and salinity at British Columbia shore stations 1973. Environment Canada. Fisheries and Marine Service, Marine Sciences Directorate, Pacific Marine Sciences Report 74-11. 107 p.

Hay, D., and J.P. Secter. 1978. A development case history, Oyster River, B.C., p. 1419-1431. *In:* Coastal Zone '78. Symposium on Technical, Environmental, Socioeconomic and Regulatory Aspects of Coastal Zone Management, San Francisco, Calif. 14-16 March 1978. Vol. II. American Society of Civil Engineers, New York, N.Y. 10017.

Higgs, T.W. 1976. Sanitary survey of the Municipality of the District of Campbell River, British Columbia, 1976. Pollution Abatement Branch, Environmental Protection Service, Pacific Region, Environment Canada, Vancouver, B.C. Surveillance Report EPS 5-PR-76-5.

Hollister, H.J. 1974. Observations of seawater temperature and salinity at British Columbia shore stations 1972. Environment Canada, Fisheries and Marine Service, Marine Sciences Directorate, Pacific Region, Pacific Marine Science Report 74-1. 105 p.

___., and A.M. Sandnes. 1972. Sea surface temperatures and salinities at shore stations of the British Columbia Coast 1914-1970. Environment Canada, Fisheries and Marine Service, Marine Sciences Directorate, Pacific Region, Pacific Marine Science Report 72-13. 92 p.

Kay, B., and T.J. Tevendale. 1974. Shellfish growing water sanitary survey of Comox Harbour area, British Columbia. Pollution Abatement Branch, Environmental Protection Service, Pacific Region, Environment Canada, Vancouver, B.C., Surveillance Report EPS 5-PR-74-13. 48 p.

Kennedy, O.D. (unpublished data). The "Plankton Watch" in Baynes Sound, April 1977-. Pacific Biological Station, Nanaimo, B.C.

Sheldon, R.W., and P.J. Warren. MS. Unpublished. The distribution of the shrimp *Pandalus jordani* in relation to sediment at Comox, Vancouver Island. Marine Ecology Laboratory, Bedford Institute of Oceanography, Dartmouth, Nova Scotia B2Y 4A2.

Tevendale, T.J. 1974a. Shellfish growing water sanitary survey of Denman Island. Pollution Abatement Branch, Environmental Protection Service, Pacific Region, Environment Canada, Vancouver, B.C., Surveillance Report EPS 5-PR-74-9.

___. 1974b. Shellfish growing water survey of Baynes Sound, Gartley Point to Deep Bay. Pollution Abatement Branch, Environmental Protection Service, Pacific Region, Environment Canada, Vancouver, B.C., Surveillance Report EPS 5-PR-74-10.

Waldichuk, M. 1953. Oceanography of the Strait of Georgia. III Character of the bottom. Fish. Res. Board Can. Pacific Prog. Rept. No. 95: 59-63.

___. 1957. Physical oceanography of the Strait of Georgia, British Columbia. J. Fish. Res. Board Can. 14: 321-486.

___. 1958. Shellfish toxicity and the weather in the Strait of Georgia during 1957. Fish. Res. Board Can., Pacific Prog. Rept. No. 112: 10-14.

___. MS, 1962. Oceanographic characteristics of Comox Harbour and approaches in relation to sea disposal of sewage. Fish. Res. Board Can., Biological Station, Nanaimo, B.C., Unpublished Manuscript on file. 49 p.

___. 1974. Application of oceanographic information to the design of sewer and industrial waste outfalls. Rapp. P. -v. Réun. Cons. int. Explor. Mer. 167: 236-259.

___., and J.H. Meikle. MS, 1969. Physical and chemical oceanographic data for Comox Harbour and Baynes Sound, 5-7 August 1969. Unpublished data on file, Pacific Environment Institute, West Vancouver, B.C.

___., J.H. Meikle and J.R. Markert. 1968. Physical and chemical oceanographic data for the east coast of Vancouver Island, 1954-1966. Volume I, Discovery Passage-Duncan Bay and Baynes Sound-Comox Harbour. Fish. Res. Board Can., Manus. Rept. No. 989. 133 p.

Waldie, R.J. 1951. Winter oceanography of Baynes Sound and the Lazo Bight. Fish. Res. Board Can., Pacific Biological Station, Nanaimo, B.C., Manus. Rept. No. 441. 9 p. plus 15 figures.

VII. FISH

Acres Consulting Services Limited. 1973. Proposed Puntledge salmon hatchery feasibility report. Rept. prepared by Acres Consulting Services Ltd. for Environment Canada, Fisheries and Marine Service, Vancouver, B.C. 45 p.

Anderson, A.D. 1973. The 1973 report on chum salmon stocks of the Johnstone Strait - Fraser River study area. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-73-9. Southern Operations Branch, Vancouver, B.C.

____. 1975. The 1974 return of chum salmon stocks to the Johnstone Strait - Fraser River study area, and prospects for 1975. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-75-14. Southern Operations Branch, Vancouver, B.C. 18 p.

____. 1976. The 1975 return of chum salmon stocks to the Johnstone Strait - Fraser River study area, and prospects for 1976. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-76-17. Southern Operations Branch, Vancouver, B.C. 12 p.

____. 1977. The 1976 return of chum salmon stocks to the Johnstone Strait - Fraser River study area, and prospects for 1977. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-77-12. Southern Operations Branch, Vancouver, B.C. 19 p.

____., and D.D. Bailey. 1974. The 1973 return of pink salmon stocks to the Johnstone Strait - Fraser River study area, and prospects for 1974. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-76-17. Southern Operations Branch, Vancouver, B.C. 11 p.

Anon. 1974. Coded wire tag use report. Washington Department of Fisheries, Hatchery Division, Pacific Coast. Unpubl. MS. 85 p.

Anon. 1975. Codes wire tag use report. Pacific coast. Washington Department of Fisheries, Hatchery Division, Pacific Coast. Unpubl. MS. 149 p.

Anon. 1976. Pacific coast coded wire tag use report for 1976. Oregon Department of Fish and Wildlife, Regional Mark Processing Center. Unpubl. MS. 56 p.

Anon. 1977. Pacific coast coded wire tag use report for 1977. Oregon Department of Fish and Wildlife, Regional Mark Processing Center, Unpubl. MS. 89 p.

Anon. 1975a. 1973. Results from micro-tagged salmon experimental groups. Washington Department of Fisheries. 170 p.

Anon. 1976a. 1974. Results from micro-tagged salmon experimental groups. *Ibid.* 324 p.

Anon. 1977a. 1975. Results from micro-tagged salmon experimental groups. *Ibid.* 477 p.

Anon. 1978. 1976. Results from micro-tagged salmon experimental groups. *Ibid.* 488 p.

Argue, A.W. 1976. Preliminary information from the 1973 and 1974 Canadian chinook and coho catch sampling and mark recovery programs. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-76-9. Southern Operations Branch, Vancouver, B.C. 32 p.

___., and S.R. Heizer. 1974. Distribution maps and tables for tag recoveries from 1963-1969 coho and chinook taggings in B.C. Canada Department of the Environment, Fisheries and Marine Service Data Record Ser. PAC/D-741. Southern Operations Branch, Vancouver, B.C. 309 p.

___., and D.E. Marshall. 1976. Size and age of chinook and coho salmon for subdivisions on the Strait of Georgia troll fishery, 1966. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-76-18. Field Operations Directorate, Vancouver, B.C. 175 p.

___., and K.R. Pitre. 1972. Distribution of commercial and sport vessels fishing Pacific salmon in southern B.C. marine waters, based on overflights from 1965-1971. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 1972. 95 p. plus maps.

___., J.C. Coursley and G.D. Harris. 1977. Preliminary revision of Georgia Strait and Juan de Fuca Strait tidal salmon sport catch statistics, 1972 to 1976, based on Georgia Strait head recovery program data. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-77-16. Field Operations Directorate, Vancouver, B.C. 68 p.

Aro, K.V. and M.P. Shepard. 1967. Spawning populations of north Pacific salmon - Pacific salmon in Canada. *In* International North Pacific Fisheries Commission, Bull. 23, 1967, by Aro, K.V., and M.P. Shepard. Fish. Res. Board Can., Pacific Biological Station, Nanaimo, B.C.

Associated Engineering Limited (AESL). 1975. Regional water supply study. School District 71. Rept. prepared by AESL, Victoria, B.C. for the Regional District of Comox-Strathcona, Courtenay, B.C. 92 p.

Axford, R. 1976. Puntledge River swim observations. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 3 p.

Bams, R.A. 1972. A quantitative evaluation of survival to the adult stage and other characteristics of pink salmon (*Onchorynchus gorbuscha*) produced by a revised hatchery method which simulates optimal natural conditions. J. Fish. Board Can. 29: 1151-1167.

___. 1973a. Evaluation of gravel incubators on first "hatchery" generation Tsolum River pink salmon, 1970-1972. Part I: Evaluation at the fry stage. Fish. Res. Board Can. Tech. Rept. No. 369. Pacific Biological Station, Nanaimo, B.C. 18 p.

___. 1973b. Evaluation of gravel incubators on first "hatchery" generation Tsolum River pink salmon 1970-1972. Part II: Evaluation at the adult stage. Fish. Res. Board Can., Tech. Rept. No. 405. Pacific Biological Station, Nanaimo, B.C. 17 p.

___. 1974. Gravel incubators: a second evaluation on pink salmon, *Onchorynchus gorbuscha*, including adult returns J. Fish. Res. Board Can. 31: 1379-1385.

___. 1976a. Survival and propensity for homing as affected by presence or absence of locally adapted paternal genes in two transplanted populations of pink salmon (*Onchorynchus gorbuscha*). J. Fish. Res. Board. Can. 33: 2716-2725.

___. 1976b. Results of pink salmon transplant using males native to the recipient stream. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 452. Pacific Biological Station, Nanaimo, B.C. 46 p.

___. and D.G. Crabtree. 1976. A method for pink salmon propogation: the Headquarters Creek experimental hatchery 1968-1974. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 627. Pacific Biological Station, Nanaimo, B.C. 70 p.

Beamish, R.J. (pers. comm.). Groundfish Biologist, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

Beamish, R.J. and M.S. Smith. 1976. A preliminary report on the distribution, abundance and biology of juvenile spiny dogfish (*Squalus acanthias*) in the Strait of Georgia and their relationship with other fishes. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 629. Pacific Biological Station, Nanaimo, B.C. 44 p.

___, J.R. Scarsbrook and F.P. Jordan. 1976. A bottom trawl study of Pacific hake and walleye pollock along the inshore areas adjacent to Vancouver Island in the Strait of Georgia. Date Record No. 4. Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C. 67 p.

Bell, G.R. and G.E. Hoskins. 1971 Investigations of wild fish mortalities in B.C. 1969-1970. Fish.Res. Board Can. Tech. Rept. No. 245. Pacific Biological Station, Nanaimo, B.C. 19 p.

Bell, L.M. and J.M. Thompson. 1977. The Campbell River estuary: Status of environmental knowledge to 1977. Special Estuary Series No. 7. Canada Department of the Environment, Fisheries and Marine Service, Pacific Environment Institute, West Vancouver, B.C. 346 p.

___, and R. Kallman. 1976. The Nanaimo River estuary Status of environmental knowledge to 1976. Special Estuary Series No. 6. *Ibid.* 297 p.

___. 1976. The Kitimat River estuary: Status of environmental knowledge to 1977. Special Estuary Series No. 5. *Ibid.* 295 p.

Bell-Irving (pers. comm.). Habitat Protection Biologist Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

Bilton, T.G. 1978. Coho salmon growth acceleration. Canada Department of the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C. 3 p. (unpublished).

___, and D.W. Jenkinson. 1976. Time and size at release experiment: three releases of three major size categories of juvenile coho salmon from Rosewall Creek in the spring of 1975. Fisheries and Marine Service, Data Record No. 7. Pacific Biological Station, Nanaimo, B.C. 16 p.

Bourque, S.C. and K.R. Pitre. 1972. Tag and recovery information for coho and chinook tagged off the lower west coast of Vancouver Island in 1969 and 1971. Canada Department of the Environment, Fisheries and Marine Service, MS.Rept. 1972-1975. Pacific Region. 113 p.

Boyd, R. (pers. comm.) Biologist. Fisheries and Environment Canada, Fisheries and Marine Service, Vancouver, B.C.

British Columbia Department of Recreation and Conservation. 1962. Submission to the Puntledge River inquiry. Fish and Wildlife Branch, Nanaimo, B. C. 8 p. plus appendices.

___. 1973. Stream surveys. Fish and Wildlife Branch, Nanaimo, B.C.

___. 1973. Oyster River swim survey. Fish and Wildlife Branch. Nanaimo, B.C.

___. (annual). Steelhead harvest analysis. Fish and Wildlife Branch. Victoria, B.C.

British Columbia Power Commission. 1960. Submission to the British Columbia Energy Board regarding fishery protection problems at the B.C. Power Commissions's Puntledge River generating plant, Victoria, B.C. 14 p.

Brown, R.G., V.D. Chahley, and D.G. Demontier. 1977. Preliminary catalogue of salmon streams and spawning escapements of Statistical Area 14 (Comox-Parksville). Canada Department of Fisheries and the Environment. Fisheries and Marine Service Tech. Rept. No. PAC/D-77-12. 128 p. Plus maps and tables.

Burns, J.E. (1976). Comox Harbour. A plan for conservation. Prepared for the Ministry of Environment, Lands Branch, Environmental Service Unit, Victoria, B.C. 57 p.

Canada Department of the Environment. 1973. Proposed Puntledge salmon hatchery. Summary report presented to Dec. 3, 1973 meeting between B.C. Hydro and Fisheries. Fisheries and Marine Service, Fisheries Operations Files, Vancouver, B.C. 5 p.

___. 1970. Annual narrative report for Comox-Parksville Sub-district, (Statistical Area 14), Fisheries and Marine Service, Operations Branch, Vancouver, B.C. 26. p.

___. 1971. Annual narrative report for Comox-Parksville Sub-district, (Statistical Area 14), *Ibid.* 18 p.

___. 1972. Annual narrative report for Comox-Parksville Sub-district, (Statistical Area 14), *Ibid.* 18 p.

___. 1973. Annual narrative report for Comox-Parksville Sub-district, (Statistical Area 14), *Ibid.* 22 p.

Canada Department of the Environment. 1976. Annual report for Comox-Parksville Sub-district, (Statistical Area 14), *Ibid.* 6 p.

___. (annual). Commercial fishery statistics - 1A worksheets, computation of landed values for Conservation District No. 3, (Statistical Area 14), Fisheries and Marine Service, Economics Branch, Vancouver, B.C.

___. (annual). Brief history by years covering salmon fishing activity, closures applied, escapement and general remarks for 1971-1976. (Statistical Area 14). Fisheries and Marine Service, Vancouver, B.C.

Canada Department of Fisheries. 1958. The fisheries problem associated with the power development of the Puntledge River, Vancouver Island, B.C. Canada Department of Fisheries, Vancouver, B.C. 40 p.

___. (unpublished). Puntledge River inquiry rebuttal by Department of Fisheries, Canada, March 29, 1962. Paper addressed to Dr. H.F. Angus, Commissioner and submitted by W.R. Hourston, Area Director. Fisheries and Marine Service, Fisheries Operations Files, Vancouver, B.C. 215 p.

Canada Department of Fisheries and the Environment. 1977a. British Columbia tidal waters sport fishing guide 1977. (pamphlet). Marine Resources Service, Vancouver, B.C.

___. 1977b. British Columbia catch statistics by area and type of gear (as reported on sales slips received by the department). Canada Department of the Environment, Fisheries and Marine Service, Fisheries Management, Vancouver, B.C. 215 p.

___. (annual). Salmon sport fishing catch statistics for B.C. tidal waters. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

___. 1978b. Georgia Strait salmon head recovery program. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Bull. 1-40. Vancouver, B.C.

___. 1978c. Report on potential Pacific coast oil ports. By Working Group on west coast deep water oil ports. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

Cook, R.J. and S.R. Heizer. 1978. Basic data for the 1976 Canadian chinook and coho catch sampling and mark recovery program. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Data Report No. 58. Field Services, Vancouver, B.C. 2681 p.

Cooper, E.L. 1970. Growth of cutthroat trout (salmo clarki) in Chef Creek, Vancouver Island, B.C. J. Fish. Res. Board Can. 27: 2063-2070.

Crouter, R.A. 1976. Memo re: Trawl net fishing - Baynes Sound and Ballenas Island, Union Bay, Cape Lazo, Hornby Island, Nanoose Bay and Satellite Channel Areas - District No. 3., B.C. 1976-1977. Fisheries and Marine Service, Field Operations Directorate, Pacific Region, Vancouver, B.C. 4 p.

DeLacy, A.C. and F. Neave. 1947. Migration of pink salmon in southern British Columbia and Washington in 1945. Biological Board of Canada, Bull. No. 74. 11 p.

Enhancement Services Branch. 1977. Salmonid enhancement program, annual report 1977. Canada Department of Fisheries and Environment, Enchancement Services Branch, Vancouver, B. C. 84 p.

EPEC Consulting Western Limited. 1975. Coal resource study of Comox Basin - Nanaimo Series, Vancouver Island, British Columbia. Preliminary environmental assessment Vol. 7. Rept. prepared by EPEC Consulting Western Ltd., Edmonton, Alta. for Weldwood of Canada, Vancouver, B.C. 186 p.

Forrester, C.R. 1969. Life History information on some groundfish species. Fish. Res. Board Can. Tech. Rept. No. 105. Pacific Biological Station, Nanaimo, B.C. 17 p.

___. and D.M. Holmberg. 1967. A summary report on the British Columbia trawl fishery in 1966 and some aspects of its investigation. Fish. Res. Board Can. Tech. Rept. No. 19. Pacific Biological Station, Nanaimo, B.C. 32 p.

___. and K.S. Ketchen. 1963. A review of the Strait of Georgia trawl fishery. Fish. Res. Board Can., Bull. No. 139. Pacific Biological Station, Nanaimo, B.C. 81 p.

___. and J. E. Prest. 1968. A summary report of the British Columbia trawl fishery in 1967 and some aspects of its investigation. Fish. Res. Board Can. Tech. Rept. No. 89. Pacific Biological Station, Nanaimo, B.C. 29 p.

___. and J.E. Smith. 1974. The trawl fishery of the Strait of Georgia and vicinity, 1960-1972. Fish. Res. Board Can. Circ. 96. Nanaimo, B.C. 47 p.

Genoe, H.S. (pers. comm.). Fisheries and Environment Canada, Puntledge River Hatchery, Senior Assessment Technician, Southern Operations Branch, Courtenay, B.C.

Godfrey, H. 1968. Some observations on juvenile marine chinook and coho salmon taken in waters adjacent to Georgia Strait in 1965. Fish. Res. Board Can. MS. Rept. Serv. No. 955. Pacific Biological Station, Nanaimo, B.C. 19 p.

Goodman, D. 1974. An assessment of the impact of a proposed access channel and breakwater on the fisheries resources of the Oyster River. Canada Department of the Environment, Fisheries and Marine Service. Tech. Rept. No. PAC/T-74-4. Vancouver, B. C. 51 p.

Harris, G. (pers. comm.). Technician for the Head Recovery Program. Fisheries and Marine Service, Vancouver, B.C.

Harrison, M.C. 1975. Resident boating on the west and northwest coasts of Vancouver Island, Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-75-13. 79 p.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can. Bull. No. 180. Ottawa, Ont. 740 p.

Healey, M. 1978. Courtenay River and estuary sampling program. Canada Department of the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C. 3 p. (unpublished).

Hearnden E.H. 1978. (News release). Puntledge River hatchery contract awarded. Canada Department of Fisheries and Environment, Fisheries and Marine Service, Operations Branch, Vancouver B.C. 26 p.

Heizer, S.R. and A.W. Argue. 1972. Basic tag and recovery information for coho and chinook salmon taggings conducted in the Strait of Georgia and Johnstone Strait in 1970 and 1971. Canada Department of the Environment, Fisheries and Marine Service MS. Rept. 1972-1973. 187 p.

___. 1976. Basic catch sampling and coded wire tag recovery data for Georgia Strait chinook and coho fisheries in 1973. Canada Department of Fisheries and the Environment, Fisheries and Marine Service Record Ser. No. PAC/D-76-9. 50 p.

Heizer, S.R. and J. Beukema. 1977. Basic data for the 1974 Canadian chinook and coho catch sampling and mark recovery program. Fisheries and Environment Canada, Fisheries and Marine Service Data Record Ser. No. PAC/D-77-6. Field Operations Directorate, Vancouver, B. C. 1573 p.

Heizer, S.R. Cook and A.W. Argue. 1978. Basic data for the 1975 Canadian chinook and coho catch sampling and mark recovery program. Canada Department of Fisheries and the Environment, Fisheries and Marine Service Data Rept. No. 57. Field Services, Vancouver, B.C. 2353 p.

Hoskins, G.E. and L.P. Hulstein. 1977. Diseases in fish from the Puntledge River system and Rosewell Creek since 1972. Annual report of the diagnostic service for 1975. Fisheries and Marine Service Tech. Rept. No. 707. Pacific Biological Station, Nanaimo, B.C.

Hourston, W,R, 1962. Brief outlining the need for fish protective facilities at the Puntledge River Hydro-electric Development. Canada Department of Fisheries and the Environment, Fisheries and Marine Service presented to Dr. H. F. Angus, Commissioner, Puntledge River. Inquiry by W. R. Hourston, Director, Vancouver, B.C. 34 p. plus appendices.

___. 1972. The herring fishery: Potential for expansion. Fisheries Service, Pacific Region. 11 p.

Humphreys, R.D. and L.A. Webb. 1970. The abundance of herring in the coastal waters of British Columbia. Canada Department of Fisheries and Forestry. Fisheries Service Tech. Rept. 1970-9. 22 p.

___. 1971. The abundance of herring spawn in coastal waters of British Columbia. Canada Department of Environment, Fisheries Service Tech. Rept. 1971-11. Vancouver, B.C. 26 p.

___. 1973. The abundance of herring spawn in coastal waters. of British Columbia. Canada Department of Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-73-10. Southern and Northern Operations Branch, Vancouver, B.C. 36 p.

Interim Planning Agreement Staff. 1974. A summary report of development possibilities in the Mid-Coast, Northern Vancouver Island and Queen Charlotte Island region of British Columbia. Prepared by the Interim Planning Agreement Staff, individuals from Canada Department of Regional Economic Expansion and British Columbia Department of Economic Development, for the British Columbia Department of Economic Development, Victoria, B. C. 175 p.

Jameson, E. and S. Warren. 1973. Estuary and watershed land status for selected river systems in British Columbia. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch. 30 p.

Ketchen, K.S. 1954. A report on the yield of the otter-trawl and hand-line fisheries of Georgia Strait in the fall and winter of 1951-52 and 1953-54. Fish. Res. Board Can. Circ. No. 61. Pacific Biological Station, Nanaimo, B.C.

____. 1955. The otter-trawl fishery in the Strait of Georgia. Fish. Res. Board. Can. Circ. No. 41. Pacific Biological Station, Nanaimo, B.C. 6 p.

____. 1961. Trawl mesh regulation in the Strait of Georgia. Fish. Red. Board Can. Pacific Biological Station, Nanaimo, B.C. 16 p.

Levings, C.D. 1967. Aspects of life history of *Lycodopsis pacifica* (Collett) 1879. MSc. Thesis, University of British Columbia, Dept. of Zoology. 81 p.

Lister, D.B. 1968. Progress report on assessment of the Puntledge River spawning channel. June 1965 to May 1968. Canada Department of Fisheries, Resource Development Branch, Vancouver, B.C. 17 p.

Lyons, C. 1974. (memo to P. Brady). Re: Oyster River channelization and fish populations. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

MacKinnon, C. 1977. Preliminary Puntledge River escapement, migration and spawning data to 1976. Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C. 10 p.

MacKinnon, C. (unpublished). Proposed biological program - Puntledge River hatchery 1978. Canada Department of the Environment, Fisheries and Marine Service, Enhancement Services Branch, Vancouver, B.C. 7 p.

MacKinnon, C., H. Genoe and D.C. Sinclair. (unpublished) Puntledge River Project 1972-1977. Canada Department of the Environment, Fisheries and Marine Service, Salmon Enhancement Branch, Vancouver, B.C. 61 p. plus appendices.

Manzer, J.I. 1969. Additional information on the migration of pink salmon in southern British Columbia and Washington in 1945 as shown by tagging. Fish. Res. Board. Can. MS. Rept. 1022. 6 p.

Marshall, D.E. 1973. Progress report on the Puntledge River program 1971 and 1972. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. 1973-8. Vancouver, B.C. 59 p.

Marshall, D.E. 1974. Review of minimum fisheries flow requirements for the Puntledge River. Unpbl. Memorandum. Canada Department of Environment, Fisheries and Marine Service, Vancouver, B.C. 14 p.

Mason, J.C. 1974a. Behavioral ecology of chum salmon fry (*Oncorhynchus keta*) in a small estuary. J. Fish. Res. Board Can. 31:83-92.

___. 1974b. Movements of fish populations in Lymn Creek, Vancouver Island: a summary from weir operations during 1971 and 1972 including comments on species life histories. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 483. Pacific Biological Station, Nanaimo, B.C. 35 p.

___. 1975. Seaward movement of juvenile fishes, including lunar periodicity in the movement of coho salmon (*Oncorhynchus kisutch*) fry. J. Fish. Res. Board Can. 32: 2542-2547.

___, and S. Machidori. 1976. Populations of sympatric sculpins, *Cottus aleuticus* and *C. asper*, in four adjacent salmon-producing coastal streams on Vancouver Island, B.C. J. Fish. Res. Board Can. Fishery Bull. 74: 131 138.

McInnes, B.E., F.W. Nash and H. Godfrey. 1974. A preliminary annotated bibliography on Gerogia Strait fishes. Fish. Res. Board Can. MS. Rept. Ser. No. 1332. Pacific Biological Station, Nanaimo, B.C. 215 p.

Meyer, P.A. and M.C. Harrison. 1976. Marina policy in the tidal area of the Pacific coast. A study of the recreational responsibilities of the Small Craft Harbours Branch, Environment Canada, Fisheries and Marine Service, Small Craft Harbours Branch, Vancouver, B.C. 39 p.

Ministry of Recreation and Conservation. 1978. British Columbia sport fishing regulations synopsis 1978/1979 for non-tidal waters. Fish and Wildlife Branch, Victoria, B.C. Queen's Printer. 19 p.

Mos, G. J. and M. C. Harrison. 1974. Resident boating in Georgia Strait. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-74-5. Vancouver, B.C. 75 p.

Narver, D. W. and F. C. Withler. 1971. Age and size of steelhead trout (*Salmo gairdneri*) in angler's catches from Vancouver Island, British Columbia streams. Fish. Res. Board Can. Circ. No. 91. Pacific Biological Station, Nanaimo, B.C. 26 p.

Neave, F. 1962. The observed fluctuations of pink salmon in British Columbia. U.B.C. Institute of Fisheries, H. R. MacMillan Lectures in Fisheries, Symposium on Pink Salmon, 1960, p. 3-14. Reproduced in Fish. Res. Board Can. Pacific Biological Station, Nanaimo, B.C. 13 p.

Newton, C.H.B. 1977. British Columbia catch statistics 1976. Canada Department of the Environment, Fisheries and Marine Service, Pacific Region. 215 p.

Paish, Howard and Associates Limited. 1972a. The west coast oil threat in perspective. An assessment of the natural resource, social and economic impacts of marine oil transport in southwest British Columbia waters. Vol. II. Prepared by Howard Paish and Associates Ltd. for Environment Canada, Vancouver, B.C. 302 p.

___. 1972b. The west coast oil threat in perspective. An assessment of the natural resource, social and economical impacts of marine oil transport in southwest British Columbia waters. Vol. III - maps. Prepared by Howard Paish and Associates Ltd. for Environment Canada, Vancouver, B.C.

___. 1974. Natural gas for Vancouver Island. B.C. Hydro and Power Authority, Gas Group. 34 p. plus maps.

Pearlstone, P.S.M. 1976. Management implications of summer hatitat characteristics of juvenile steelhead trout (*Salmo gairdneri*) in the Big Qualicum River. Fish and Wildlife Branch, Fisheries Management Rept. No. 67. University of British Columbia, Vancouver, B.C. 13 p.

Pearce Bowden Economic Consultants Limited (PBECL). 1971a. The value of non-resident sport fishing in British Columbia. Prepared by PCECL for British Columbia Fish and Wildlife Branch, Study Rept. No. 4. Queen's Printer. 60 p.

___. 1971b. The value of fresh water sport fishing in British Columbia. Prepared by PBECL for British Columbia Fish and Wildlife Branch. Study Rept. No. 5. Queen's Printer. 60 p.

Peck, T. 1978. The salt chucker. Sportguide Series Vol. 2. Published by Western Canada T.V. Week Limited, 6520 Beresford St., Burnaby, B.C. 46 p.

Prakash, A. 1962. Seasonal changes in feeding coho and chinook (spring) salmon in southern British Columbia waters. J. Fish. Res. Board Can. 18: 851-866.

Prest, J. 1968. Catch and effort statistics of the British Columbia trawl fishery in 1967. Fish Res. Board Can.

Tech. Rept. No. 56. Pacific Biological Station, Nanaimo, B.C. 85 p.

Prichard, A.L. 1932. The tagging of the pink salmon and the chum salmon in British Columbia in 1929 and 1930. Biological Board of Canada Bull. No. 31. 16 p.

___, and A.C. DeLacy. 1944. Migration of the pink salmon (*Oncorhychus gorbuscha*) in southern British Columbia and Washington in 1943. Fish. Res. Board Can. Bull. No. 66. 23 p.

Regional District of Comox-Strathcona. 1970. Comox Lake area study. Regional District of Comox-Strathcona. 39 p.

Reid, G.E. 1974a. (Memo to D. St. Arnoud) Re: Brooklyn Creek stream inventory. Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

___. 1974b. (memo to J. Secter), Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

___. 1975. Cutthroat and steelhead trout catch and effort statistics for lower Oyster River, British Columbia. Department Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 6p.

Sinclair, D. (pers. comm.). Senior Salmonid Enhancement Biologist. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Pacific Region, Vancouver, B.C.

Sinclair, W.F. 1972. The British Columbia sport fishermen. Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C.

Sjolund, W.R. (pers. comm.). Biologist. British Columbia Fish and Wildlife Branch, Campbell River, B.C.

Smiley, H.L. 1977. Extent of herring spawn - Area 14. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Comox, B.C. 18 p.

Smith, J.E. 1971. Catch and effort statistics of British Columbia trawl fishery in 1970. Fish. Res. Board. Can. Tech. Rept. No. 257. Pacific Biological Station, Nanaimo, B.C. 97 p.

Tautz, A. and P.A. Slaney. (pers. comms.). Ministry of Environment, Fish and Wildlife Branch, University of British Columbia, Vancouver, B.C.

Taylor, F. H. C. 1964. Life history and present status of British Columbia herring stocks. Fish. Res. Board Can. Bull. No. 143. Ottawa, Ont. 81 p.

___. and W. P. Wickett. 1967. Recent changes in abundance of British Columbia herring, and future prospects. Fish Res. Board Can. Circ. No. 80. Pacific Biological Station, Nanaimo, B.C. 8 p. plus tables and figures.

Taylor, M. 1977. 1976 Salmon sport fishing catch statistics for British Columbia tidal waters. Canada Department of the Environment, Fisheries and Marine Service. 43 p.

Thornton, B. (pers. comm.). President of the British Columbia Steelhead Society, Comox, B.C.

Trent, J.A. 1978. Information Re: Indian food fish catch - Area 14. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Courtenay, B.C. 4 p.

Trent, J.A. (pers. comm., 1979). Fisheries Officer, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Comox, B.C.

Underwood, McLellan and Associates Limited. 1975. Preliminary draft report of assessment of the impact of the marine resource sector on the North Vancouver Island, Mid-Coast, Queen Charlott Island Region. Report prepared by Underwood, McLellan and Associates for British Columbia Department of Economics Development, I. P. A. Regional Co-ordinator, Victoria, B.C. 50 p.

Walker, C.E., D.B. Lister and R.A.L. Harvey, 1962. Migration of chum salmon from lower Johnstone Strait to Strait of Georgia and tributary streams, 1962. Tech. Rept. 1969-1. Canada Department of Fisheries and Forestry. Vancouver, B.C. 31 p.

___, and J.R. McLeod. (undated) Catalogue of salmon spawning streams and escapement populations. Statistical Area 14. Fisheries and Marine Service, Vancouver, B.C.

Webb, L.A. 1974. The abundance of herring spawn in the coastal waters of British Columbia. Fisheries and Marine Service Tech. Rept. Ser. PAC/T-73-17. Southern and Northern Operations Branch, Vancouver, B.C. 39 p.

___. 1976. Review of the 1975-1976 herring fishery and spawn abundance. Canada Department of Fisheries and the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-76-19. Field Services Directorate, Vancouver, B.C. 33 p.

___, R.O. Boyd and B.J. Lockner. 1977. The 1977 herring roe pre-fishery charter vessel monitoring and sampling program. Canada Department of the Environment, Fisheries and Marine Service Data Record Ser. PAC/D-77-7. Field Services Directorate, Pacific Region, Vancouver, B.C. 12 p.

Westrheim, J. (pers. comm., 1979). Groundfish Biologist, Pacific Biological Station, Nanaimo, B.C.

Western Canada Hydraulic Laboratories Limited. 1972. Investigations of the proposed entrance channel for Pacific Playgrounds Marina. Port Coquitlam, B.C. 15 p.

Windsor, J.S. 1958. Report on the fisheries problem of Puntledge River, B. C. Power Commission, Planning Committee MS. Victoria, B.C. 17 p. plus appendices.

Withler, F.C. 1972. Research needs for intensive management of British Columbia steelhead. Fish. Res. Board Can. Circ. No. 92. Pacific Biological Station, Nanaimo, B.C. 41 p.

Zyblut, E.R. 1972. The 1972 report on chum salmon stocks in the Johnstone Strait - Fraser River study area. Canada Department of the Environment, Fisheries and Marine Service, Tech. Rept. 1972-9. Pacific Region, Vancouver, B.C. 11 p.

VII. INVERTEBRATES

Anderson, L.S. 1960. Toxic shellfish in British Columbia. Am. J. Publ. Health, 50: 71-83

Arney, D.B. and B. Kay. 1976. Shellfish growing water sanitary survey of the Vancouver Island coastline, Campbell River to Kye Bay, British Columbia. Canada Department of the Environment, Fisheries and Marine Service, Environmental Protection Service, Rept. No. EPS 5-PR-76-6. West Vancouver, B.C. 12 p.

Bell-Irving, R. (unpublished). Shoreline survey data: East coast of Vancouver Island (1977). Canada Department of the Environment, Fisheries and Marine Service, Pacific Region, Habitat Protection Directorate, Vancouver, B.C.

Bernard, F.R. 1970. A distributional checklist of the marine molluscs of British Columbia: based on faunistic surveys since 1950. Syesis 3: 73-94.

___, N. Bourne and D.B. Quayle. 1967. British Columbia faunistic survey - a summary of dredging activities in western Canada 1878-1966. MS. Rept. Ser. No. 920. Nanaimo, B.C.

___, N. Bourne and D.B. Quayle. 1968. British Columbia faunistic survey - a summary of dredging activities 1966-1967. Fish Res. Board Can. MS. Rept. Ser. No. 975. Nanaimo, B.C. plus maps.

___, N. Bourne and D.B. Quayle. 1968. British Columbia faunistic survey - a summary of dredging activities 1966-1967. Fish Res. Board Can. MS. Rept. Ser. No. 975. Nanaimo, B.C. 6 p. plus maps.

___, and D.B. Quayle. 1970. British Columbia faunistic survey - a summary of dredging activities 1970-1972. Fish Res. Board Can. MS. Rept. Ser. No. 1240. Pacific Biological Station, Nanaimo, B.C.

Birtwell, I.K. 1978. (memo to M. Waldichuk). Re: effects of proposed outfall sites for the regional sewage system on fisheries resources in the area. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

Bourne, N. (pers. comm.). Biologist, Canada Department of the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

___, and D.W. Smith. 1972. Breeding and growth of the horse clam, *Tresus capax* (Gould), in southern British Columbia. Proc. Nat. Shellfisheries Assoc. 62: 38-46.

Bousfield, E.L. 1956. Ecological investigations on shore invertebrates of the Pacific coast of Canada, 1955 Bull. No. 147, Ann. Rept. Nat. Museum of Canada, Ottawa, Ont.

___. 1963. Investigations on sea-shore invertebrates of the Pacific coast of Canada, 1957 and 1959. Part I. Station list. Nat. Museum of Canada, Bull. No. 185, Ottawa, Ont.

Boutillier, J. (pers. comm.). Biologist, Canada Department of the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

Boyd, R. (pers. comm.). Biologist, Canada Department of the Environment, Fisheries and Marine Service, Pacific Region, Vancouver, B.C.

Butler, T.H. (pers. comm.). Biologist, Canada Department of the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

___, and G.V. Dubokovic. 1955. Shrimp and prawn prospecting on the British Columbia coast, June to December 1954. Fish. Res. Board Can. Circ. No. 35. Pacific Biological Station, Nanaimo, B.C. 82 p.

___, and H.E.J. Légaré. 1954. Shrimp prospecting in regions off the British Columbia coast, November 1953 to March 1954. Fish. Res. Board Can. Circ. No. 31. Pacific Biological Station, Nanaimo, B.C. 42 p.

Canada Department of Environment. 1975. Pamphlet describing contaminated shellfishing areas. Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C.

___. 1976. British Columbia tidal waters sport fishing guide 1976. Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C.

Canada Department of Fisheries. 1958. Upper Puntledge River Survey 1954. Appendix 2 *In*: The fisheries problems associated with the power development of the Puntledge River, Vancouver Island, B.C. Canada Department of Fisheries, Vancouver, B.C.

Canada Department of Fisheries and the Environment. 1978. Sites of geoduck beds, shrimp beds, clam beds, oyster beds and herring spawn sites in the Comox Harbour area. Fisheries and Marine Service, Vancouver, B.C. (unpublished data)

Canadian Forestry Service. 1977. Forest insect and disease conditions - Vancouver Forest District, Pacific Forest Research Centre, Victoria, B.C. 11 p.

Clague, J.J. 1976. Sedimentology and geochemistry of marine sediments near Comox, British Columbia. Geol. Surv. Can., Paper 76-21. 21 p.

Cockbain, A.E. 1963. Distribution of foraminifera in Juan de Fuca and Georgia Straits, British Columbia, Canada. Contr. Cushman Found. for Foram. Res. 14: 37-57.

Cox, R. (pers. comm.). Conservation Officer, Ministry of Environment Marine Resources Branch, Victoria, B.C.

Derksen, G.D. and T.J. Tevendale. 1974. Shellfish growing water sanitary survey of Denman Island, British Columbia, 1974. Canada Department of the Environment, Fisheries and Marine Service, Environmental Protection Service, Rept. No. EPS 5-PR-74-9. West Vancouver, B.C. 47 p.

Ellis, D.V. 1968. Quantitative benthic investigation. V. Species data from selected stations (Strait of Georgia and Adjacent Inlets), May 1965 - May 1966. Fish. Res. Board. Can. Tech. Rept. No. 73. Nanaimo, B.C.

EPEC Consulting Western Limited. 1975. Coal resource study of Preliminary environmental assessment. Vol. 7. Rept.prepared by EPEC Consulting Western Ltd. for Weldwood of Canada, Vancouver, B.C. 186 p.

Fisheries and Marine Service (unpublished). Oyster production in British Columbia between 1971 and 1975. Environment Canada, Pacific Region, Vancouver, B.C.

Fulton J. (pers. comm.). Biologist, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

Goodman, D. 1974. An assessment of the impact of a proposed access channel and breakwater on the fisheries resources of the Oyster River. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-74-4. Southern Operations Branch, Vancouver, B.C. 51 p.

___, and P.R. Vroom. 1974. An Assessment of the impact of proposed marina development of fisheries resources of the Campbell River estuary. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T74-13. Vancouver, B.C.

Henderson, C. and P. Capes. eds. (undated). A naturalist guide to the Comox Valley and adjacent areas, including Campbell River. The Comox-Strathcona Natural History Society, Courtenay, B.C. 68 p.

Heritage, G.C., P.A. Breen and N.F. Bourne. 1976. Pacific Oyster breeding in Pendrell Sound, 1975. Fish. Res. Board Can. MS. Rept. No. 1406. Nanaimo, B.C. 91 p.

Jackson, K.J. (pers. comm.). Shellfish Co-ordinaror, Canada Department of the Environment, Fisheries and Marine Service, Pacific Region, Vancouver, B.C.

Kay, B. and T.J. Tevandale, 1974a. Shellfish growing water sanitary survey of Comox Harbour area, British Columbia, 1974. Canada Department of the Environment, Fisheries and Marine Service, Environmental Protection Service, EPS-5-PR-74-13. Vancouver, B.C. 49 p.

___. 1974b. Shellfish growing water sanitary survey of Baynes Sound Gartley Point to Deep Bay, British Columbia. Canada Department of the Environment, Fisheries and Marine Service, Environmental Protection Service, EPS 5-PR-74-10. West Vancouver, B.C. 79 p.

Kennedy, O. D. (pers. comm.). Biologist, Canada Department of Fisheries and Environment, Pacific Biological Station, Nanaimo, B.C.

Kozloff, E.N. 1973. Seashore life of Puget Sound, the Strait of Georgia and the San Juan Archipelago. J. J. Douglas Limited. Vancouver, B.C. 282 p. plus plates.

Lewis, A.G. (pers. comm.). Professor, University of British Columbia, Dept. Zoology, Vancouver, B.C.

Marine Resources Branch. (unpublished). Quantity and value of Pacific oysters harvested in British Columbia. Ministry of the Environment, Victoria, B.C.

Mason, J.C. 1974. Behavioural ecology of chum salmon fry (*Oncorhynchus keta*) in a small estuary. J. Fish. Res. Board Can. 31: 83-92.

Mason, J. and S. Machidori. 1976. Population of sympatric sculpins, *Cottus aleuticus* and *Cottus asper*, in four adjacent salmon-producing coastal streams on Vancouver Island, B.C. J. Fish. Res. Board Can., Fisheries Bull. 74 : 131-141.

Ministry of Environment (undated). Flora and fauna of Miracle Beach Park. Parks Branch Files, Victoria, B.C.

Mounce, J.R. 1973. An introductory guide to stream insects of southern Vancouver Island. Fish. Res. Board Can. Circ. No. 95.

Mundie, A. (pers. comm.). Biologist, Canada Department of the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

Nelson, H. and D. Goyette. 1976. Heavy metal contamination in shellfish with emphasis on zinc contamination of the Pacific oyster, *Crassostrea gigas*. Canada Department of the Environment, Fisheries and Marine Service, Environmental Protection Service Rept. No. EPS 5-PR-76-2. West Vancouver, B.C. 57 p.

Northcote, T.C. (pers. comm.). Professor, University of British Columbia, Dept. Zoology, Vancouver, B.C.

Paish, Howard and Associates. 1972. The west coast oil threat in prespective. An assessment of the natural resourses, social and economical impacts of marine oil transport in southwest British Columbia water. Vol. III - maps. Prepared by Howard Paish and Associates Ltd. for Environment Canada, Vancouver, B.C.

Peden, A. (pers. comm.). Curator of Marine Biology, B.C. Provincial Museum, Victoria, B.C.

Pollution Control Branch. 1974. Intertidal (beach) biology: Appendix E. *In*: Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of the Environment, Pollution Control Branch, Water Resources Service for British Columiba Department of the Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 44 p.

Prakash, A. and F.J.R. Taylor. 1966. A "red water" bloom of *Gonyaulax acatenella* in the Strait of Georgia and its relation to paralytic shellfish toxicity. J. Fish. Res. Board. Can. 23: 1265-1270.

Quayle, D.B. 1961. Denman Island oyster disease and mortality 1960. Fish. Res. Board Can. MS. Rept. No. 713. Pacific Biological Station, Nanaimo, B.C. 9 p.

____. 1964. Distribution of introduced marine mollusca in British Columbia waters. J. Fish. Res. Board. Can. 21: 1155-1181.

____. 1966. Shellfish toxicity records, 1942-1965. Fish. Res. Board Can. MS. Rept. No. 860. Biological Station, Nanaimo, B.C. 210 p.

____. 1969(a). Paralytic shellfish poisoning in British Columbia. Fish. Res. Board Can. Bull. 168. 68 p.

____. 1969(b). Pacific oyster culture in British Columbia. Fish. Res. Board Can. Bull. 169. Ottawa, Ont. 192 p.

____. 1971. Pacific oyster raft culture in British Columbia. J. Fish. Res. Board Can. Bull. 178. 34 p.

____; and N. Bourne. 1972. The clam fisheries of British Columbia. Fish. Res. Board. Can. Bull. 179. 70 p.

____, and D.W. Smith. 1976. A guide to oyster farming. Ministry of Recreation and Travel Industry, Marine Resources Branch, Victoria, B.C. 54 p.

Regional District of Comox-Strathcona. 1975. Land use and resources within the region. Regional District of Comox-Strathcona, Planning Department, Courtenay, B.C. 63 p.

Scudder, G.G.E. (pers. comm.). Professor, Chairman of the Department of Zoology, University of British Columbia, Vancouver, B.C.

Sheldon, R.W. and P.J. Warren (unpublished). The distribution of the shrimp, *Pandalus jordani*, in relation to sediment at Comox, Vancouver Island. Bedford Institute of Oceanography, Marine Ecology Laboratory, Halifax, N.S.

Smith, D. (pers. comm.). Shellfish Biologist, Head of Shellfish Division. Ministry of Environment, Marine Resources Branch, Victoria, B.C.

Tarnowski, J. (pers. comm.). Baynes Sound Oyster Company, P.O. Box 127, Union Bay, B.C.

Waldichuk, M. 1958. Shellfish toxicity and the weather in the Strait of Georgia during 1957. Fish. Res. Board. Can. Pac. Progr. Rept. 112: 10-14.

Wood, C. (pers. comm.). Survey Technican, Pacific Forest Research Centre, Canadian Forestry Service, Vancouver, B.C.

VII. FLORA

Austin, A. (pers. comm.). Professor, University of Victoria, Dept. Biology, Victoria, B.C.

___, and R. Adams. 1972. Development of a method for surveying red algal resources in Canadian pacific waters. Rept. prepared by A. Austin and R. Adams for British Columbia Department of Recreation and Conservation, Marine Resources Branch, Victoria, B.C. 172 p. plus maps.

Baranguary, J.A. and R.B. Smith. 1972. Dwarf mistletoe in British Columbia and recommendations for their control. Canadian Forestry Service, Victoria, B.C. 18 p.

Booth, T. 1969. Marine fungi from British Columbia: Monocentric chytrids and chytridiaceous species from coastal and interior halomorphic soils. Syesis 2: 141-161.

British Columbia Fish and Wildlife Branch. (undated). Comox Lake survey. Nanaimo, B.C. 2 p.

Canadian Department of Fisheries. 1958. Upper Puntledge River survey, 1954. Appendix 2. *In:* The fisheries problems associated with the power development of the Puntledge River, Vancouver Island, B.C. Canada Department of Fisheries, Vancouver, B.C. 11 p.

Collins, F.S. 1913. The marine algae of Vancouver Island. Geol. Surv. Can. Mem. Mus. Bull. 1: 99-137.

Coon, M. (pers. comm.). Algal Biologist, Head of Seaweed Division, Ministry of Environment, Marine Resources Branch, Victoria, B.C.

___, 1973. Oyster River study. Ministry of Environment, Marine Resources Branch, Victoria, B.C. 5 p. plus photographs.

Ecosign Limited. (undated). Analysis of the impact of the Mount Washington ski development on local biota. Vancouver, B.C.

EPEC Consulting Western Limited. 1975. Coal resource study of Comox Basin-Nanaimo series, Vancouver Island, B.C. Rept. prepared by EPEC Consulting Western Ltd for Weldwood of Canada, Preliminary Environmental Assessment. Vol. 7. Vancouver, B.C. 186 p.

Foreman, R.E. 1976. Ecology and population dynamics of *Nereocytis blethkeana.* BERP Rept. No. 76-2. University of British Columbia, Dept. Botany, Vancouver, B.C. 89 p.

Foreman, R.E. and J. Root. 1975. Macrophyte studies in the Strait of Georgia. A review of the current status of macrophyte knowledge and research. BERP Rept. No. 75-2. University of British Columbia, Dept. Botany, Vancouver, B.C. 52 p.

Fulton, J.D., O.D. Kennedy, J. Skelding and K. Stephens. 1969. Data record: Physical, chemical and biological data in the Strait of Georgia, 1968. Canada Department of the Environment, Fisheries and Marine Service MS. Rept. No. 1049. Pacific Biological Station, Nanaimo, B.C.

Goodman, D. 1974. An assessment of the impact of a proposed access channel and breakwater on the fisheries resources of the Oyster River. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. Ser. No. PAC/T-74-4. Southern Operations Branch, Vancouver, B.C. 51 p.

Greenius, A.W. 1967. The general status of the seaweed industry in British Columbia. Rept. prepared by A.W. Greenius, British Columbia research council, for British Columbia Department of Recreation and Conservation, Victoria B.C. 37 p.

Halsey, T.G. 1968. Autumnal and over-winter limnology of three small eutrophic lakes with particular reference to experimental circulation and trout mortality. J. Fish. Res. Board Can. 25: 81-99.

Hardy, G.A. (undated). The natural history of the Forbidden Plateau area, Vancouver Island, British Columbia. Provincial Museum Rept. No. B240B63. Victoria, B.C. 63 p.

Harris, R.D. 1953. (memo). Re: eelgrass status in 1953. Canada Department of Fisheries and Forestry, Canadian Wildlife Service, Delta, B.C. 4 p.

Harrison, P.G. and K.H. Mann. 1975. Detritus formation from eelgrass (*Zostera marina* L.): The relative effects of fragmentation, leaching and decay. Limnol. and Oceanogr. 20: 924-934.

Hughes, G.C. 1969. Marine fungi from British Columbia; occurance and distribution of lignicolous species. Syesis 2: 121-140.

Hutchinson, A.H. and C.C. Lucas. 1931. The epithalassa of the Strait of Georgia. Can. J. Res. 5: 231-284.

Jawanda, B.S. 1954. A geographical study of Vancouver Island. M. A. Thesis, University of British Conumbia, Dept. Geology and Geography, Vancouver, B.C. 244 p.

Kennedy, K. A. (unpublished). Plant communities and productivity of the estuaries on the east coast of Vancouver Island. M. Sc. Thesis (in progress), University of British Columbia, Dept. Botany, Vancouver, B.C.

Kennedy, K.A. and B.R. Waters. (unpublished). Courtenay River estuary. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 61 p.

Kennedy, O.D. (pers. comm.). Biologist, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Pacific Biological Station, Nanaimo, B.C.

Krajina, V.J. 1965. Biogeoclimatic zones and classification of British Columbia. Ecol. of Western North America. 1: 1-17.

___. 1970. Ecology of forest trees in British Columbia. Ecol. of Western North America. 2: 1-146.

___, and R.H. Spilsbury. 1953. Forest associations on the east coast of Vancouver Island. Forestry Handbook of British Columbia. p. 142-145; 2nd edition (1959): 582-585.

Légaré, J.E.H. 1957. The qualitative and quantitative distribution of plankton in the Strait of Georgia in relation to certain oceanographic factors. J. Fish. Res. Board Can. 14: 521-552.

Leslie, F. (pers. comm.). Forester, Crown Zellerbach, Coquitlam, B.C.

Mason, J.C. 1974. Movements of fish populations in Lymn Creek, Vancouver Island. A summary from weir operations during 1971-1972 including comments on species life histories. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 483. Pacific Biological Station, Nanaimo, B.C. 35 p.

McKelvey, R. (unpublished). A survey of the migratory birds using the Comox Harbour area, 1974-1975. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 60 p. plus data

___. (unpublished). A survey of the migratory birds using the Oyster River area, 1974-1975. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 18 p. plus data.

McRoy, C. P., R.J. Barsdate and M. Nebert. 1972. Phosphorous cycling in eelgrass (*Zostera marina* L.) ecosystem. Limnol. and Oceanogr. 17: 58-67.

Ministry of Environment. (undated). Flora and fauna of Miracle Beach Park. Parks Branch, Victoria, B.C.

Packee, E.C. 1974a. The biogeoclimatic subzones of Vancouver Island and the adjacent mainland and islands. MacMillan Bloedel Limited, Forestry Division, Forest Res. Note, Nanaimo, B.C. 11 p. plus appendix.

___. 1974b. The biogeoclimatic subzones of Vancouver Island and the adjacent mainland, based on climax vegetation (third approx.) MacMillan Bloedel Limited, Forestry Division (maps).

Parsons, T.R., R.J. LeBrasseur and W.R. Barrclough. 1970. Levels of production in the pelagic environment of the Strait of Georgia, British Columbia: A review. J. Fish. Res. Board Can. 27: 1251-1264.

Pollution Control Branch. 1974. Intertidal (beach) biology. Appendix E. *In:* Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of the Environment, Pollution Control Branch, Water Resources Service for British Columbia Department of the Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 44 p.

Regional District of Comox-Strathcona. 1974. Greenbelts: An evaluation of proposed sites. Regional District of Comox-Strathcona, Planning Department, Courtenay, B.C. 24 p.

Rodgers, R. (pers. comm.). Conservation Officer, Ministry of Environment, Fish and Wildlife Branch, Courtenay, B.C.

Stephens, K., J.D. Fulton and O.D. Kennedy. 1969. Summary of biological oceanographic observations in the Strait of Georgia, 1965-1968. Fish. Res. Board Can. Tech. Rept. No. 110. Pacific Biological Station, Nanaimo, B.C. 11 p. plus figures.

Stockner, J.G., D.D. Cliff and K.R.S. Shortreed. (unpublished). The phytoplankton ecology of the Strait of Georgia, British Columbia. Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Pacific Environment Institute, West Vancouver, B.C. 21 p. plus figures and tables.

Trent, J.A. (pers. comm. 1979) Fisheries Officer. Canada Department of Fisheries and Environment, Fisheries and Marine Service, Comox, B.C.

Underwood, McLellan and Associates Limited. 1975. Preliminary draft report of assessment of the impact of the marine resource sector on the Vancouver Island, Mid-coast, Queen Charlotte Island region. Rept. prepared by Underwood, McLellan and Associates Ltd. for British Columbia Department of Economic Development, Victoria, B.C. 50 p.

Waldichuk, M. (unpublished). Observations in the marine environment related to esturine ecosystem disruption in coastal area development. Rept. prepared for GESAMP Working Group on the Pollution Implications of Seabed Exploration and Coastal Area Development. London, England. Pacific Environment Institute Files, West Vancouver, B.C. 28 p.

Widdowson, T.B. 1964. A study of variation in the genus *Alaria* Grenville. Ph. D. Thesis, University of British Columbia, Dept. Botany, Vancouver, B.C. 229 p.

IX. WILDLIFE

American Ornithologists' Union. 1973. Thirty-second supplement to the American Ornithologists' Union checklist of North American Birds. Auk. 90: 411-419.

___. 1976. Thirty-third supplement to the American Ornithologists' Union checklist of North American Birds. Auk. 93: 876-879.

Banfield, A.W.F. 1974. The mammals of Canada. University of Toronto Press, Toronto, Ont. 438 p.

Bendell, J. (pers. comm.). Professor, University of Toronto, Toronto, Ont.

___. 1955. Age, breeding behaviour and migration of the sooty grouse, *Dendragapus obscuras fuliginonsus* (Ridgeway). Trans. North America Wildlife Conference 20: 367-381.

___. (unpublished). A study of the life history and population dynamics of the sooty grouse. Ph.D. Thesis, University of British Columbia, Dept. Zoology, Vancouver, B.C.

___ and P.W. Elliott. 1966. Habitat selection in the blue grouse. Condor 68: 431-466.

___. 1967. Behaviour and the regulation of numbers in blue grouse. Canada Department of the Environment Canadian Wildlife Service Rept. Ser. No. 4, Delta, B.C.

Bendell, J.F., D.G. King and H.D. Mossop. 1972. Removal and repopulation. J. Wild. Mgmt. 34: 1153-1165.

Bigg, M. (pers. comm.). Marine Mammalogist, Pacific Biological Station, Nanaimo, B.C.

Blood, D.A. 1969. Trumpeter swan survey: report of the regional biologist, Fish and Wildlife Branch of British Columbia. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

British Columbia Department of Recreation and Conservation. 1976. Hunter sample, 1975. Wildlife Management Division Rept. No. 11. Fish and Wildlife Branch, Victoria, B.C.

British Columbia Fish and Wildlife Branch. 1976. Southern British Columbia coastal wildlife resources map. British Columbia Department of Recreation and Conservation, Victoria, B.C.

British Columbia Fish and Wildlife Branch. 1977a. Wildlife Distribution Mapping. Big Game Series-Deer. Map number 1s, Scale 1:2,000,000. Ministry of Recreation and Conservation, Victoria, B.C.

___. 1977b. *Ibid.* Elk Map number 1s, Scale 1:2,000,000, Victoria, B.C.

___. (unpublished). Deer hunting statistics for management units 1-15. *Ibid.* Nanaimo, B.C. 96 p.

___. (unpublished). Survey of wintering birds seen along the shoreline of eastern Vancouver Island, *Ibid.* Nanaimo, B.C.

British Columbia Provincial Museum. 1976. Map of sea birds of the Vancouver Island area. Scale: 1 in. = 8 mi., Victoria, B.C.

Brooks, A.A. 1972. Animals of Comox-Strathcona area. Intermediate Teacher. 13: 97-104.

Campbell, R.W. and R.G. Foottit. 1941. Franklin's gull in British Columbia. Syesis 5: 1972.

Canada Department of the Environment. 1970. The Canada Land Inventory land capability classification for wildlife. The Canada Land Inventory Rept. No. 7. Queen's Printer, Ottawa, Ont.

___. (unpublished). Courtenay River estuary - available wildlife data. Input to the Estuary Working Group from Canadian Wildlife Service. Pacific Environment Files, West Vancouver, B.C.

Canada Land Inventory. 1967a. Alberni. (92 F) Waterfowl Capability map. Scale 1:250,000. Ministry of Environment, Environment and Land Use Committee Secretariat, Victoria, B.C.

___. 1976b. Alberni. (92 F). Ungulate Capability map. *Ibid.*

Canadian Wildlife Service (unpublished). A survey of birds utilizing the Oyster River during the winter and spring of 1973-1974, Delta, B.C.

Comox-Strathcona Natural History Society. (unpublished). Checklist of migrant and resident birds seen on or from Crown Zellerbach property at the mouth of the Courtenay River, Courtenay, B.C. 1 p.

___. 1975. Checklist of birds seen in the Comox Valley, American Birds 29: 178-602.

Davies, R. (pers. comm.). Inventory Biologist, Ministry of Environment, Fish and Wildlife Branch, Nanaimo, B.C.

___, W. Kale, B. Van Drinnen and I. Smith. (unpublished). Aerial surveys of birds found on the east coast of Vancouver Island. Ministry of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

Dawe, N. (pers. comm.). Biologist, Canada Department of the Environment, Canadian Wildlife Service, Qualicum, B.C.

___. (unpublished). Inventory of the birds, mammals, reptiles, amphibians and plants on land owned by Canadian Wildlife Service, between Rosewall Creek and Mud Bay Canada Department of the Environment, Canadian Wildlife Service, Qualicum, B.C.

Drent, R.H. and C.J. Guiguet. 1961. A catalogue of British Columbia seabird colonies. Occ. Papers of the British Columbia Provincial Museum. No. 12. 173 p.

Environment Canada. 1978. Birds protected in Canada under the Migratory Birds Convention Act. Canadian Wildlife Service Occ. Paper No. 1. 40 p.

EPEC Consulting Western Limited. 1975. Coal reserves study of Comox Basin - Nanaimo Series, Vancouver Island, B.C. Vol. 7. Report prepared by EPEC Consulting Western Ltd. for Weldwood of Canada, Vancouver, B.C. 186 p.

Gibson, B. (pers. comm.). Engineer Forester, Crown Zellerbach, Courtenay, B.C.

Godfrey, E.A. 1966. The birds of Canada. National Museum of Canada. Bull. No. 203. Biol. Ser. 73. Ottawa, Ont. 428 p.

Guiguet, C.J. (pers. comm.). Curator, Birds and Mammals British Columbia Provincial Museum, Victoria, B.C.

Haigland, W. (pers. comm.). "Whales no more" (in progress). 6719 Bryant Street, Burnaby, B.C.

Hancock, D.A. and D. Stirling. 1973. Some of the common and uncommon birds of British Columbia. Hancock House Pub., Saanichton, B.C. 67 p.

Herbert, D. (pers. comm.). Regional Wildlife Biologist, Ministry of Environment, Fish and Wildlife Branch, Nanaimo, B.C.

Henderson, L. and P. Capes. eds. (undated). A naturalists guide to the Comox Valley and adjacent areas including Campbell River. Comox-Strathcona Natural History Society, Courtenay, B.C. 68 p.

Martin, A.C., H.S. Zimand and A.L. Nelson, 1951. American wildlife and plants: A guide to wildlife food habits. Dover Pub. Inc. New York. 500 p.

McKelvey, R. (pers. comm.). Wildlife technician, Canadian Wildlife Service, Delta, B.C.

McKelvey, R. (unpublished). A survey of migratory birds using the Comox Harbour area, 1974-1975. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 60 p. plus data.

McKelvey, R. (unpublished). A survey of migratory birds using the Oyster River during the winter and spring of 1974-1975. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 18 p. plus data.

McKelvey, R. and G. Kaiser. (unpublished). Aerial surveys of birds from and along the east coast of Vancouver Island. Canadian Department of the Environment, Canadian Wildlife Service, Delta, B.C.

McTaggart-Cowan, I. and C.J. Guiget. 1973. The mammals of British Columbia. British Columbia Provincial Museum, Victoria, B.C. 414 p.

Ministry of Environment. (unpublished). Flora and fauna of Helliwell Park. Parks Branch Files, Victoria, B.C.

___. (undated). Flora and fauna of Miracle Beach Park. Parks Branch Files, Victoria, B.C.

Ministry of Recreation and Conservation. 1978. British Columbia hunting regulations synopsis 1977-78. Fish and Wildlife Branch, Victoria, B.C. 50 p.

Mitchell, G.J. 1952. A study of some members of the Nyrocinae wintering in the coastal waters of southern British Columbia. M. Sc. Thesis, University of British Columbia, Dept. Zoology, Vancouver, B.C. 94 p.

Munro, J.A. 1931. Introduction to bird study in British Columbia. C.F. Banfield Pub., Victoria, B.C.

Munro, J.A. 1941. Studies of waterfowl in British Columbia: Greater scaup duck and lesser scaup duck. Can J. Res. 19: 113-138.

___. 1949. Studies of waterfowl in British Columbia: Baldpate. Can. J. Res. 27: 289-304.

___, and W.A. Clemens. 1932. Food of the American merganser (*Mergus merganser americanus*) in British Columbia. J. Wild. Manag. Vol. 3: 46-53.

___, and W.A. Clemens. 1937. The American merganser in British Columbia and its relation to the fish popluation. Fish. Res. Board. Can. Bull. No. 55. Pacific Biological Station, Nanaimo, B.C. 50 p.

___ 1939. Food and feeding habits of red-breasted merganser in British Columbia. Fish. Res. Board Can. Studies No. 212.

Munro, J.A. and I. McTaggart-Cowan. 1947. A review of the bird fauna of British Columbia. British Columbia Provincial Museum, Department of Education, Victoria, B.C. 285 p.

Nation, M. (pers. comm.). Wildlife Assistant, Ministry of Environment, Fish and Wildlife Branch, Nanaimo B.C.

Noble, M.D. and W.A. Morris. 1972. (memo). British Columbia notes on the food habits of waterfowl in estuaries, marshes and open bays. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 8 p.

Novakowski, N.S. 1970. Endangered Canadian mammals Can. Field Nat. 84: 18-23.

Redfield, J.A. 1972. Demography and genetics in colonizing populations of blue grouse. Canada Department of the Environment, Canadian Wildlife Service Rept. Ser. No. 4.

Regional District of Comox-Strathcona. 1975. A report on land use and resources within the region. Regional District of Comox-Strathcona. Planning Department, Courtenay, B.C. 63 p.

Rodgers, R. (pers. comm.). Regional Conservation Officer, Ministry of the Environment, Fish and Wildlife Branch, Courtenay, B.C.

Smith, I. 1970. Trumpeter swan survey: Winter 1970 report of the Regional Biologist. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

Smith, I.D. and D. Blood. 1971. Native swans on Vancouver Island over the period 1969-71. Can. Field. Nat. 86: 213-216.

___, and G.W. Smith (unpublished). 1971 spring counts of nesting waterfowl on Vancouver Island. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

Smith, G.W. (unpublished). A preliminary evaluation of wildlife resources in the vicinity of a proposed ski development of Mount Washington, Courtenay, B.C. Ministry of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

Taylor, E.W. (unpublished). Marine-associated birds of the British Columbia coast. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 65 p.

Trethewey, D. (pers. comm.). Biologist. Canada Department of Fisheries and the Environment, Canadian Wildlife Serice, Delta, B.C.

Zwickel, F.C. 1965. Early mortality and the numbers of blue grouse. (Unpubl.) Ph.D. Thesis, University of British Columbia, Dept. Zoology, Vancouver, B.C.

___. 1972a. Dispersion of female blue grouse during the brood season. Condor 74.

___. 1972b. Removal and Repopulation of blue grouse in an increasing population. J. Wildl. Mgmt. 36: 1141-1152.

___. 1975. Nesting parameters of blue grouse and their relevance to populations. Condor 77: 423-430.

___. 1977. Local variations in the time of breeding of female blue grouse. Condor 79: 185-191.

___, and J.F. Bendell. 1972a. Blue grouse, habitat and populations. Proc. XVth Inter. Ornith. Cong. p. 150-169.

___. 1972b. Observation on food habits of incubting female blue grouse. Condor 74: 493-494.

Zwickel, F.C. and J.A. Dake. 1977. Primary molt of blue grouse (*Dendragapus obscurus*) in its relation to reproductive activity and migration. Can. J. Zool. 55: 1782-1787.

X. LAND AND WATER USE

Acres Consulting Services Limited. 1973. Proprosed Puntledge salmon hatchery feasibility report. Report prepared by Acres Consulting Servcies Ltd. for Environment Canada, Fisheries and Marine Services, Vancouver, B.C. 45 p.

Anthony, E.D. and P.J. Leslie. 1966. A proposed greater water district for the Comox Valley. British Columbia Department of Lands, Forests and Water Resources, Water Rights Branch, Victoria, B.C. 13 p. plus appendix.

Associated Engineering Services Limited (AESL). 1951. Preliminary report of sewage in Courtenay, B.C. with particular reference to the sanitary system and disposal works. Rept. prepared by AESL, Vancouver, B.C. for Cour-enay, B.C. 8 p.

___. 1959. Report on a proposed sewage system to serve the city of Courtenay. Rept. prepared by AESL, Vancouver, B.C. for the city of Courtenay, B.C.

Associated Engineering Services Limited (AESL). 1959. Report on a proposed sewage system to serve the City of Courtenay. Prepared by AESL, Vancouver, B.C. for the City of Courtenay, B.C.

___. 1961. Report on a proposed sanitary sewage system to serve the Village of Comox, B.C. Prepared by AESL, Vancouver, B.C. for the village of Comox, B.C. 9 p. plus appendix.

___. 1965. Courtenay water supply. Prepared by AESL, Vancouver, B.C. for the City of Courtenay, B.C. 32 p. plus maps.

___. 1967. City of Courtenay sewage treatment facilities. Prepared by AESL, Vancouver, B.C. for the City of Courtenay, B.C. 13 p.

___. 1968. Submission to the director of the Pollution Control Branch with respect to treatment and disposal of sewage at Courtenay, B.C. Prepared by AESL, Vancouver, B.C. for the City of Courtenay, B.C. 9 p.

___. 1970. Regional waste disposal study. Prepared by AESL, Vancouver, B.C. for the Regional District of Comox-Strathcona, Courtenay, B.C. 5 p. plus appendices.

Associated Engineering Services Limited. 1971. Report on extention of sewer system 1971. Prepared by AESL, Vancouver, B.C. for the Corporation of the Village of Cumberland, B.C. 17 p.

___. 1973. Village of Cumberland storm drainage plan. Prepared by AESL, Vancouver, B.C. for the Village of Cumberland, B.C. 16 p.

___. 1975. Regional Water study. School District 71. Rept. prepared by AESL, Vancouver, B.C. for the Regional District of Comox-Strathcona, Courtenay, B.C. 92 p.

1976a. Black Creek - Oyster Bay water study. Prepared by AESL, Vancouver, B.C. for the Regional District of Comox-Strathcona, Courtenay, B.C. 15 p. plus appendices.

___. 1976b. Wolf Lake Study. Report prepared by AESL for Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C. 18 p. plus tables and Figures.

___. 1977. District 71 Transportation Review - Summation Report. Prepared by AESL for the Regional District of Comox-Strathcona, Courtenay, B.C. 52 p. plus appendix.

___. 1977. Oyster Bay Marina preliminary design report. Prepared by AESL, Vancouver, B.C. for the Regional District of Comox-Strathcona, Courtenay, B.C. 15 p. plus appendices.

___. 1977. Marine considerations of the District 71 transportation review. Prepared by AESL, Vancouver, B.C. for the Ministry of Highways and Public Works, Victoria, B.C. 10 p.

AVG Management Science Limited. 1971. Recreation study Regional District of Comox-Strathcona (Area of School District no. 71). Prepared by AVG Management Science Ltd., Vancouver, B.C. for the Planning Dept., Regional District of Comox Strathcona, Courtenay, B.C. 67 p. plus appendices.

Barker, M.L. 1974. Water resources and related land uses - Strait of Georgia - Puget Sound Basin. Canada Department of the Environment., Lands Directorate, Geog. Paper No. 56. Ottawa, Ont. 55 p. plus water use map and generalization on land use map.

Bell, L.M. and R.J. Kallman. 1976. The Nanaimo River estuary: Status of environmental knowledge to 1976. Special Estuary Series No. 5. Canada Department of the Environment, Fisheries and Marine Service, Pacific Environment Institute, West Vancouver, B.C. 328 p.

Benn, D.R. 1972. Interpretation of British Columbia Recreation Capability maps. W. C. Yeomans & Associates, Victoria, B.C. 3 p.

British Columbia Department of Agriculture. 1966. Second approximation report Vancouver Island Area, Victoria, B.C.

British Columbia Department of Agriculture. 1974. Agricultural operations and use of chemicals. Appendix I. *In*: Provincial Interagency evaluation of Comox Harbour. Report prepared by British Columbia Department of Agriculture for British Columbia Department of Environment, Environment and Land Use Committee Secretariat, Victoria, B.C.

British Columbia Department of Recreation and Conservation. 1962. Submission to the Puntledge River Inquiry, Fish and Game Branch, Nanaimo, B.C. 8 p. plus appendices.

____. 1965. The British Columbia Provincial Park Act, 1965, C. 31, S.I. British Columbia Parks Branch, Victoria, B.C. 6 p.

____. 1973. B.C. Parks list. British Columbia Parks Branch, Victoria, B.C.

____. 1974a. Recreation. Appendix B. Program 5. *In*: Provincial agency evaluation of Comox Harbour. Report prepared by British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch for British Columbia Department of Environment, Environment and Land Use Committee Secretariat, Victoria, B.C.

____. 1974b. Lands and Forests log boom surveys Appendix B. Program 4. *In: Ibid.* 4 p.

____. 1974c. Land status information for various British Columbia estuaries. Fish and Wildlife Branch, Victoria, B.C. Unpubl. data 22 p.

British Columbia Forest Service. 1971. Sustained yield from British Columbia's forest lands. Pub. B. 55. Information Division, Victoria, B.C. 12 p.

____. 1972a. Report of the Forest Productivity Committee, year ended December 31, 1972. Victoria, B.C. 20 p. plus appendices.

____. 1972b. Management of British Columbia's Forest Lands. Pub. B. 57. Information Division, Victoria, B.C. 21 p.

British Columbia Lands Service. 1975. Catalogue of maps and air photographs for British Columbia. British Columbia Lands Forests and Water Resources. Surveys and Mapping Branch, Victoria, B.C.

British Columbia Ministry of the Environment. 1976. Catalogue of maps and publications. Environment and Land Use Committee Secretariat, Victoria, B.C. 15 p.

Burns, J.E. 1974. (memo to G.E. Reid). Re: Upper Oyster slides. British Columbia Department of Lands, Forests and Water Resources, Lands Branch, Victoria, B.C. 4 p.

Burns, J.E. (unpublished). Comox Harbour - A plan for conservation. Prepared for British Columbia Department of Lands, Forests and Water Resources, Lands Branch Environment Services Unit, Victoria, B.C. 57 p.

Canada Department of the Environment. 1965. The Canada Land Inventory. Soil capability classification for agriculture. Information Canada, Ottawa, Ont. 16 p.

____. 1966. The climates of Canada for agriculture. The Canada Land Inventory Rept. No. 3. Queen's Printer, Ottawa,

____. 1970a. Land capability classification for forestry. The Canada Land Inventory. Rept. No. 4. Information Canada, Ottawa, Ont. 72 p.

____. 1970b. Land capability classification for wildlife. The Canada Land Inventory. Lands Directorate, Ottawa, Ont. 30 p.

Canada Department of the Environment. 1973. Courtenay River estuary. Available land use data. Input to the Estuary Working Group from member agencies. Pacific Environment Institute Files, West Vancouver, B.C.

____. 1973c. Pipeline construction guide. Tech. Rept. . 1973-2. Report prepared by the Environmental Quality Unit for Canada Department of the En ironment, Fisheries and Marine Service, Southern Operations Branch, Vancouver, B.C. 8 p.

Canada Department of Fisheries. 1958. The fisheries problems associated with the power development of the Puntledge River, Vancouver Island, B.C. Canada Department of Fisheries, Vancouver, B.C. 40 p.

Canada Department of Fisheries and the Environment. 1978. Potential Pacific coast oil ports: A comparative environmental risk analysis. Fisheries and Environment Canada Working Group on West Coast Deepwater Oil Ports. Vol. I, 98 p. and 21 figures. Vol. II, supplementary appendices, various pagenations.

Canada Department of Regional Economic Expansion. 1969. Land capability classification for out-door recreation. Canada Land Inventory Rept. No. 6. Queen's Printer, Ottawa, Ont 114 p.

___. 1970. Objectives scope and organization. The Canada Land Inventory Rept. No. 1. Queen's Printer, Ottawa, Ont. 61 p.

Canadian Hydrographic Service. 1965. British Columbia pilot Vol. 1. Southern portion of the coast of British Columbia (seventh edition). Canada Department of Mines and Technical Surveys, Marine Sciences Branch, Canadian Hydrographic Service, Ottawa, Ont. 678 p.

Carson, J.G. 1957. Daily farm study on Vancouver Island, 1954-55. Canada Department of Agriculture, Economics division, Ottawa, Ont.

Comox District Free Press. 1974. Estuary plan taking shape. Comox Distruct Free Press. April 10. Courtenay, B.C.

Crown Zellerbach Canada Limited. 1976. About Crown Zellerbach. Issued by Crown Zellerbach Ltd. Public Relations Department, Vancouver, B.C. 26 p.

___. 1978. Visitor's guide and road map. Crown Zellerbach, Coast Wood Supply Division, Courtenay, B.C.

Dayton and Knight Limited. 1974. Wastewater disposal Canadian Forces Base Comox, British Columbia. Rept. prepared by Dayton and Knight Ltd., West Vancouver, B.C. for the Department of National Defence, Comox, B.C. 48 p.

___. 1976. Regional wastewater treatment for return to the environment. Rept. prepared by Dayton and Knight Ltd., West Vancouver, B.C. for the Department of National Defence, Comox, B.C. 59 p. plus appendices.

DeMong, R. 1978. Summary of agriculture in the Comox Valley. British Columbia Department of Agriculture, Courtenay, B.C. Unpubl. data. 4 p.

Ecroyd, L.G. 1955. Main trading centres (Vancouver Island): The Alberni Valley, Nanaimo, Courtenay, Cumberland, Comox, Duncan, Campbell River, Victoria. *In:* Western Business and Industry 29: 71-72, 74, 86.

EPEC Consulting Western Limited. 1975. Coal resource study of Comox Basin-Nanaimo Series, Vancouver Island, British Columbia. Preliminary Environmental Assessment. Vol. 7. Report prepared by EPEC Consulting Western Ltd. for Weldwood of Canada, Vancouver, B.C.

Goard, D.S. and G. Dickinson. 1971. A bibliography of social and economic research pertaining to rural British Columbia. Rept. prepared by D.S. Goard and G. Dickinson under Canada Land Inventory Project No. 49015 for Canada Department of Regional Economic Expansion, Ottawa, Ont. 44 p.

Halstead, E.C. and A. Treichel. 1963. Groundwater resources of the coastal lowland and adjacent islands, Nanoose Bay to Campbell River, east coast, Vancouver Island. Geol. Surv. Can. Bull. 144. Otaawa, Ont. 42 p. plus maps.

Hardwick, W.G. 1961. Changing logging and sawmilling sites in coastal British Columbia. p. 1-7. *In:* The Canadian Association of Geographers - British Columbia Division. Occ. Papers No. 2.

Hurley, V. (pers. comm.). Supervisor of Field Services, Regional District of Comox-Strathcona, Courtenay, B.C.

Interim Planning Agreement Staff. 1974. Mid-Coast region, social demographic and labour force statistics. Rept. prepared by the Interum Planning Agreement Staff, individuals from Canada Department of Regional Economic Expansion and British Columbia Department of Economic Development for the British Columbia Department of Economic Development, Victoria, B.C. 39 p.

Jameson, E. and S. Warren. 1973. Estuary and watershed land status for selected rivers in British Columbia. Rept. prepared by E. Jameson and S. Warren for the British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Victoria, B.C. 30 p.

Jawanda, B.S. 1954. A geographical study of Vancouver Island. M. A. Thesis. University of British Columbia, Dept. Geography Vancouver, B.C. 244 p.

Kerr, D. 1952. The physical basis of agriculture in British Columbia. Econ. Geog. 28: 229-239.

Lacate, D.S. 1969. Guidelines for bio-physical land classification. Canada Department of Fisheries and Forestry, Canadian Forestry Service Publ. No. 1264, Vancouver, B.C. 61 p.

LeBaron, B. 1975. Oyster River foreshore development social impact assessment. Rept. prepared by B. LeBaron, Errington, B.C. for British Columbia Department of Lands, Forests and Water Resources, Lands Branch, Environmental Services Unit, Victoria, B.C. 57 p.

Livingston, E. 1962. Groundwater in the Comox area. British Columbia Department of Lands, Forests and Water Resources, Water Rights Branch, 5 p. plus appendices.

___. 1974. (memo to R. Sharp) Re: Groundwater resources on the east coast of Vancouver Island. *In:* Regional water study, School District 71. AESL, Victoria, B.C. 92 p. plus appendices.

McLarnon, S.J. (ed.). 1977. Oyster River: Farm, classroom, and laboratory. p. 6. *In:* University of British Columbia Alumni Chronicle. Vol. 31. 30 p.

Meyer, P.A. and M.C. Harrison. 1976. Marina policy in the tidal area of the Pacific Coast. A study of the recreational responsibilities of the Small Craft Harbours Branch, Canada Department of the Environment, Small Craft Harbours Branch, Vancouver, B.C. 39 p.

Ministry of Lands, Parks and Housing. 1979. Foreshore lease information. Director of Land Management, Victoria, B.C. 5 p.

Mitchell, D. 1971. Archaeology of Gulf of Georgia area. Syesis 4. Suppl. 1. 228 p.

Morrison, D.C. 1976. (memo to T. Cockburn). Re: Oyster River estuary. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 2 p.

Mos, G.J. and M.C. Harrison. 1974. Resident boating in Georgia Strait. Environment Canada, Fisheries and Marine Service Tech. Rept. Ser. No. PAC/T-74-5. Southern Operations Branch, Vancouver, B.C. 75 p.

Munson, P. 1974. Future of estuary at a crossroals. Comox Free Press. March 20, Courtenay, B.C.

O'Brien, J. 1975. About Oyster Marina, let's be reasonable. Comox District Free Press. March 26, Courtenay, B.C.

Percival, R. 1977. Marina conflicts develop. The Campbell River Upper Islander. January 26, Campbell River, B.C.

Pollution Control Branch. 1974. Summary report on water quality evaluation of Comox Harbour and associated environs. Appendices A-J. Rept. prepared by British Columbia Department of Environment, Pollution Control Branch, Water Resources Service for British Columbia Department of Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 16 p. plus appendices.

Regional District of Comox-Strathcona. 1970. Comox Lake area study. Regional District of Comox-Strathcona, Courtenay, B.C. 39 p.

____. 1972. Economic fact book. Regional District of Comox-Strathcona, Courtenay, B.C.

____. 1974. Greenbelts: An evaluation of proposed sites. Regional District of Comox-Strathcona, Planning Department, Courtenay, B.C. 24 p.

____. 1975. A report on land use and resources within the region, 1975. *Ibid.* 63 p.

____. 1976a. Official regional plan for the Regional District of Comox-Strathcona (Draft Text). *Ibid.* 37 p.

____. 1976b. Official regional plan. Second draft. December 1976. *Ibid.* 32 p.

____. 1976c. Draft regional plan issues. Background information package. *Ibid.* 24 p.

____. 1976d. Population growth and distribution. A forecast to the year 2001, with a prediction of growth distribution for the settled east coast area. *Ibid.* 17 p. plus appendices.

____. 1977. Official regional plan. *Ibid.* 25 p.

____. 1978. Economic profile. *Ibid.* 53 p.

____. 1979a. Economic profile. *Ibid.* 54 p.

____. 1979b. Population data and forecast. *Ibid.* 31 p. plus appendices.

Rennie, P.J. 1967. Measure for measure. Canada Department of Forestry and Rural Development, Forestry Branch, Departmental Pub. No. 1195. Ottawa, Ont. 31 p.

Sorboe, M.M. and E.D. Woodward. 1964. Dairy farming on Vancouver Island. Canada Department of Agriculture, Economics Division, Vancouver, B.C.

Stanley Associates Engineering Limited. 1975. Environmental and land use sector study. Part I, inventory: Queen Charlotte Islands, North Vancouver Island and Mid-Coast Region. Current environmental concerns and land use conflicts. Rept. prepared by Stanley Associates Engineering Ltd. for British Columbia Department of Economic Development, GDA/IPA Studies, Victoria, B.C. 32 p.

Statistics Canada. 1967. 1966 census of Canada. Population divisions and subdivisions western provinces. Catalogue 92-606. Vol. 1. Table 9:61, Information Canada, Ottawa, Ont.

____. 1972. 1971 census of Canada. Population census divisions and subdivisions western provinces. Catalogue 92-707, Vol. 1. Part 1. Table 6:67. *Ibid.*

____. 1973a. 1971 census of Canada, special bulletin. Geography: land use areas and densities of statistical units. Catalogue 98-701 (SG-701). Table 2:46. *Ibid.*

____. 1973b. 1971 census of Canada. Population census subdivisions (historical). Catalogue 92-702. Vol. 1. Part 1. Table 2:113. *Ibid.*

____. 1973c. 1971 census of Canada. Agriculture, British Columbia. Catalogue 96-711. Vol IV. Part 3. Table 36:4. *Ibid.*

____. 1974a. 1971 census catalogue. Population, housing, agriculture and employment. Catalogue 11-506. *Ibid.* 79 p.

____. 1974b. Shipping report, part II, 1972. International seaborne shipping (by port). Catalogue 54-203. Table 6:27. *Ibid.*

____. 1975a. Shipping reprot, part II, 1973. International seaborne shipping (by port). Catalogue 54-203. Table 6:23. *Ibid.*

____. 1975b. 1975 catalogue of publications, data files and unpublished information. Catalogue 11-204E. *Ibid.* 315 p.

____. 1976a. Shipping report, part II, 1975. International seaborne shipping (by port). Catalogue 54-203. Table 6:23. *Ibid.*

____. 1976b. Population preliminary counts. 1976 census of Canada - census divisions. Table 2:77-78. *Ibid.*

Stubbs, G.D. 1973. Vancouver Island tourist study, 1972. B.A. Thesis, University of Victoria, Dept. Geography, Victoria, B.C. 87 p.

Subcommittee on Multiple Use. 1970. Towards integrated resource management. Report prepared by sub-committee on multiple use, Canada Department of Regional Economic Expansion for a meeting of the National Committee on Forest Land, Quebec, P.Q., May 1969. Queen's Printer, Ottawa, Ont. 47 p.

Underwood, McLellan and Associates Limited. 1975. Preliminary draft report of assessment of the impact of the marine resource sector on the North Vancouver Island, Mid-Coast, Queen Charlotte Island region. Rept. prepared by Underwood, McLellan and Associates Ltd., Vancouver, B.C. for British Columbia Department of Economic Development, I.P.A. Regional Co-ordinator, Victoria, B.C. 50 p.

University of British Columbia. 1965. Faculty of Graduate Studies community and regional planning. Planning for regional development in British Columbia with special application to Northern Vancouver Island. Vancouver, B.C.

Van Horne, H.B. and J.B. Maxwell. 1949. Agriculture in central Vancouver Island 1946: An economic study of commercial and part-time farming. Canada Department of Agriculture, Economics Division, Ottawa, Ont.

Verner, C. and G. Dickinson. 1970. A socio-economic survey of the Vancouver Island area. Rept. prepared by C. Verner and G. Dickinson under Canada Land Inventory Project No. 49015, Rept. No. 15, A.R.D.A. for University of British Columbia, Adult Education Research Center, Vancouver, B.C. 72 p. plus appendices.

____. 1971. Rural people in the Vancouver Island area. A summary of a socio-economic survey. Rept. prepared by C. Verner and G. Dickinson under Canada Land Inventory Project No. 49009, Digest Rept. No. 9 for University of British Columbia, Adult Education Research Center, Vancouver, B.C. 6 p.

Wakefield, L.M. (pers. comm.). Sailing Directory, Canadian Hydrographic Service, Victoria, B.C.

Waldichuk, M. (MS, 1962). Oceanographic characteristics of Comox Harbour and approaches in relation to sea disposal of sewage. Fish. Res. Board Can. Pacific Biological Station, Nanaimo, B.C. 33 p.

Western Canada Hydraulic Laboratories Limited. 1972. Investigation of the proposed entrance channel for Pacific Playground Marina. Port Coquitlam, B.C. 15 p.

XI. POLLUTION AND WATER QUALITY

Acres Consulting Service Limited. 1973. Proposed Puntledge salmon hatchery feasibility report. Rept. prepared by Acres Consulting Service Ltd. for Environment Canada, Fisheries and Marine Service, Vancouver, B.C. 45 p.

Arney, D.B. and B. Kay. 1976. Shellfish growing water sanitary survey of Vancouver Island coastline, Campbell River to Kye Bay, British Columbia. Canada Department of the Environment, Environmental Protection Service Rept. No. EPS 5-PR-76-6. West Vancouver, B.C. 129 p.

Associated Engineering Services Limited (AESL). (unpublished). Comox Valley regional sewage disposal plan. Interum Rept., Vancouver, B.C. Canada Department of the Environment, Environmental Protection Service Files, West Vancouver, B.C. 9 p.

Baillie, K. and M. Morrison. 1977. Heavy metal values for fish on Vancouver Island. Ministry of Environment, Pollution Control Branch, Victoria, B.C.

Bams, R.A. 1976. Results of a pink salmon transplant using males native to the recipient stream. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 452. Pacific Biological Station, Nanaimo, B.C. 56 p.

Bell-Irving, R. (pers. comm.). Habitat Protection Biologist, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Habitat Protection Directorate, Vancouver, B.C.

Bond, K. (pers. comm.). Habitat Protection Technician, Ministry of Environment, Fish and Wildlife Branch, Campbell River, B.C.

___. 1978 (memo to S. Mahannah). Re: Debris catcher on Wattaway Creek. Ministry of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C.

British Columbia Department of Agriculture. 1974. Agricultural operations and use of chemicals. Appendix I. *In:* Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of Agriculture for British Columbia Department of Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 9 p.

British Columbia Fish and Wildlife Branch. (unpublished). Stream survey reports. Department of Recreation and Travel Industry, Nanaimo, B.C.

___. 1974. Lands and Forests log boom surveys. Appendix B. *In:* Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch for British Columbia Department of the Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 4 p.

British Columbia Forest Service. 1974. Water environment quality study of Comox and Prince Rupert harbours. Appendix G. *In:* Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of Lands, Forests and Water Resources, Forest Service for British Columbia Department of the Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 11 p.

Brown, A.A. 1976. Oyster River flooding and erosion. British Columbia Department of Lands, Forests and Water Resources, Water Investigations Branch Water Investigation File No. P73-31. Victoria, B.C. 9 p.

Brown, R.F., V.D. Chahley and D.G. Demontier. 1977. Preliminary catalogue of salmon streams and spawning escapements of Statistical Area 14 (Comox-Parksville). Canada Department of Fisheries and the Environment, Fisheries and Marine Service Tech. Rept. No. PAC/D-77-12. Vancouver, B.C. 128 p. plus tables.

Burns, J.E. 1974. (memo to G.E. Reid). Re: Two blowdowns on Oyster River. Canada Department of the Environment, Fisheries and Marine Service, Records Section, Oyster River Stream Obstruction File, Vancouver, B.C.

___. (unpublished. The importance of streamside vegetation to trout and salmon in British Columbia. Ministry of Environment, Fish and Wildlife Branch, Nanaimo, B.C. 12 p.

___. (unpublished). Comox Harbour. A plan for conservation. Rept. prepared for Ministry of Lands, Forests, and Water Resources, Lands Branch, Environmental Services Unit, Victoria, B.C. 57 p.

Canada Department of the Environment. 1973a. British Columbia Forest Service guidelines for clearcut logging, streambank. shoreline and water quality protection. Fisheries and Marine Service, Vancouver, B.C. 26 p.

___. 1973b. Courtenay River estuary - available pollution data. Input to the Estuary Working Group from Canada Department of the Environment, Environmental Protection Service, Pacific Environmentat Institute Files, West Vancouver, B.C.

___. 1976. Oil and chemical spill counter-measures map series-biological resources. Environmental Protection Service, NTS 92F/14, 92/K3, West Vancouver, B.C.

Canada Department of Fisheries. 1958. The fisheries problems associated with the power development of the Puntledge River, Vancouver Island. Canada Department of Fisheries, Vancouver, B.C.

Clague, J.J. 1976. Sedimentology and geochemistry of marine sediments near Comox, British Columbia. Geol. Surv. Can. Paper 76-21, Ottawa, Ont. 21 p.

Clark, M.J.R. and J.D. Ellis. 1975. British Columbia Resources Service discharge and environmental data (EQUIS). Ministry of Environment, Pollution Control Branch Rept. No. 75-9. Victoria, B.C.

Conlan, K.E. (unpublished). The biological effects of log dumping and storage in southern British Columbia. Report (1). Methods of log handling and transport. M. Sc. Thesis, University of Victoria, Dept. Biology, Victoria, B.C. 15 p. plus appendices.

___. (unpublished). The biological effects of log dumping and storage in southern British Columbia. Report (2). Literature review and M. Sc. progress report. University of Victoria, Dept. Biology, Victoria, B.C. 22 p.

___, T.R. Andrews and D.L. Tillapaugh. 1973. A preliminary assessment of the impact of intertidal log dumping and storage on the faunal community and sediment characteristics of Buckley Bay. British Columbia Department of Recreation and Conservation, Marine Resources Branch, Victoria, B.C. 12 p. plus tables.

Dayton and Knight Limited. 1976. Report to Department of National Defence on feasibility of integrating waste water, treatment and return to the environment at Canadian Forces Base Comox, with Regional District of Comox-Strathcona sewerage plan. Rept. prepared by Dayton and Knight Ltd. West Vancouver, B.C. for Canada Department of National Defence, Comox, B.C. 59 p. plus appendices.

Derksen, G.D. and T.J. Tevendale. 1974. Shellfish growing water sanitary survey of Denman Island. Canada Department of the Environment, Environmental Protection Service Rept. No. EPS 5-PR-74-9. West Vancouver, B.C. 47 p.

Environment Canada. 1977. Ocean dumping Control Act reprints issued December 1975 to December 1976 for the Pacific Region. Environmental Protection Service, West Vancouver, B.C.

Environmental Protection Service. 1972. Brief presented to the British Columbia Pollution Control Board inquiry into food processing, agriculturally oriented and other miscellaneous industries. Canada Department of the Environment, West Vancouver, B.C. 154 p.

___. (unpublished). Shellfish growing water sanitary survey of British Columbia. Canada Department of the Environment, West Vancouver, B.C.

Gibson, B. (pers. comm.). Engineer-Forester, Crown Zellerbach, Courtenay, B.C.

Goodman, D. 1974. An assessment of the impact of a proposed access channel and breakwater on the fisheries resources on the Oyster River. Canada Department of the Environment, Fisheries and Marine Services Tech. Rept. No. PAC/T-74-4. Southern Operations Branch, Vancouver, B.C. 51 p.

Hall, D. (pers. comm.). Manager, Crown Zellerbach, Courtenay Division, Courtenay, B.C.

Hallam, R. (pers. comm.). Project Biologist. Canada Department of Fisheries and the Environment, Environmental Protection Service, West Vancouver, B.C.

Harbo, R.M. and I.K. Birtwell. 1977. Mercury content of some marine organisms from coastal waters of southern British Columbia. Canada Department of Fisheries and the Environment, Fisheries and Marine Service Tech. Rept. Ser. PAC/T-77-5. Vancouver, B.C. 24 p.

Hatten, J. 1974. (memo to H.D. DeBeck). Re: Water licence applications for irrigation. Canada Department of the Environment, Fisheries and Marine Service, Records Section, Oyster River Stream Obstruction Files, Vancouver, B.C.

Hooton, R.S. (unpublished). Aspects of the freshwater fisheries resources of the Cowichan River - a submission prepared for the Cowichan Estuary Task Force. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 23 p.

Ince, J.C. 1976. Environmental law: A study of legislation affecting the environment of British Columbia. West Coast Environmental Law Association, Vancouver, B.C. 209 p.

Information Branch. 1978. Planning work near the water? Fisheries and Environment Canada, Fisheries and Marine Service, Information Branch, on file at the Pacific Region Office, Vancouver, B.C. 4 p.

Jackson, K. (pers. comm.). Shellfish Co-ordinator, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

Kay, B. and T.J. Tevendale. 1974a. Shellfish growing water sanitary survey of Baynes Sound, Gartley Point to Deep Bay, British Columbia. Canada Department of the Environment, Environmental Protection Service Rept. No. EPS-5-PR-74-10. West Vancouver, B.C. 79 p.

___. 1974b. Shellfish growing water sanitary survey of Comox Harbour area, British Columbia. Canada Department of the Environment, Environmental Protection Service Rept. No. EPS-5-PR-74-13. West Vancouver, B.C. 49 p.

Kennedy, K. and B.R. Waters. (unpublished). Courtenay River estuary. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 61 p.

Marshall, D.E. 1973. Progress report on the Puntledge River program, 1971-1972. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. 1973-8. Vancouver, B.C. 59 p.

Maxwell, H.G. and G.G. Speers. 1975. Debris survey of Wolf and Willemar lakes. Crown Zellerbach Research and Development Tech. Serv. Rept. Richmond, B.C. 9 p.

McKelvey, R. (unpublished). Migratory birds using the Comox Harbour area 1974-1975. Canada Department of the Environment, Canadian Wildlife Service, Delta, B.C. 60 p. plus data.

McLaren, R.E. 1975. Federal approaches to water pollution control in Canada. Paper presented to the 13th Pacific Science Congress, August 28, 1975. Canada Department of the Environment, Environmental Protection Service Files, West Vancouver, B.C. 9 p.

McMynn, R.G. 1970. Greenbelts or leave strips to protect fish. Why? British Columbia Department of Recreation and Conservation, Commercial Fisheries Branch, Victoria, B.C. 36 p.

Neilson, C.L. 1972. (memo to W. Reidel). Pesticide usage in Comox Bay area. British Columbia Department of Lands, Forests and Water Resources, Victoria, B.C.

Okano, A.T. 1974. Comox Lake debris. Crown Zellerbach Research and Development Tech. Surv. Rept. Richmond, B.C. 18 p.

Pacific Northwest Pollution Control Council. 1971. Log storage and rafting in public waters. A Task Force report. G. Hansen Chairman of the Task Force, Washington State University, Dept. Ecology, Olympia, Washington, U.S.A. 56 p.

Paish, Howard and Associates Limited. 1972a. The west coast oil threat in perspective. An assessment of the natural resource, social and economic impacts of marine oil transport in southwest British Columbia waters. Vol. II. Rept. prepared by Howard Paish and Associates Ltd. for Environment Canada, Vancouver, B.C. 302 p.

____. 1972b. The west coast oil threat in perspective. An assessment of the natural resource, social and economic impacts of marine oil transport in southwest British Columbia waters. Vol. III - maps. Prepared by Howard Paish and Associates Ltd. for Environment Canada, Vancouver, B.C.

Patten, R.K. (unpublished). Comox Harbour and vicinity bacteriological survey. British Columbia Department of Environment, Pollution Control Branch, Coast Region, Victoria, B.C. 11 p.

Pollutech Pollution Advisory Services. 1976. Environmental effects of dredging operations: a literature review. Rept. prepared by Pollutech Pollution Advisary Services for Canada Department of the Environment, Environmental Protection Service Rept. No. EPS-5-PR-76-1. West Vancouver, B.C. 31 p.

Pollution Control Branch. 1974a. Wastewater and solid waste disposal. Appendix A. *In:* Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of Environment, Pollution Control Branch, Resources Service for British Columbia Department of the Environment, Environment and Land Use Committee Sectretariat, Victoria, B.C. 16 p. plus appendices.

____. 1974b. River water quality. Appendix C. *In: Ibid.* 32 p.

____. 1974c. Oceanography water quality. Appendix D. *In: Ibid.* 76 p.

____. 1974d. Pesticides and herbicides. Appendix J. *In: Ibid.* 7 p.

____. 1975. Summary report on water quality evaluation of Comox Harbour and environs. Appendices A-J. *In: Ibid.* 70 p.

Rodgers, R. (pers. comm.). Conservation Officer, Ministry of Environment, Fish and Wildlife Branch, Courtenay, B.C.

Roundwaithe, A. 1975. Pollution and law in Canada. International Self-Counsel Press Limited, Vancouver, B.C.

SPEC. 1974. Preservation of the Courtenay River estuary. Presented to the Regional District of Comox-Strathcona, Courtenay, B.C. 9 p.

Stewart, M. (pers. comm.). Engineer. Associated Engineering Services Limited, Vancouver, B.C.

Thornton, B. (pers. comm.). President, Steelhead Society, Courtenay Chapter, Courtenay, B.C.

Upper Island Health Unit. 1974. Health. Appendix H. *In:* Provincial interagency evaluation of Comox Harbour. Rept. prepared by British Columbia Department of Health, Upper Island Health Unit, Courtenay, B.C. for British Columbia Department of Environment, Environment and Land Use Committee Secretariat, Victoria, B.C. 19 p.

___. (unpublished). Fecal coliform counts for Comox Harbour and Baynes Sound. Ministry of Health, Courtenay, B.C.

Vancouver People's Law School. 1976. Pollution and environmental law. 601-207 West Hastings Street, Vancouver, B.C. 31 p.

Venus, E. (pers. comm.). Manager, MacMillan Bloedel, Menzies Bay Division, Campbell River, B.C.

Wards, B.A. 1976. Study of existing and historical ocean dump sites in the Pacific Region. Prepared for Environment Canada, Environmental Protection Service, Ocean Dumping Section, Vancouver, B.C. 101 p.

Waldichuk, M. 1974. Application of oceanographic information to the design of sewer and industrial waste outfalls. Rapp. P - Reun. Const. int. Explor. Mer. 167: 236-259.

___. 1977. Observations in the marine environment related to estuarine ecosystem disruption in coastal area development. Rept. prepared for GESAMP Working Group on the Pollution implications of seabed exploration and coastal area development. London, England. Pacific Environment Institute Files, West Vancouver, B.C. 28 p.

___. (MS, 1962). Oceanographic characteristics of Comox Harbour and approaches in relation to sea disposal of sewage. Fish. Res. Board Can. Pacific Biological Station, Nanaimo, B.C. 37 p. plus figures.

___, J.H. Meikle and J.R. Markert. 1968. Physical and chemical oceanographic data from the east coast of Vancouver Island 1954-1956. Vol. I. Discovery Passage, Duncan Bay and Baynes Sound-Comox Harbour. Fish. Res. Board Can. MS. Rept. Ser. No. 989. Pacific Biological Station, Nanaimo, B.C. 133 p.

Walker, C.E. and J.R. McLeod. (undated). Catalogue of salmon spawning areas and escapement populations. Statistical Area 14. Canada Department of the Environment, Fisheries and

Marine Service, Vancouver, B.C.

Werner, A.E. (pers. comm.). Chemist, Canada Department of Fisheries and the Environment, Pacific Environment Institute, West Vancouver, B.C.

___. 1968. Accumulation and composition of sediments from polluted waters off the British Columbia coast, 1963-1966. Fish. Res. Board Can. MS. Rept. Ser. No. 963. Pacific Biological Station, Nanaimo, B.C. 81 p.

___, and R. Angotti. 1973. Data record: Natural decay of immersed wood particles. Fish. Res. Board Can. MS. Rept. Ser. No. 1278. Pacific Environment Institute, West Vancouver, B.C. 168 p.

Wilcocks, T. (memo to T. Bird). Re: Slide from logging road. Canada Department of Environment, Fisheries and Marine Service, Records Section, Oyster River Stream Obstruction File, Vancouver, B.C.

Wilson, D.M. (pers. comm.). Project Biologist. Canada Department of Fisheries and the Environment, Environmental Protection Service, West Vancouver, B.C.

XII. EFFECTS OF DEVELOPMENT

Associated Engineering Service Limited (AESL). 1976. Wolf Lake study. Rept. prepared by AESL for Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C. 18 p. plus figures.

___. (unpublished). Comox Valley regional sewage disposal plan. Interim report. Rept. prepared by AESL for the City of Courtenay, B.C. Canada Department of the Environment, Environmental Protection Service Files, West Vancouver, B.C.

Alley, J. (pers. comm.). Planner, Ministry of Lands, Parks and Housing, Land Management Branch, Nanaimo, B.C.

Bams, R. 1976. Results of a pink salmon transplant using males native to the recipient stream. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. No. 629, Pacific Biological Station, Nanaimo, B.C. 44 p.

Bell-Irving, R. (pers. comm.). Habitat Protection Biologist, Canada Department of Fisheries and the Environment, Fisheries and Marine Service, Vancouver, B.C.

Burns, J.E. 1976. Comox Harbour: A plan for conservation. Prepared for the Ministry of Environment, Lands Branch, Environment Services Unit, Victoria, B.C. 57 p.

Conlan, K.E. (unpublished). The biological effects of log dumping and storage in southern British Columbia. Report (2). Literature review and M. Sc. progress report. University of Victoria, Dept. Biology, Victoria, B.C. 22 p.

Dayton and Knight Limited. 1976. Report to the Department of National Defense on feasibility of integrating waste water, treatment and return to the environment of Canadian Forces Base Comox, with Regional District of Comox- Strathcona sewerage plan. Rept. prepared by Dayton and Knight Ltd., West Vancouver, B.C. for Canada Department of Defence, Comox, B.C.

Egan, J. (pers. comm.). District Land Manager, Ministry of Lands, Parks and Housing, Land Management Branch, Courtenay, B.C.

Kennedy, K. and B.R. Waters. (unpublished). Courtenay River estuary. British Columbia Department of Recreation and Conservation, Fish and Wildlife Branch, Nanaimo, B.C. 14 p.

MacKinnon, C., H. Genoe and D.C. Sinclair. (unpublished). The Puntledge River Project 1972-77. Canada Department of Environment, Fisheries and Marine Service, Salmon

Enhancement Branch, Vancouver, B.C. 61 p. plus appendices.

Marshall, D.E. 1973. Progress report on the Puntledge River program, 1971-1972. Canada Department of the Environment, Fisheries and Marine Service Tech. Rept. 1973-8. Salmon Enhancement Branch, Vancouver, B.C.

Walker, C.E. and J.R. McLeod. (undated). Catalogue of salmon spawning streams and escapement populations. Statistical Area 14. Canada Department of the Environment, Fisheries and Marine Service, Vancouver, B.C.

AUTHOR INDEX

- A -

- B -

- B -

- C -

- C -

- D -

- E -

- F -

- F -

- G -

- H -

- H -

- I -

- J -

- K -

- M -

- N -

- N -

- O -

- P -

- Q -

- R -

- R -

- S -

- T -

- U -

- V -

- W -

- W -

- Y -

- Z -