BULK LIQUIDS TERMINAL
SOUTH KAIEN ISLAND
PRINCE RUPERT, B.C.

VOLUME II
ENVIRONMENTAL REPORT

prepared for
PRINCE RUPERT PORT CORPORATION

prepared by
TERA PLANNING LTD
and
HAY & CO CONSULTANTS INC

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1.0 INTRODUCTION

This environmental report is part of a 4-volume series of reports which address the proposed bulk liquids terminal at South Kaien Island, Prince Rupert, B.C. This volume deals with the environmental inventory, assessment and mitigation opportunities of the South Kaien terminal.

The information contained in this volume was derived from a broad range of sources, in particular, the reports Prince Rupert Petrochemical Project Detailed Environmental Studies by Transtec Canada Limited and Simon TR Holding Limited (1981) prepared for Prince Rupert Terminals Limited and a number of environmental inventories conducted for the Ridley Island coal terminal as part of the Northcoast Environmental Analysis Team prepared for Federal-Provincial Joint Committee on Tsimpsean Peninsula Port Development titled Prince Rupert Bulk Loading Facility, Phase 2, environmental studies associated with the Fairview Terminal expansion published in 1989, and environmental compensation for the Fairview Terminal expansion including the eelgrass transplant conducted in 1990 and 1992. All of the environmental inventories and assessments for the above projects were conducted by TERA Planning Ltd which, since 1975, has maintained an active database for Chatham Sound and Prince Rupert Harbour.

*. The phasing of the Prince Rupert bulk liquids terminal project from Phase 1, temporary LPG, to Phase 2, permanent LPG with land-based tankage, to Phase 3, the MTBE and other bulk liquids terminal, is reflected in the assessment of the environmental impacts. For Phases 1 and 2, environmental impact assessment is included in Chapter 4. For the Phase 3, bulk liquids terminal, an initial environmental evaluation is described in Chapter 6.

2.0 OBJECTIVES

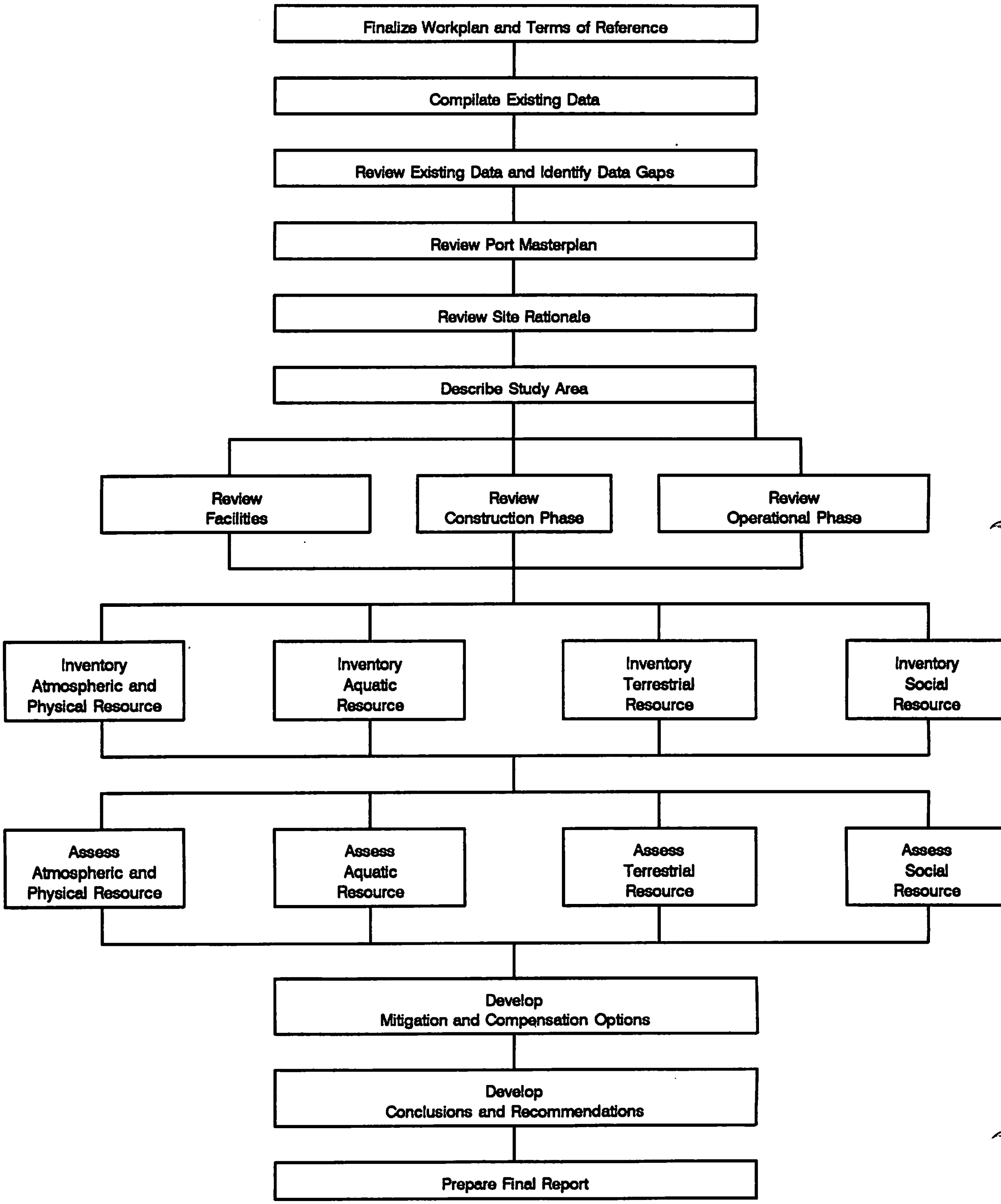
The objectives of this study are three-fold and include the review of the Prince Rupert masterplan, the review of site rationale for the South Kaien Island site, and a review of the detailed project description. As depicted in Figure 2.1-1, after the inventory of environmental resources, an assessment of the environmental impacts will be conducted. This, in turn, will allow the development of mitigation and compensation options for the proposed bulk liquids terminal at South Kaien Island.

Specifically, the objectives for this project are three-fold:

- an inventory of the atmospheric, aquatic, terrestrial and social resources at South Kaien Island;
- an assessment of these resources to determine the environmental sensitivity and impacts associated with the bulk liquids terminal; and
- the development of mitigation and compensation options for the identified environmental impacts.

Figure 2.1-1

PRINCE RUPERT PORT CORPORATION BULK LIQUIDS (LPG) TERMINAL TASK FLOWCHART



3.0 **ENVIRONMENTAL INVENTORY**

3.1 Atmospheric Resources

3.1.1 Climate

The climate of the region is characterized by mild, humid conditions with generally cloudy skies, abundant rainfall and prevailing southeasterly winds. The maritime climate at the site of the marine terminal is a result of the area's mid-latitude location on the continent's west coast and the separation from the interior by the southeast-northwest trending Coast Mountain Range. Climate is controlled by several factors; the most important being the general atmospheric circulation, the influence exerted by the Pacific Ocean, and the topography, both regional and local scales.

The Prince Rupert area is influenced by prevailing westerly global winds and is thus a region which experiences migratory low and high pressure systems. The low pressure (cyclonic) disturbances which are frequently embedded in this general westerly flow typically produce clouds due to continual air mass uplift, southerly surface winds and precipitation. Conversely, high pressure systems (anticyclonic) usually produce clear skies, calmer winds, and less precipitation. The weather and climate of an area is strongly dependent upon the relative frequency and persistence of specific air mass types.

Synoptic Season Patterns

The synoptic seasonal pattern which affects this region of British Columbia is well understood. During winter, low pressure areas in the Gulf of Alaska move towards the north coast of B.C. and control the winter climate in Chatham Sound. These low pressure systems are present for approximately 52% of all days in the Prince Rupert area. High pressure systems, conversely account for only 28% of the days. During the

Table 3.1-1

CLIMATE RECORD FOR PRINCE RUPERT

Latitude 54°18'N Longitude 130°26'W Elevation 52 m

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
TEMPERATURE													
Mean Daily Temperature (°C)	-0.2	2.3	3.0	5.4	8.3	10.8	12.8	13.1	11.4	7.9	3.8	1.6	6.7
Mean Daily Max Temp (°C)	3.3	5.7	6.2	9.2	12.2	14.1	16.0	16.5	15.1	11.2	7.1	4.8	10.1
Mean Daily Min Temp (°C)	-3.7	-1.3	-0.5	1.5	4.4	9.6	9.6	9.6	7.4	4.6	0.3	-1.6	3.1
Extreme Max Temp (°C)	12.8	17.8	17.2	23.4	27.2	25.5	27.8	28.7	23.9	21.1	18.9	18.9	28.7
Extreme Min Temp (°C)	-24.4	-17.2	-17.2	-6.7	-1.7	1.1	2.8	2.8	-2.2	-5.6	-17.8	-22.8	-24.4
PRECIPITATION													
Mean Rainfall (mm)	183.7	191.6	173.9	180.9	139.5	129.5	103.0	158.4	233.4	366.2	258.9	250.0	2369.0
Mean Snowfall (cm)	49.9	23.2	25.9	7.3	0.1	0.0	0.0	0.0	0.0	0.1	8.8	36.4	151.7
Mean Total Precipitation (mm)	227.5	222.1	200.8	190.0	139.5	129.5	103.0	158.4	233.4	366.5	268.4	284.1	2523.2
Extreme Rainfall in 24 hrs (mm)	68.3	95.0	51.9	98.6	56.8	53.3	52.6	87.6	88.4	105.4	69.9	89.6	105.4
Extreme Snowfall in 24 hrs (cm)	39.9	23.9	19.8	10.4	1.5	T	0.0	0.0	0.0	1.3	19.8	29.5	39.9
Extreme Precip in 24 hrs (mm)	70.6	95.0	51.9	98.6	56.8	53.3	52.6	87.6	88.4	105.4	69.9	89.6	105.4
Mean No Days with Measurable Rain	15	17	19	18	18	17	16	16	18	24	20	20	218
Mean No Days with Measurable Snow	9	5	8	4	0	0	0	0	0	0	2	7	35
Mean No Days with Frost	6	10	12	4	0	0	0	0	0	3	9	11	65
Relative Humidity (%)	84	82	81	80	81	84	87	89	88	85	84	84	84
Wind Prevailing Direction	SE	SE	SE	SE	SE	W	W	SE	SE	SE	SE	SE	SE
Wind Speed (km/h)	15.1	16.9	15.9	16.5	14.7	12.9	11.1	11.1	12.7	17.2	16.2	16.8	14.7
Peak Wind (km/h)	109	113	113	109	93	72	64	64	80	135	137	111	137
Mean No. Days with Fog	2	1	1	1	1	4	6	8	7	2	2	2	37

LEGEND: T = Trace

PERIOD OF RECORDS: Normals - 1951-1981; Hourly - 1961-1983; Extremes - 1962-1980

SOURCE: Environment Canada, Atmospheric Environment Service, Prince Rupert Principal Station Data summer season, the high pressure systems are more prevalent occurring 67% of the time. The frequent cyclonic disturbances are usually short lived and transient, with the high pressure systems more persistent.

Temperature

The mean annual temperature range in the Prince Rupert area is characteristic of the northern British Columbia coast region. The mean annual daily temperature is approximately 7°C, and the mean daily values fall within a relatively narrow range (about 14°C) in the course of a year due to the moderating influence of the Pacific Ocean (Table 3.1-1). Temperature extremes are due to occasional outbreaks of cold arctic air masses during winter and warm dry continental air advances during the summer. Temperatures range from +18° to -24°C in winter and +28°C to +1°C in summer. The coldest temperature ever recorded is -24.4 °C and the warmest temperature is +28.7°C.

Precipitation

Precipitation falls on approximately three days out of five, on an annual basis, reflecting the importance of cyclonic disturbances. The mean annual total precipitation for Prince Rupert Airport is 2523 mm with 71% of the precipitation falling between September and April.

The heaviest rainfall usually occurs in the month of October when Prince Rupert Airport receives an average of 366.5 mm of precipitation. In October, on average, precipitation falls on 24 days of the month. Rainfall does not fall in the form of thundershowers. Only two days, on average, per year receive thunderstorms.

Although most precipitation falls as rain (94%), there is usually 152 cm of snowfall. Snow is associated with warm, moist frontal systems advancing over colder air trapped in valleys. The driest months are May, June and July when as little as 103 mm precipitation may fall. Regionally precipitation increases with elevation. The greatest rainfall recorded in a 24 hour period is 105.4 mm.

Wind

Available records may not adequately describe surface patterns experienced at the South Kaien Island site as wind conditions are very localized. Generally, the prevailing wind is from the southeast year round, with northwesterlies prevalent during the summer months (Tables 3.1-1, 3.1-2 and 3.1-3). The average wind speed is 14.7 km/h with the peak wind speed recorded at 137 km/h. Southeast winds are also associated with rain. On average, when the winds are southeast, rain falls 53% of the time. The general wind distribution is explained by the seasonal frequency of specific synoptic patterns.

Other Climatic Conditions

Relative humidity for the Prince Rupert Airport is quite high, averaging 80% to 89% during all months.

Fog occurred, annually, on average 37 days for the period 1951-1980. Fog is most frequent in July, August and September, accounting for 57% of the annual, total days with fog. The fog is generally attributed to high atmospheric humidity during the early morning hours.

The total hours of bright sunshine is low, with an average annual total of 1224.1 hours recorded at Prince Rupert Airport (Table 3.1-4). This represents 27% of the possible hours of sunshine. The average monthly hours of bright sunshine ranges between a high of 189 hours in May to a low of 32 hours in December.

Table 3.1.2

PRINCE RUPERT AIRPORT, B.C.
PERCENTAGE FREQUENCY WIND DIRECTION (AND CALMS) AND MEAN WIND SPEED BY MONTHS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
N	4.6	3.5	3.3	2.7	2.4	2.1	1.8	2.5	3.0	2.7	4.2	4.6
NE	18.1	12.3	11.9	9.8	7.4	4.3	4.1	5.7	8.2	9.8	14.5	16.3
E	22.9	22.4	19.5	14.9	10.5	8.3	8.0	10.0	15.4	18.7	23.3	25.0
SE	27.1	34.3	29.5	32.2	25.1	20.5	20.1	23.5	29.7	39.1	32.9	30.3
S	4.6	5.5	6.5	8.5	11.2	11.5	13.5	11.0	8.1	8.4	5.4	4.4
SW	3.8	3.4	4.4	5.5	7.2	10.2	10.3	8.1	5.0	3.7	3.6	3.8
W	3.9	3.9	8.1	11.3	19.3	24.8	21.8	18.1	10.0	4.4	2.8	3.3
NW	3.8	4.2	7.0	7.2	7.3	6.6	6.4	6.3	7.0	4.5	3.3	3.0
CALM	11.2	10.5	9.8	7.9	9.6	11.7	14.0	14.8	13.6	8.7	10.0	9.3
MEAN SPEED (km/hour)	15.1	16.9	15.9	16.5	14.7	12.9	11.1	11.1	12.7	17.2	16.2	16.8

Table 3.1.3

PERCENTAGE FREQUENCY OF PRECIPITATION OBSERVATIONS BY WIND DIRECTION FOR PRINCE RUPERT AIRPORT

JANUARY

	RAIN	SNOW	FREEZING RAIN	NO PRECIPITATION
CALM	5.1	16.4	42.8	12.4
N	.7	3.4	0.0	6.2
NE	3.9	10.1	28.6	23.9
E	17.5	24.1	14.3	24.4
SE	57.3	28.5	14.3	17.1
S	6.7	3.7	0.0	4.0
SW	3.8	3.3	0.0	4.1
W	3.4	5.0	0.0	3.7
NW	1.6	5.5	0.0	4.2

JULY

	RAIN	SNOW	FREEZING RAIN	NO PRECIPITATION
CALM	12.3	0.0	0.0	14.5
N	1.8	0.0	0 .0	1.9
NE	3.7	0.0	0.0	4.2
E	8.2	0.0	0.0	7.9
SE	39.1	0.0	0.0	14.8
S	16.3	0.0	0.0	12.7
SW	6.6	0.0	0.0	11.3
W	8.2	0.0	0.0	25.6
NW	3.8	0.0	0.0	7.1

Table 3.1.4

AVERAGE HOURS OF BRIGHT SUNSHINE (1951-80) AND AVERAGE CLOUD COVER CONDITIONS (1963-72)

	Jan	Feb	Mar	Apr	Mar	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
BRIGHT SUNSHINE													
Average Hours	48.0	63.3	93.9	135.0	189.2	150.7	142.7	138.3	116.6	64.8	49.6	32.0	1224.1
% of Possible	19.4	23.1	25.6	32.1	38.2	29.4	27.7	29.9	30.4	19.8	19.3	13.9	27.2
CLOUD COVER Mean Cloudiness (1/10)	7.1	7.6	7.2	6.9	6.6	7.3	7.7	7.5	7.3	7.7	7.6	7.1	
% Freq Clear Skies	10.4	8.4	7.9	9.4	8.9	4.9	4.4	5.3	7.5	6.1	6.7	10.7	
% Freq 1/10-5/10	18.7	15.5	19.6	21.8	26.1	21.7	18.0	19.6	17.8	14.7	16.0	18.7	
% Freq 6/10-9/10	21.3	20.8	24.8	25.2	26.5	29.2	25.7	25.4	26.7	26.1	25.8	21.5	
% Freq Overcast	49.6	55.3	47.4	43.6	38.5	44.2	51.9	49.7	48.0	53.1	51.5	49.1	

3.2 Physical Resources

3.2.1 Bedrock Geology

The portion of Kaien Island west of Highway 16 is underlain by meta-sedimentary amphibolite rocks of early Mesozoic or Paleozoic age. In the area of the proposed project, these consist primarily of feldspathic schist, with lesser amounts of quartzite and hornblende schist (Hutchison, 1979).

Bedrock stratification is evident throughout; on the project site, rocks dip to the east at an angle of approximately 35%. Steeply-dipping bedrock and glacial scour have resulted in ridges and other irregularities in the micro-topography. Bedrock generally occurs within 2 m of the surface (Golder & Associates, 1981). In the vicinity of Bishop Island, a small intrusion of diorite can be seen.

3.2.2 Physiography and Landforms

The Prince Rupert area, including all of Kaien Island, is located within the Hecate Depression of the Coastal Trough, a subdivision of the Coast Mountains and Island physiographic region (Holland, 1964). Kaien Island is surrounded to the north, east and southeast by the mainland of the Tsimpsean Peninsula, and to the south and west by Watson, Ridley and Digby islands. The land to the east of Kaien Island is separated from it by a structurally-controlled channel, and lies in the Coast Mountains physiographic subdivision.

Kaien Island itself is roughly egg-shaped and is about 11 km long, with an area of approximately 45 km^2. It consists of a rounded, central mountain ridge with moderately steep slopes, surrounded by a flatter coastal lowland zone of varying width. Mount Hays, the central point, reaches an elevation of approximately 800 m above sea level.

The area of the proposed marine terminal consists of a single small knoll between the shore and Ridley Island access road. East of the access road the slope falls back down to the level of the reclaimed isthmus between Ridley and Kaien Islands.

Slopes of 30% to 60% occur on the knoll just above the shore, and immediately east of Ridley Island access road. The remainder of the site, including the top of the knoll is relatively level, with the exception of road and rail cuts and the edges of filled areas which exceed 50% slope in some locations. The highest point in the study area, approximately 100 m asl, occurs at the summit of the northeast corner of the property. The plateau of the knoll is approximately 38 m asl.

The slope map (Figure 3.2-1) shows that site to be moderately sloping. Essentially, a terrace is formed at 38 m asl, which slopes steeply up Mount Hays to the north of this terrace. To the southwest, the same terrace slopes steeply down towards the CNR railway and then drops gently into the intertidal of the entrance of Prince Rupert Harbour.

To the east, below the Ridley Island access road, the site is relatively flat and has been disturbed by filling, grading and ditching between the grain terminal and the access road.

Previous reports (Slaney & Co, 1973; TERA Environmental Resource Analysts Ltd, 1975; 1982) do not mention the existence of any unique landforms in the project area, and none were observed during the reconnaissance survey.

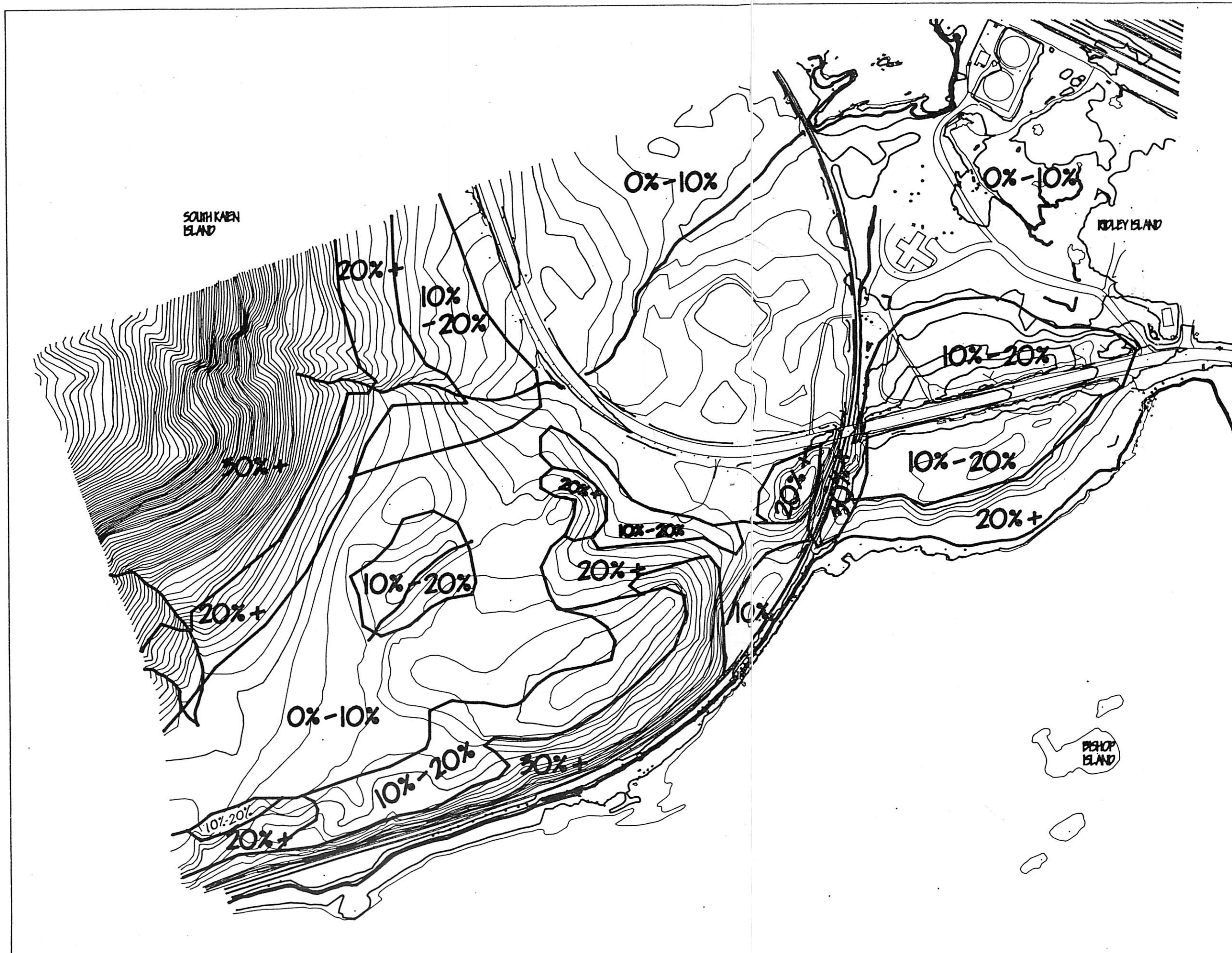
3.2.3 Soils

Soils in the study area are derived from fine to coarsely textured till and colluvium greater than 1 m in depth with pronounced horizons, including a thin gleyed A-horizon (ie. a surface soil layer in which nutrients have been leached downward) and below it an illuviated rust coloured B-horizon (in which the leached nutrients of the A-horizon have collected) (Photo 3.2-1). These soils are ranked mainly as podzols at the broadest category of the Canadian Soil Classification System. Podzols generally occur in forested areas of high precipitation and coarsely textured soil (often sandy loam), which result in leached nutrient poor-medium, acidic A-horizon, an accumulation of iron (and hence the red colour) and organic matter in their B-horizon (sub-surface layer), and a thick mor or moder humus layer indicative of slow decomposition of organic litter (due to the cool climate). Despite the relative impoverishment of podzols, the abundant precipitation and long growing season of the region permit maximum utilization if the available nutrients, evident in the remarkable dimensions of some of the veteran conifers.

Organic soils are also prevalent in the region, however they are infrequent in the study site due to the near absence of areas in which precipitation may pool. Organic soils develop in areas of poor drainage and high watertables which restrict the supply of oxygen for decomposition. Under these conditions organic matter accumulates faster than it decomposes.

The surficial materials present on Kaien Island generally include glacial till, colluvium, organic bog deposits, marine deposits and bedrock. Colluvial deposits are massive to slightly stratified, unsorted to poorly sorted sediments with a variety of particle sizes and shapes, and are associated with the steeper portions of the site. A thin layer of till and some marine clay overlay bedrock on the majority of the site (Golder & Associates, 1981). Bedrock outcrops occur along the shoreline and in the cut of the CNR and highway access into the Ridley bulk terminal.

Reference to the surficial material map (Figure 3.2-2) shows that the dominant surficial material consists of glacio marine deposits which in turn have weathered into organic fibrisols. These have been identified by Golder & Associates as peat. However, closer examination shows that they are fibrisols which have high mineral content, which makes these soils more suitable for disposal.



NO.	DESCRIPTION	DATE	BY

REVISIONS

PRINCE RUPERT PORT CORPORATION

110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :

PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING

Figure 3.2-1

SLOPE

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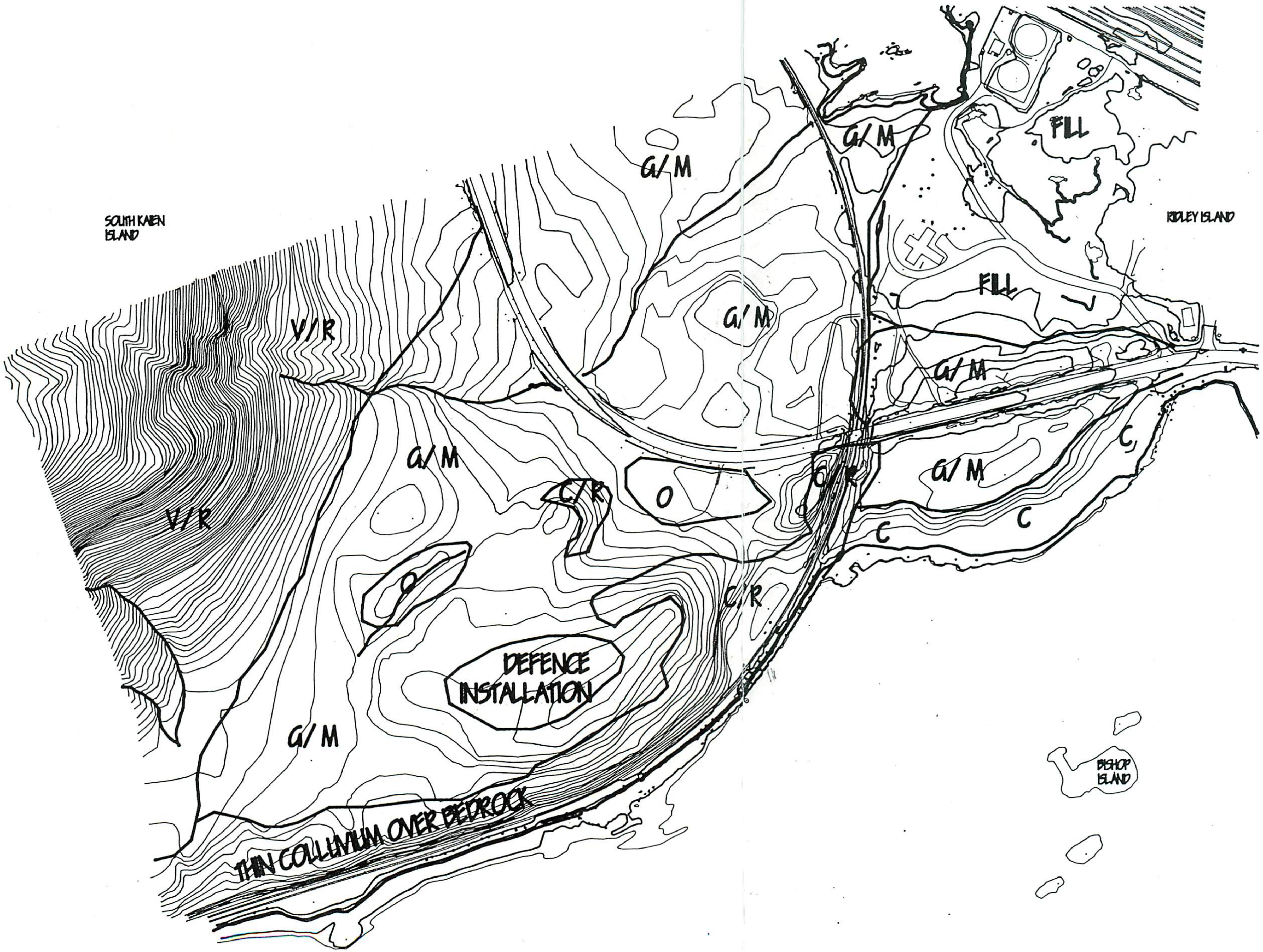

V ORGANIC VENEER OVER BEDROCK
C COLLUVIUM
R BEDROCK
G/M GLACIOMARINE SILT & CLAY
FILL ANTHROPOGENIC MATERIAL
O ORGANIC

NO.	DESCRIPTION	DATE	BY

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110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :
Figure 3.2-2
SURFICIAL MATERIALS

Designed		Project No. LPG-1		Drawing No.
Drawn	PS	Scale	1:5000	01
Checked	HH	Date	93/10/24	of 3

Photo 3.2-1
Sandy, leached podzolic soil showing
high water table

3.2.4 Drainage

A southeast flowing stream (unnamed creek) enters the site as it passes through two 80 cm diameter concrete culverts under the CNR track where it empties into the southwest corner of the Lagoon (Figure 3.2-3). Another set of culverts on the east side of the Lagoon connects the Lagoon to Porpoise Harbour. Creek flow was approximately 2 litres per second during a summer site visit, although the width of the creek bed suggests considerably greater flow during freshet. No other active or inactive streams were observed on the site. This creek drains an area of 80 ha and has been dammed by the previous DND. At that location a small wetland and pond exists.

Reference to the drainage map (Figure 3.2-3) shows that near surface groundwater drainage flows off the terrace (DND site) and, at times of heavy precipitation, cascades down the rock bluffs onto the CNR right-of-way. Because of the fine texture of the soil material and low percolation of the soil mantle, near surface groundwater flows are slow and surface sheet flow dominant.

3.2.5 Geological Hazards

The site is located away from previous mass wasting and debris flows which have occurred both to the east and to the northwest of the site. In fact, soils above the site and associated with the small unnamed creek adjacent to the site are relatively stable and not prone to failure.

3.3 Aquatic Resources

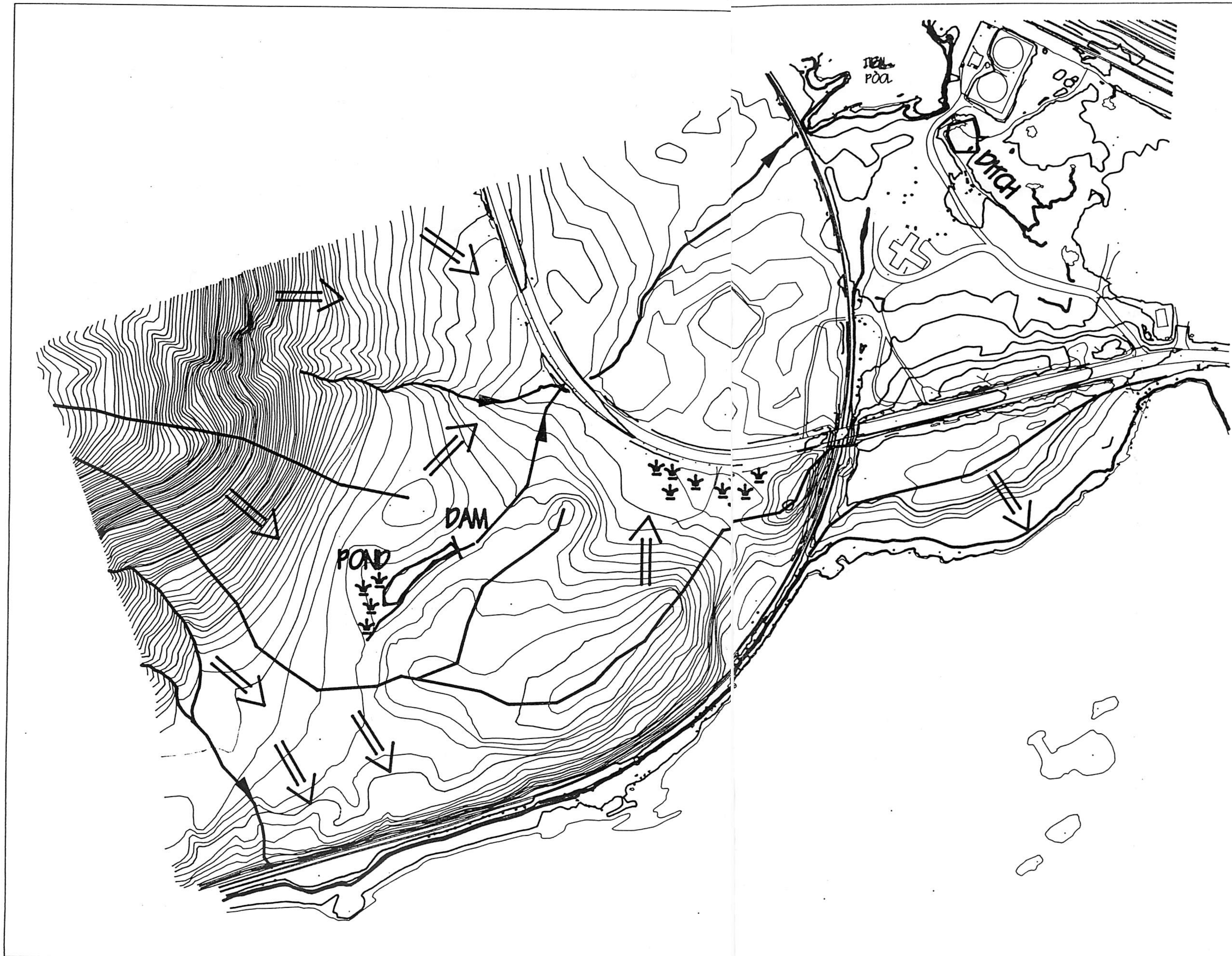
3.3.1 Oceanography

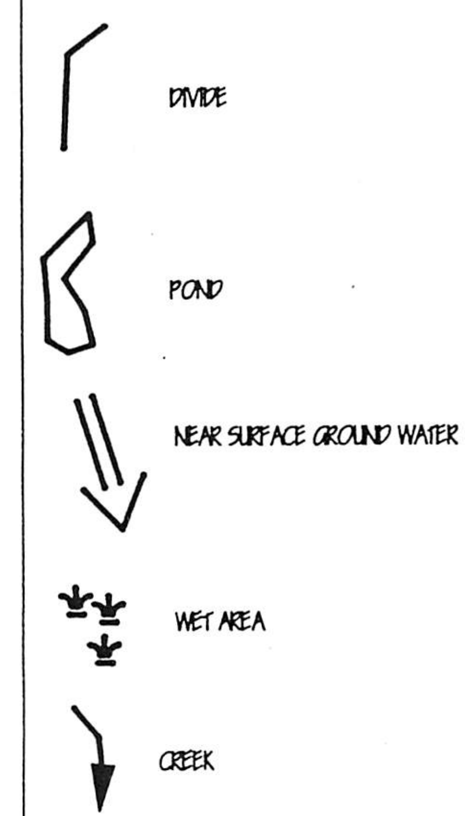
Chatham Sound

Chatham Sound is a semi-enclosed basin on the northern British Columbia coast having a surface area of approximately 1500 km^2. It is connected to the open waters of Hecate Strait and Dixon Entrance through numerous passages and channels, of which the largest and deepest (over 400 m) is north of Dundas Island. A submarine ridge supporting a chain of shoals and islands, the most notable of which are Stephens, Melville and Dundas, separates Chatham Sound from Dixon Entrance. The northern end of this ridge is broken by a deep irregular channel which extends westward to join the deep trench of Clarence Strait, west of Revillagigedo Channel. The effective sill depth in this irregular channel is approximately 170 m. In contrast to the northern end of Chatham Sound where depths are generally greater than 200 m, the southern portion is characterized by numerous groups of islands (such as the Rachael and Lucy groups) together with other detached islets and rocks.

From the northeast corner of the Sound, Portland Inlet extends inland for 45 km. There is effectively no sill across the mouth of this inlet, where depths are comparable to those in the northern end of Chatham Sound, being in excess of 550 m in some cases. The three main channels connecting Chatham Sound with Hecate Strait are Edye Passage to the south (between Porcher and Prescott islands), Bell Passage (to the north of Stephens Island), and Brown Passage (south of Melville Island).

Currents throughout Chatham Sound are driven primarily by the effects of the astronomical tide, wind, and fresh-water discharge from the Nass and Skeena Rivers. The tide propagates northward along this portion of the coast of British Columbia as a progressive wave, with local high and low water corresponding to the passage of a wave





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110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

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DRAWING TITLE :

Figure 3.2.3

DRAINAGE

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Checked HH	Date 93/10/24	of 3

peak and trough, respectively. The speed of propagation is limited by its shallow water value which is proportional to the square root of the depth. As the wave travels northward it is split by the Queen Charlotte Islands into two portions: one that travels relatively quickly through the deeper offshore waters west of the islands; and another that travels more slowly through Hecate Strait. The two waves recombine at the north end of Hecate Strait after the offshore component enters through Dixon Entrance. The interaction of the two progressive waves strongly modifies the phase relationship between the tidal elevation and current so that the response may more closely resemble the standing wave pattern observed in the Strait of Georgia (Thomson, 1981). This confluence of the tides occurs over a poorly defined region in the vicinity of Chatham Sound, and appears to shift its location on a seasonal basis. The result is that the tidal elevations and currents in Chatham Sound and in Prince Rupert Harbour have large amplitudes and may exhibit a complex phase relationship. In a purely progressive wave the occurrence of extremes in elevation and in current coincide; while in a pure standing wave extremes in elevation correspond to slack water. Any variation between these extreme cases may occur in this area, depending on the local character of the tidal wave.

The navigation dangers resulting from tidal streams through the various channels are described in the B.C. Pilot. Edye Passage has a minimum width of 1 km and is easily navigable. Tidal streams flood east and ebb west at 3 to 4 km/h.

Bell Passage is also about 1 km wide and is of sufficient depth to be used by moderate-sized vessels. There are, however, considerable navigational dangers in the vicinity. Tidal streams set east to west at a rate of 4 km/h.

Brown Passage provides the most direct route from Dixon Entrance to Prince Rupert and the southern portion of Chatham Sound. Generally, the tidal streams follow the axis of the channel with the flood setting southeast and the ebb northwest at a rate of 4 km/h.

However, in the vicinity of Triple Island the currents are strong and irregular, running 4 to 8 km/h.

Tidal streams in Chatham Sound generally do not exceed 4 km/h, with lower speeds occurring toward the north between Dundas Island and the north part of Tsimpsean Peninsula. The east and north travelling streams entering the Sound by Brown and Edye passages join those from Malacca Passage and move north up the main channel.

Tidal measurements have been made at Prince Rupert since 1939, as well as for periods of one to several months at locations within the mouth of the Skeena River, such as Claxton and Essington. The tides are of the semi-diurnal mixed type, having two highs and two lows in a tidal day, with a large diurnal inequality between succeeding lows and highs. The tidal range in this region is the largest on the Canadian Pacific Coast with mean values of about 5 m, and extreme ranges of greater than 7 m. Due to the large tidal amplitude, correspondingly large volumes of water move into and out of Chatham Sound in relatively short periods of time resulting in tidal currents of up to 8 km/h in various passages. There is, as well, considerable daily movement of water to and from bays and inlets. Observations made at anchor stations on the seaward side of Kaien Island illustrate the important role which the tides play in determining the distribution of salinity and temperature at any particular time. In most cases, variations in salinity, temperature and fresh water concentrations correlate with tidal variations.

Portions of the discharge of two large rivers, the Skeena and the Nass, flow into Chatham Sound. The Nass River flows initially into Portland Inlet and thence into the northern end of Chatham Sound on its passage to Dixon Entrance (Tables 3.3-1 and 3.3-2). Skeena River water enters the Sound through a series of channels separating the mainland from coastal islands, particularly Smith, DeHorsey, Kennedy and Porcher, and via a series of passages between these islands. It has been estimated that 25% of

Table 3.3-1
MEAN MONTHLY DISCHARGES FOR STREAMS IN TSIMPSEAN PENINSULA, 1982
(m^3/s)

STREAM	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MEAN
Boneyard Cr.	-	3.97	2.54	3.65	3.28	3.68	1.83	2.46	2.86	6.16	3.18	-	-
Diana Cr.	3.48	4.31	3.33	4.98	4.28	2.89	2.52	3.61	3.60	5.05	5.29	3.88	3.90
Kloiya R.	6.85	5.46	5.00	7.19	5.94	3.87	2.87	3.35	6.38	11.60	10.00	8.85	6.56
Nass R	146.00	129.00	123.00	323.00	1240.00	2060.00	1700.00	1200.00	825.00	840.00	458.00	219.00	779.00
Thumle R.	4.69	5.77	5.36	8.62	9.48	13.50	11.32	4.12	6.97	17.10	14.60	9.63	-
Union Cr.	5.83	5.40	4.86	5.60	6.26	6.92	5.67	2.15	4.48	11.70	15.20	11.10	7.20
Skeena R. at USK	194.00	169.00	151.00	381.00	1860.00	2830.00	1770.00	973.00	739.00	831.00	543.00	291.00	911.00

Table 3.3-2
DISCHARGE EXTREMES FOR PERIOD OF RECORD

STREAM	MAXIMUM INSTANTANEOUS DISCHARGE m^3/s, DATE	MAXIMUM DAILY DISCHARGE m^3/s, DATE	MINIMUM DAILY TOTAL DISCHARGE m^3/s, DATE	DISCHARGE dam^3
Diana Cr.	66.3/Oct 24, 1972	55.2/Oct 24, 1972	0.19/Jul 3, 1965	123,000
Kloiya R.	170.4/Nov 19, 1971	107.3/Nov 19, 1971	0.13/Nov 20, 1973	207,000
Nass R.	8,920/Oct 29,1974	9,460/Oct 15, 1961	24.4/Mar 15, 1948	24,600,000
Thumle R.	-	56.6/Oct 23, 1929	1.44/Jan 4, 1929	-
Union Cr.	-	43.6/Sep 16, 1930	0.27/Jan 22, 1930	227,000
Skeena R. at USK	8,100.0/Jun 12, 1972	9,340.0/May 26, 1948	51.8/Mar 1, 1950	28,700,000

the Skeena River flow moves through Inverness Passage while the other 75% flows equally between Marcus Passage (separating Smith and DeHorsey islands from Kennedy Island) and Telegraph Passage (Trites, 1956).

The main channels at the mouth of the Skeena River are well flushed by the action of the tides which results in a high degree of vertical homogeneity (Hoos, 1975). Seasonal variations in the degree of mixing are evident as a result of variations in river discharge and tidal action. The estuary water is very turbid, especially during the spring freshet and heavy autumn rains, due to the presence of suspended glacial flour and silt.

The whole of Chatham Sound is essentially a large estuary whose surface circulation is determined primarily by the fresh water discharges from the Nass and Skeena rivers. It constitutes one of the two largest estuarine areas on the B.C. coast, the other being the Fraser River Estuary in Southwest British Columbia. Generally, estuarine circulation occurs when a large volume of fresh water from a river flows out along the surface from the head of an inlet. As it moves seaward, this layer entrains saline water from beneath it, which is also carried seaward. This loss is replenished by deeper water which flows with a net movement landward. Estuarine circulation in inlets is well modelled by a vertical, two-dimensional approximation which ignores cross-inlet variations in water properties.

In the case of Chatham Sound, however, the presence of a fresh water influx from two rivers, combined with the highly irregular coast line, and horizontal extent of the Sound, make it considerably more complex than the simple two dimensional approximation which is adequate for most of the inlets along the B.C. coast.

Regarding the distribution of salt within north coastal waters, Crean (1967) noted three persistent regimes of surface salinity:

- low salinity: Chatham Sound, Clarence Strait, the northern shores and the west central areas of Dixon Entrance;
- higher salinity: northern Hecate Strait; and
- highest salinity: mouth of Dixon Entrance.

These areas showed the most pronounced differences during summer as a consequence of the spring freshet in the neighbouring river systems. During the summer of 1954, salinity increased regularly from 24 ppt adjacent to Port Simpson to 28 ppt near Triple Island in Brown Passage.

Dixon Entrance exhibited a persistent halocline which was more intense and shallower in summer than in winter. This pattern coincided with a marked thermocline in summer and autumn. These features were considered characteristic of coastal waters dominated by estuarine discharge.

Higgins and Schouwenburg (1973) reported temperature and salinity data collected in Chatham Sound and the Skeena River estuary. As expected, the area nearest the estuary exhibited lower mean salinities and greater salinity ranges. This effect was most pronounced in Inverness Passage.

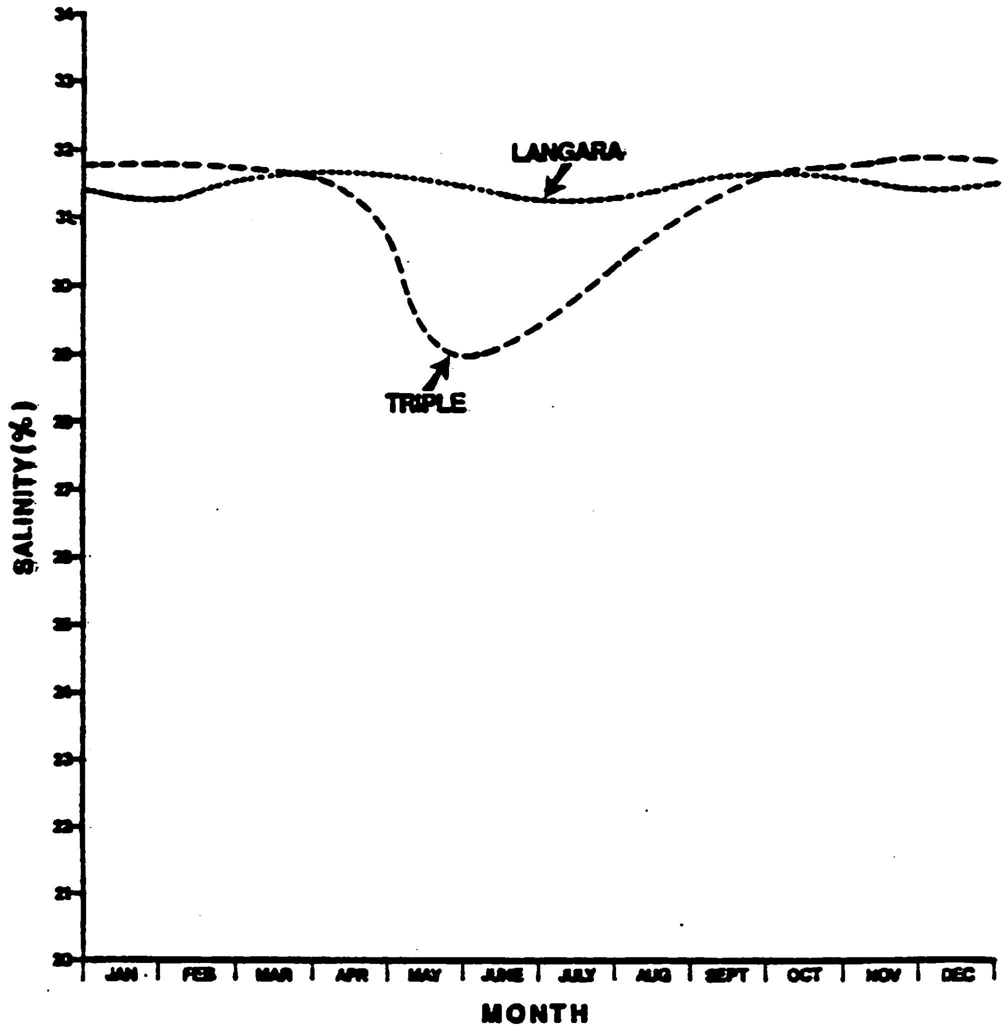
The average monthly mean discharge for the Skeena River is shown in Table 3.3-1. as being approximately 911 m^3/s. The annual cycles are dominated in June by the major peak associated with the spring thaw, while the secondary maximum in October reflects the high precipitation during that month. The diluting effects of the rivers on the waters of Chatham Sound vary seasonally, therefore, from low runoff periods of late summer or early autumn to freshet conditions in June.

The waters of Chatham Sound are generally well stratified and more sensitive to the effects of changing Skeena River discharge rates than the more open regions of Dixon Entrance, as well as more enclosed areas such as Porpoise Harbour (Packman, 1979).

Long term averages (1953 to 1962) of the monthly mean salinities for the surface waters off the coast of Triple Island reflect the seasonal variation of this diluting effect (Figure 3.3-1) (Pickard and McLeod, 1952). They show a strong minimum in June which is related to peak discharge conditions of the Skeena River. Throughout the remainder of the year, October to March, salinities are similar to those at Langara Island in Dixon Entrance, which show little change in magnitude throughout the entire year due to the dominant oceanic influence. Estuary surface temperatures are generally depressed by Skeena River water in winter (Figure 3.3-2) (Pickard and McLeod, 1952). The larger temperature maxima are associated with locations which exhibit lower salinities in the summer. This may be due to the high stability of the surface water and the consequent reduction in the downward dissipation of heat by eddy diffusion. Trites (1956) found the horizontal variation of temperature over the Sound to be slight.

The path of fresh water through Chatham Sound is dependent on the volume of fresh water discharged from the Skeena and Nass rivers. During freshet (May to June) the amount of fresh water present can be 3 to 4 times the mean value (Cameron, 1948). The average fresh water distribution and salinity patterns for normal discharge conditions (Figure 3.3-3) suggest that the brackish surface layer is generally confined to the upper 5 or 10 m depending on location, wind, tide and the discharge from the two rivers (Cameron, 1948a). Most of the fresh water in the southern and central part of Chatham Sound is derived from the Skeena River. Under normal conditions, Nass River discharge tends to be concentrated along the north shore of the Sound, moving past Wales Island north of Dundas Island into Dixon Entrance (Figure 3.3-4).

During normal river discharge conditions approximately 70% of the Skeena River water moves northward past Tugwell Island, along the Tsimpsean Peninsula to merge with Nass River water (Trites, 1956). The greater part then leaves Chatham Sound through Dundas Passage with possibly a smaller amount passing through Hudson Bay Passage. Only a small proportion (approximately 30%) of the Skeena River discharge reaches Dixon Entrance and Hecate Strait through the central and southern passages. This

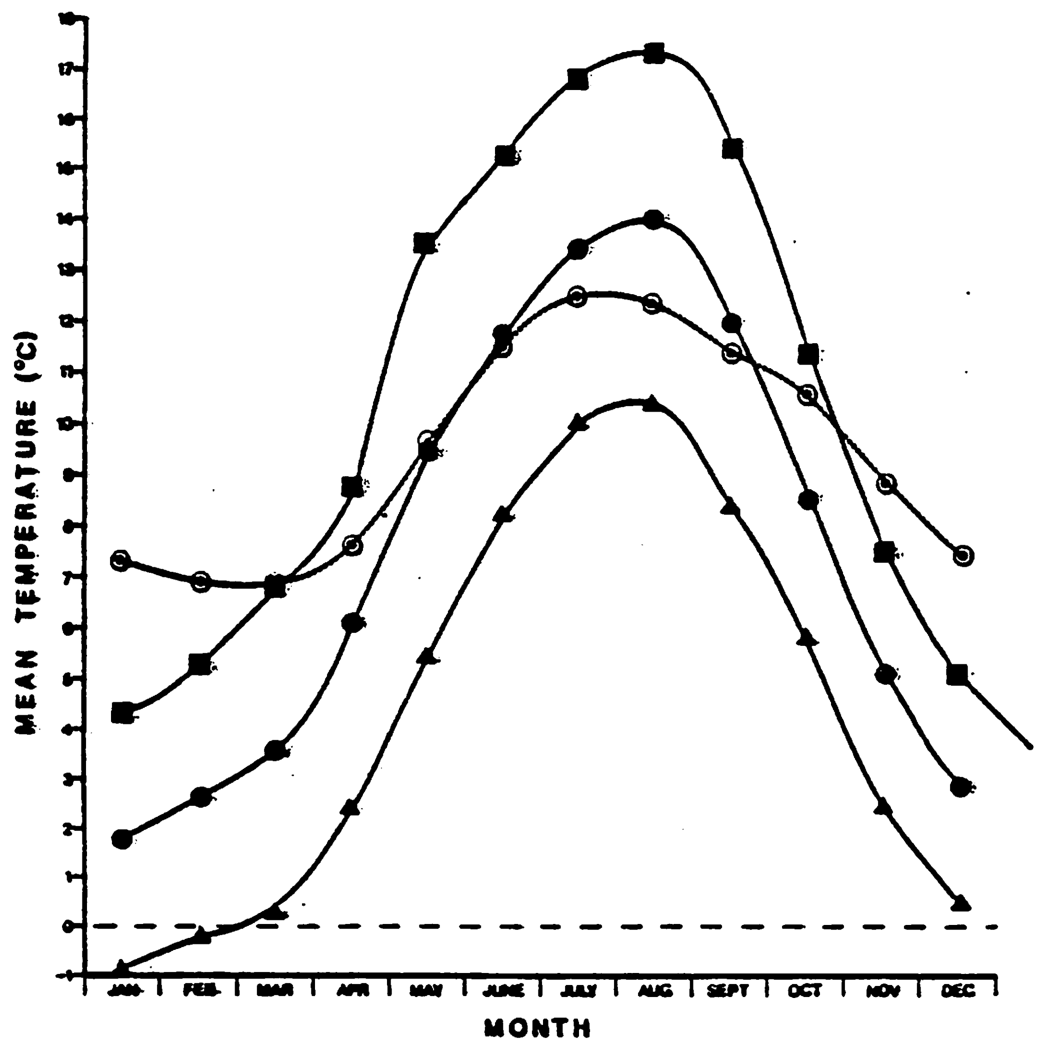


SOURCE: PICKARD & MacLEOD, 1962

Figure 3.3-1

MEAN MONTHLY SALINITY AT STATIONS ON THE BRITISH COLUMBIA COAST

PETROCHEMICAL TERMINAL



LEGEND

- PRINCE RUPERT AIR TEMPERATURE
- PRINCE RUPERT MAXIMUM AIR TEMPERATURE
- PRINCE RUPERT MINIMUM AIR TEMPERATURE
- TRIPLE ISLAND WATER TEMPERATURE

NOTES

1. TRIPLE ISLAND — 54° 17' 45" N. / 130° 52' 50" W.

SOURCES: - WATER TEMPERATURES FROM PICKARD & McLEOD, 1963
- AIR TEMPERATURES FROM A.E.S., 1971

Figure 3.3-2

MEAN MONTHLY SEA AND AIR TEMPERATURES NEAR KAIEN ISLAND, B.C.

PETROCHEMICAL TERMINAL

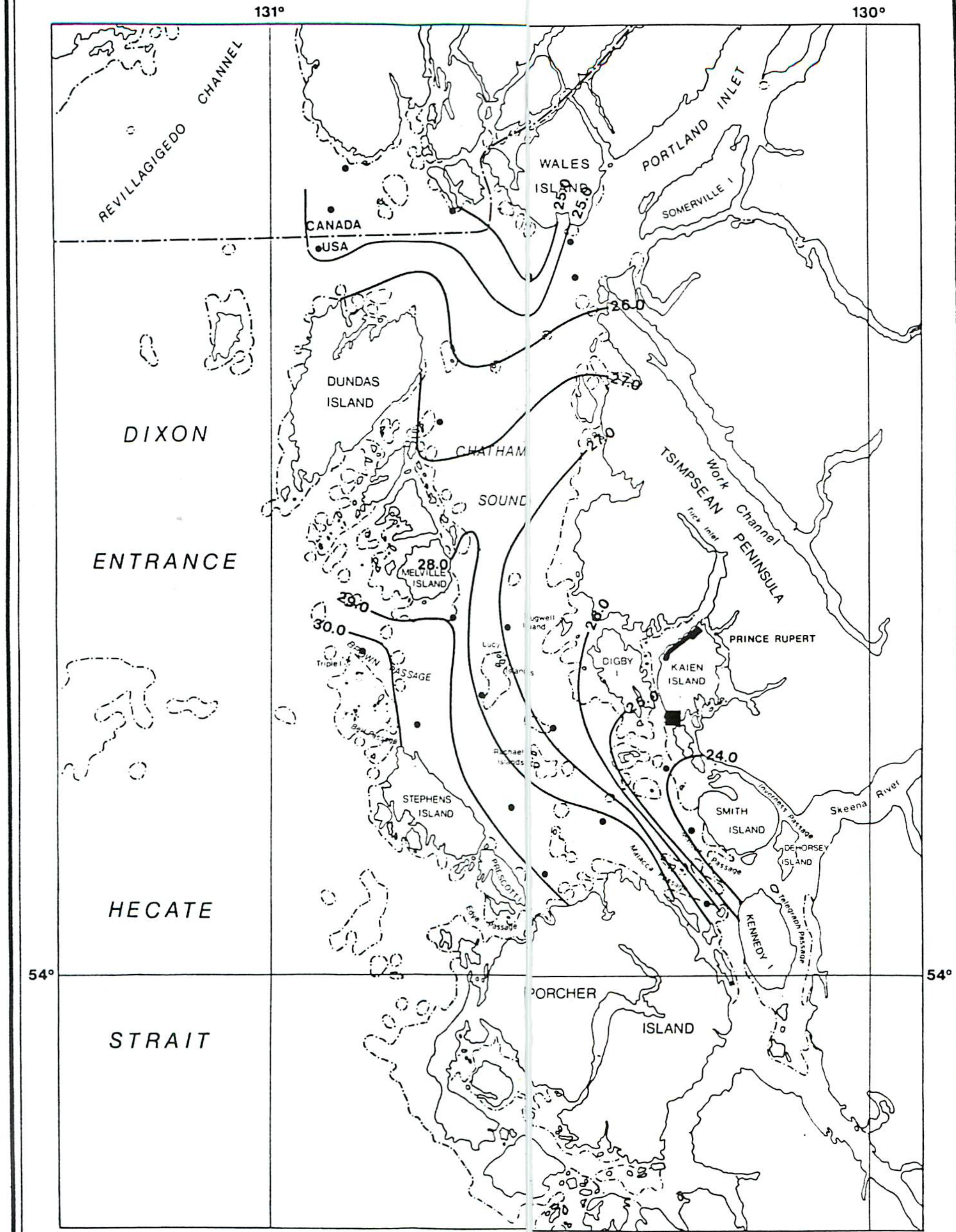


Figure 3.3-3

SURFACE SALINITY SKEENA RIVER

PETROCHEMICAL TERMINAL

Source: Trites, 1956

LEGEND

■ TERMINAL SITE

• STATION

24.0 SURFACE SALINITY*
(IN PARTS PER THOUSAND)

* NORMAL RIVER CONDITIONS, AUG. 10 - 19, 1948

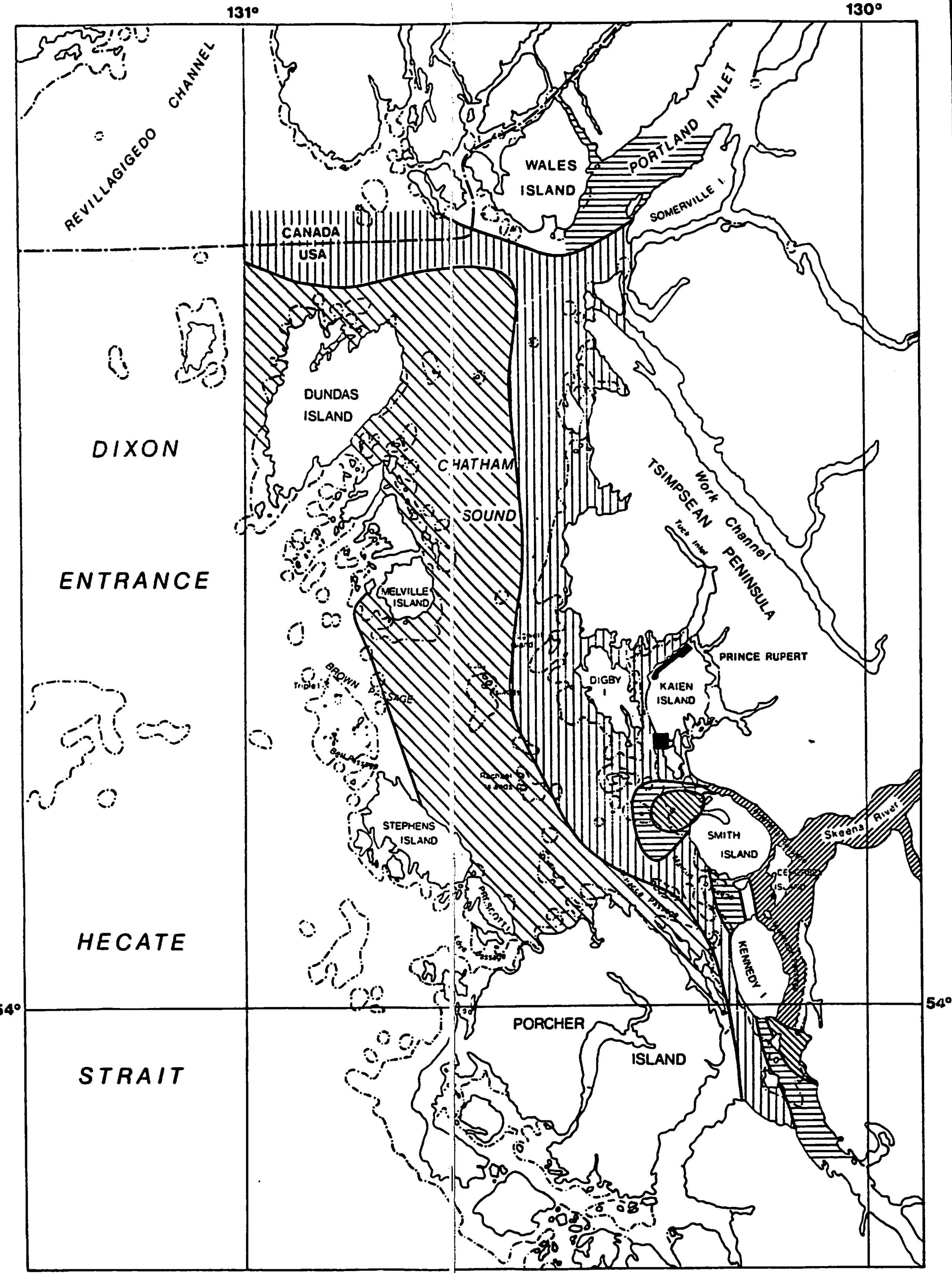
KILOMETRES

0 5 10 15 20 25

Figure 3.3-4

FRESHWATER UNDER NORMAL CONDITIONS SKEENA ESTUARY

PETROCHEMICAL TERMINAL



Source Cameron, 1948a

LEGEND

■ TERMINAL SITE

1% TO 6%*

6% TO 10%

10% TO 15%

15% TO 20%

> 20%

* PERCENT IN UPPER 20 M, AUG 10-19, 1948

KILOMETRES

0 5 10 15 20 25

northward diversion of Skeena River water as it enters Chatham Sound is due, in part, to the Coriolis effect which diverts water to the right of the direction of flow in the northern hemisphere.

Under normal discharge conditions, Nass River water tends to be concentrated along the north shore of the Sound, moving past Wales Island north of Dundas Island into Dixon Entrance. During freshet, fresh water leaves the Chatham Sound through all passages and channels, the largest volume being transported north of Dundas Island (Hoos, 1975). Nass River water is thought to extend as far south as Melville Island where it may interfere with the northern movement of Skeena River water past Dundas Island (Figure 3.3-5).

Figure 3.3-5 summarises the distribution of fresh water in Chatham Sound during freshet conditions. Figures 3.3-6 and 3.3-7 show in somewhat greater detail, typical average surface water salinity contour in the vicinity of Smith and Ridley islands for May and September 1948 (Slaney & Co, 1973; from Cameron, 1948).

Like other large British Columbia rivers, the Skeena and Nass rivers discharges may undergo significant year-to-year variations related to certain large scale climatological factors which can, in turn, be translated into year-to-year variations in oceanographic processes in Chatham Sound.

Prince Rupert Harbour

The City of Prince Rupert is located on the northwest side of Kaien Island, around which lies a complicated string of basins and inlets interconnected by constricted channels. Prince Rupert Harbour is a fairly deep, narrow channel connected to Chatham Sound at its southern end by a narrow (600 m) passage, and to Tuck Inlet at the north end. Its minimum depth is approximately 18 m.

Tidal elevations at Prince Rupert are noted for their large amplitude. Harmonic analysis of time-series of surface elevations performed by the Canadian Hydrographic Service (Table 3.3-3) shows that the dominant tidal constituents are the lunar and solar diurnal constituents (M2 and S2), followed by the diurnal (K1) constituent.

The large tidal amplitudes result in some fast tidal streams. This is particularly noticeable in the narrow passages that connect some of the larger bodies of water together.

Current velocities in this region are mainly governed by the large tidal range, which has mean and large values of 4.9 m and 7.7 m, respectively. The wind, particularly during severe winter storms, may strongly influence or even dominate surface circulation over time periods of from several hours to a few days (Waldichuck, 1968). Data collected in October 1964 indicate a north-south oscillation of currents in phase with the rise and fall of the tides at the entrance of Prince Rupert Harbour (Figures 3.3-8 and 3.3-9). In the vicinity of Prince Rupert Grain Terminal No. 2, and the proposed terminal site, tidal streams range from 2.8 km/h toward the north on the flood to 4.6 km/h toward the south on the ebb. Further offshore, south of the Kinahan Islands, the flood is set eastward at 1 km/h, while the ebb sets westward at 3 km/h. Directly south of Ridley Island the flood and ebb set eastward and westward, respectively, at up to 4 km/h.

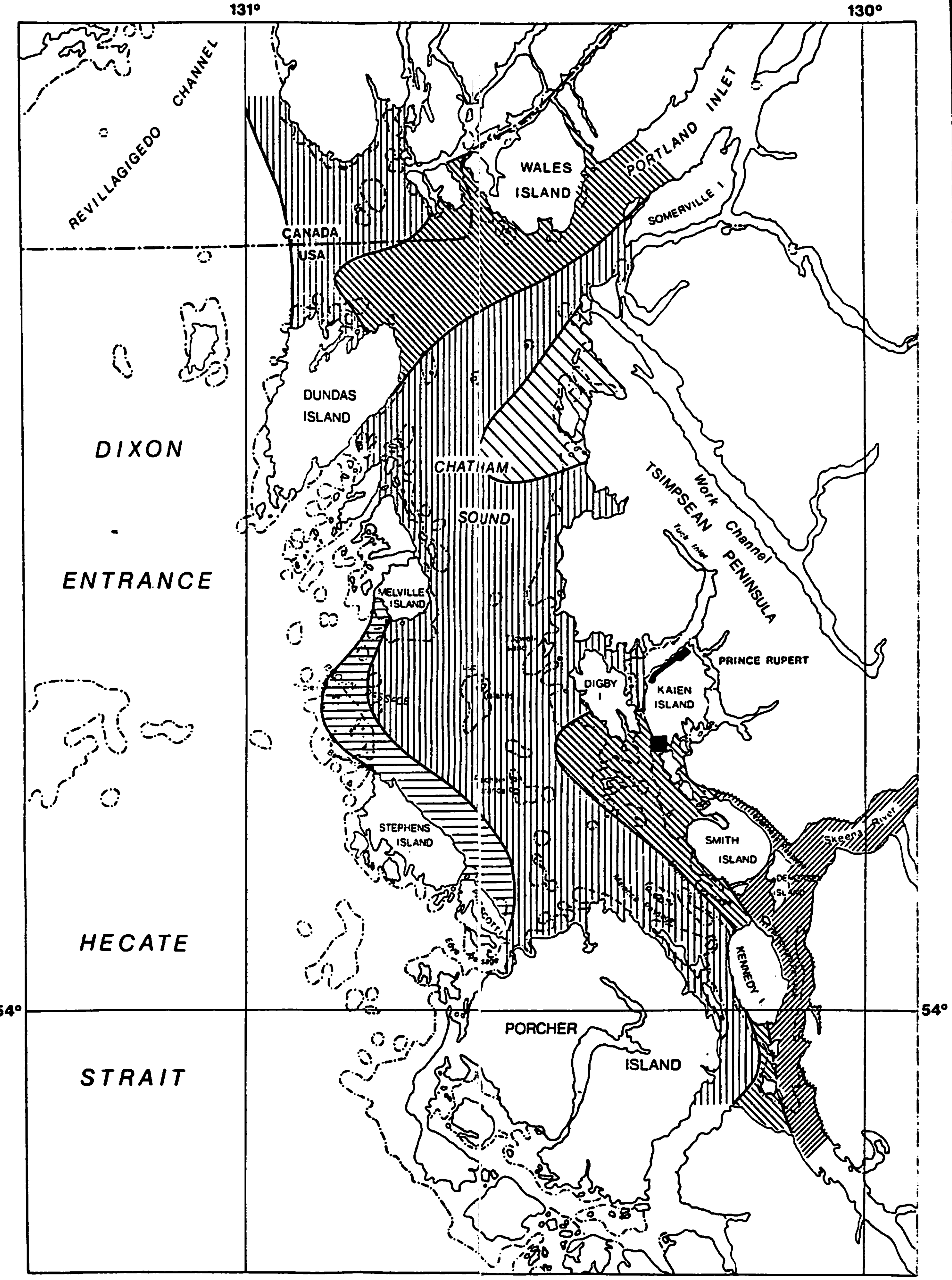
Friction results in bottom currents that are generally slower than at the surface. Synoptic measurements suggest the existence of a net northward current at 20 m and 30 m water depth and a southward current at 5 m water depth (NEAT, 1974). Observations recorded in the B.C. Pilot (1974) suggest maximum tidal streams of 4 to 6 km/h may occur in Prince Rupert Harbour.

Although Prince Rupert Harbour does not receive effluent directly from any major rivers, local sea water characteristics are largely determined by the volume discharge of the Skeena River (Slaney & Co, 1973). Surface salinity decreases (rather than increases)

Figure 3.3-5

FRESHWATER DURING FRESHET SKEENA ESTUARY

PETROCHEMICAL TERMINAL



Source: Cameron, 1948a

LEGEND

■ TERMINAL SITE

< 6%

6% TO 10%

10% TO 15%

15% TO 20%

> 20%

KILOMETRES

0 5 10 15 20 25

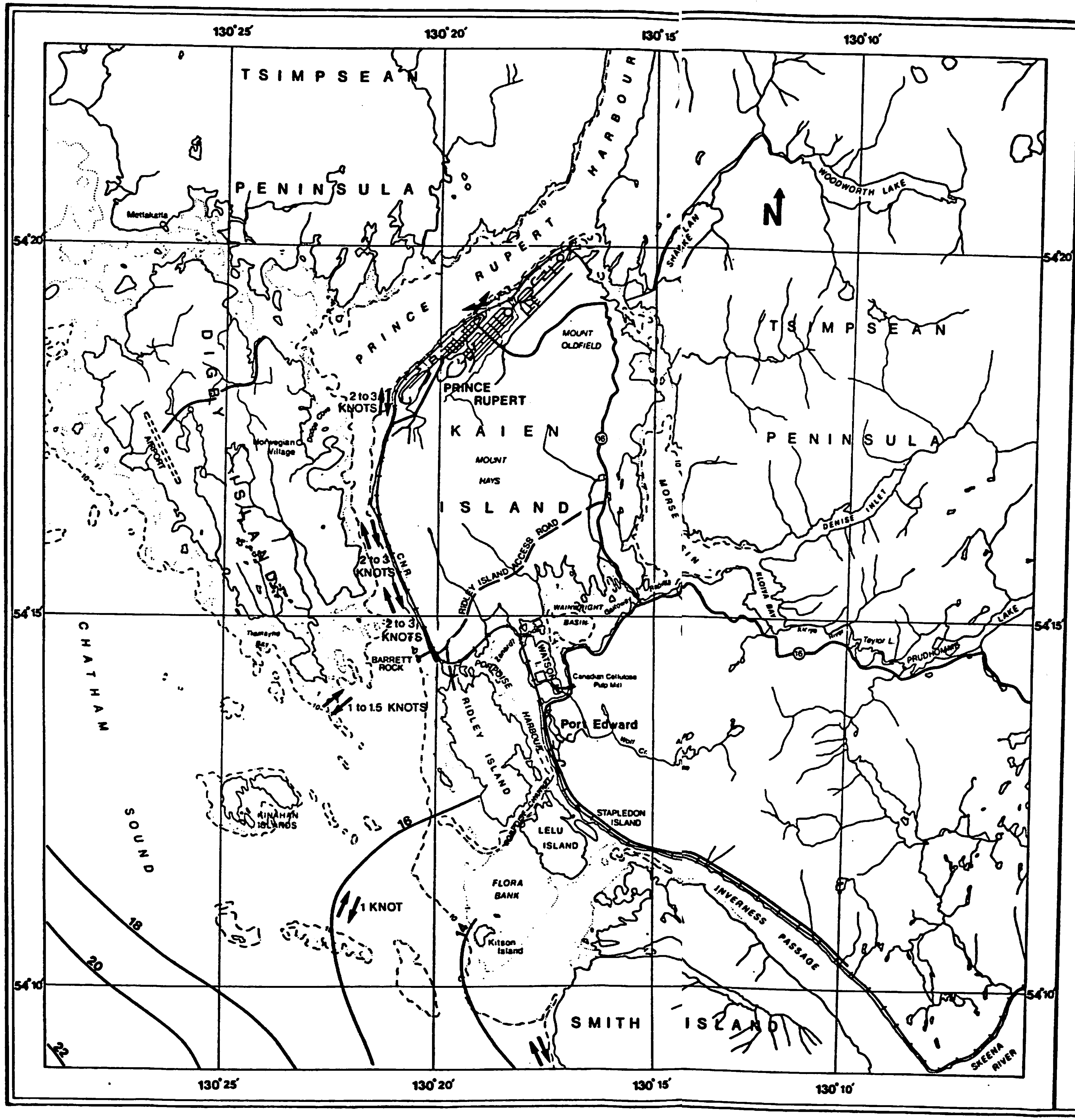


Figure 3.3-6

TIDAL CURRENTS IN PORPOISE HARBOUR AND AVERAGE SALINITY AT SIX FEET IN CHATHAM SOUND, MAY 25 TO 28, 1948

PETROCHEMICAL TERMINAL

Source: Dept. of Environment, Ottawa

LEGEND

22 SALINITY (IN PARTS PER THOUSAND)

TIDAL CURRENT

NOTE: DEPTH IN FATHOMS.

KILOMETRES

2 1 0 2 4

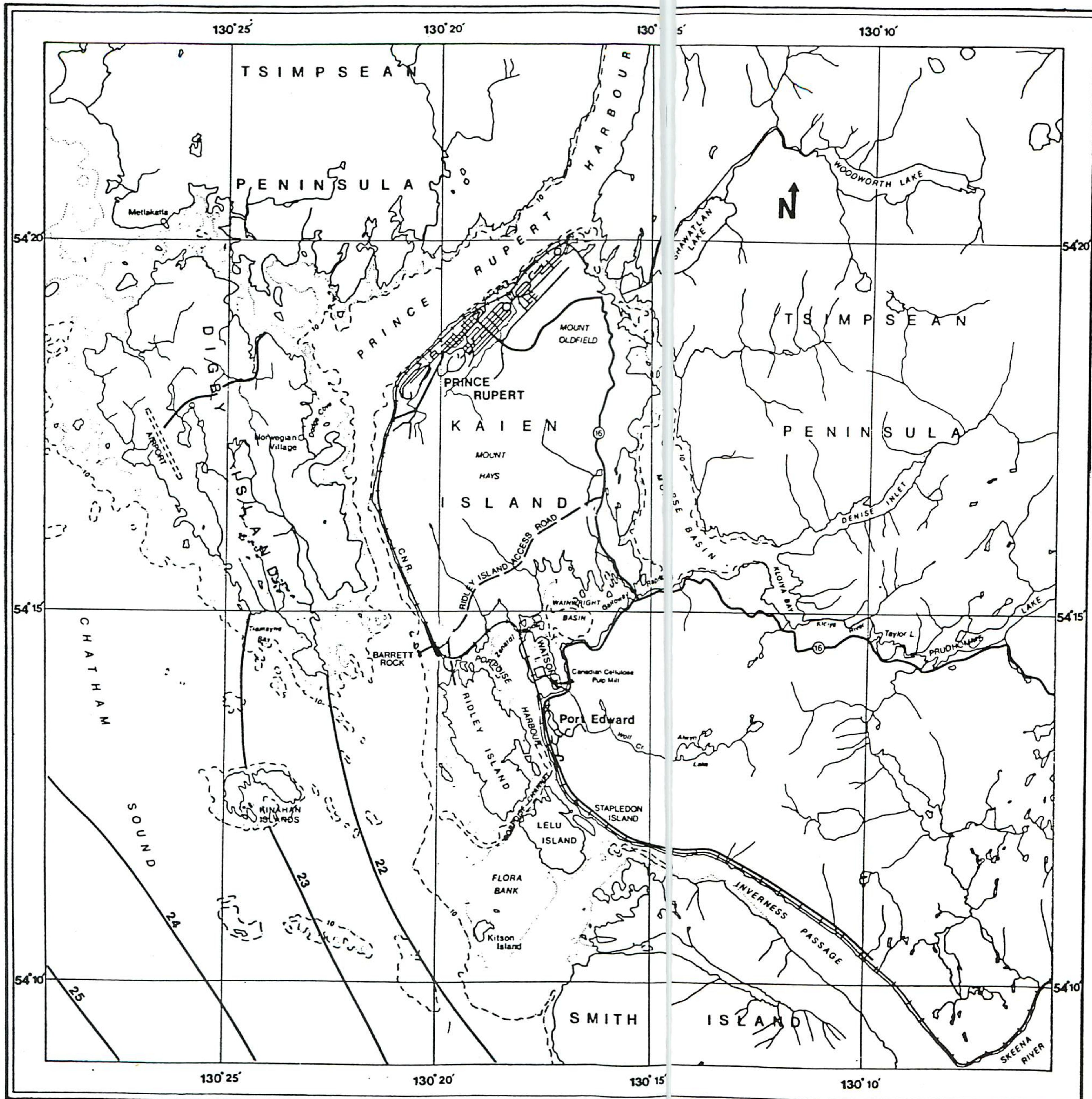


Figure 3.3-7

AVERAGE SURFACE SALINITY IN CHATHAM SOUND SEPTEMBER 8 TO 10, 1948

PETROCHEMICAL TERMINAL

Source Dept. of Environment, Ottawa

LEGEND

22 SURFACE SALINITY*
(IN PARTS PER THOUSAND)

NOTE: DEPTH IN FATHOMS.

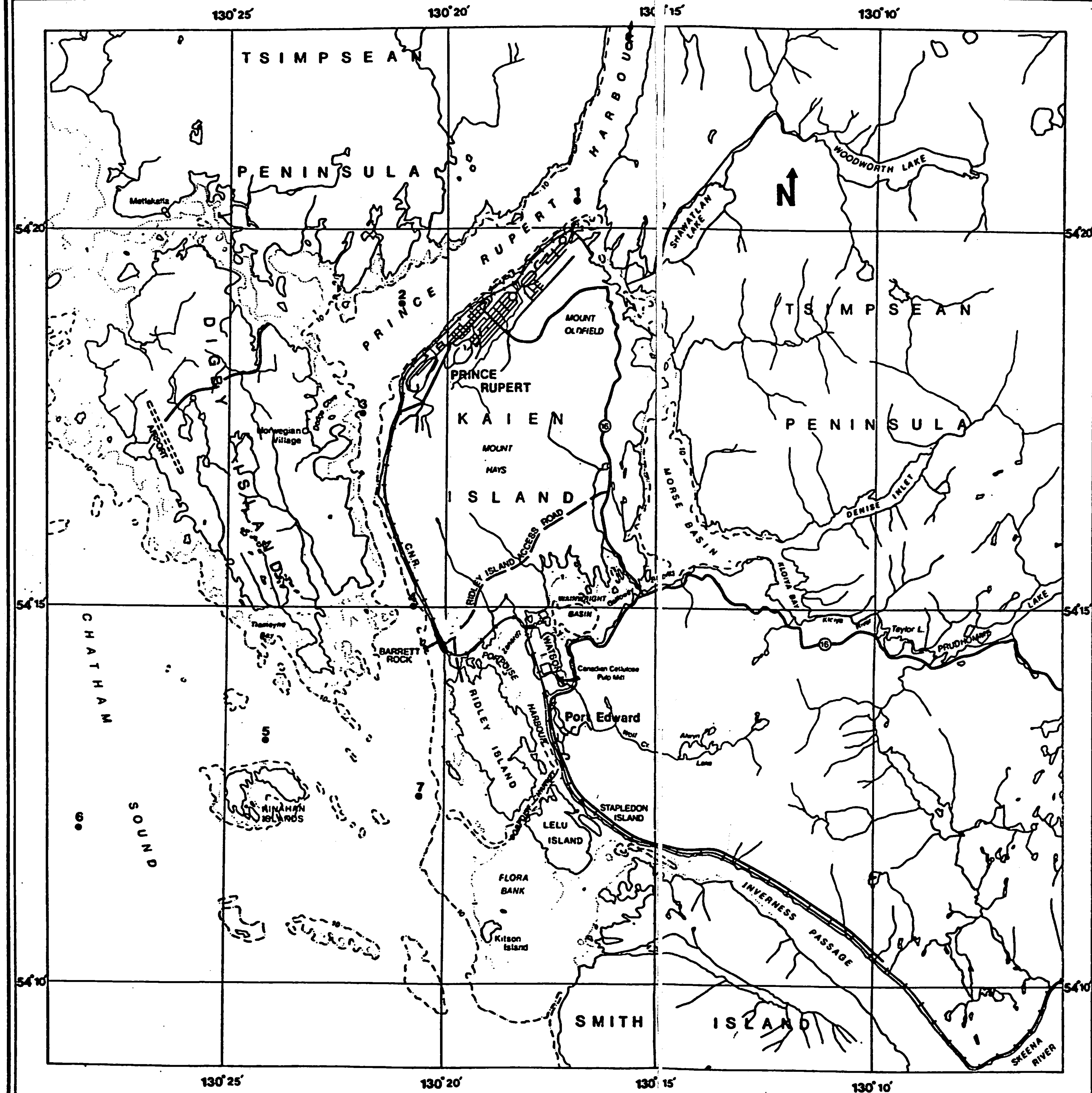
KILOMETRES

2 1 0 2 4

Figure 3.3-8

LOCATIONS OF HYDROGRAPHIC STATIONS NEAR PRINCE RUPERT HARBOUR NOVEMBER 1974

PETROCHEMICAL TERMINAL



Source: Neat, 1975

LEGEND

1 HYDROGRAPHIC STATION

NOTE: DEPTH IN FATHOMS.

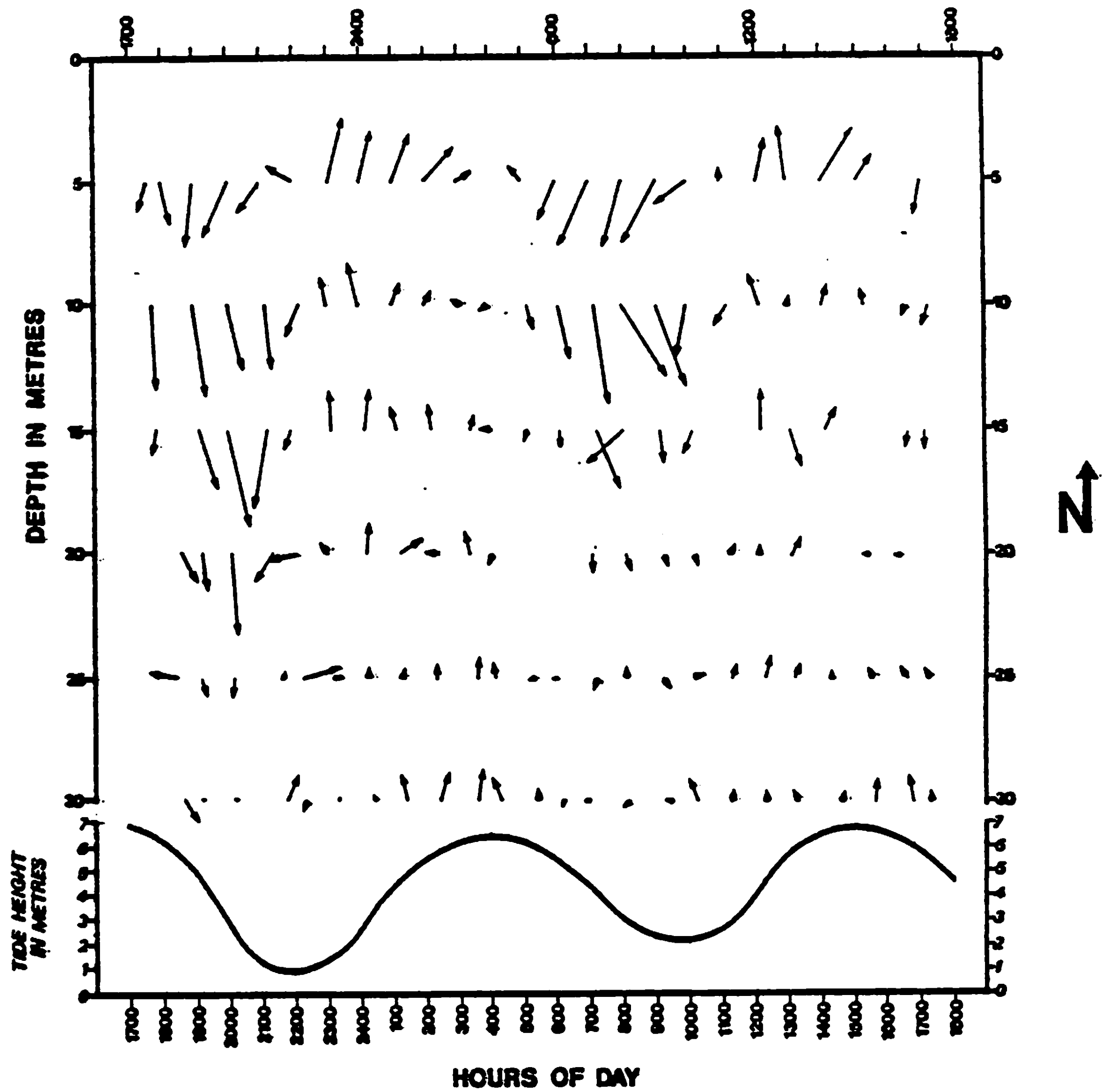
KILOMETRES

2 1 0 2 4

Table 3.3-3

LARGEST HARMONIC CONSTITUENTS FOR SURFACE ELEVATION IN PRINCE RUPERT HARBOUR

RANK	CONSTITUENT	FREQUENCY (cph)	AMPLITUDE (m)	GREENWICH PHASE (°)
	Z0		3.85	0
1	M2	0.0805114	1.94	267.4
2	S2	0.0833333	0.64	299.2
3	K1	0.0417808	0.51	259.7
4	N2	0.0789993	0.39	242.8
5	O1	0.0387307	0.31	243.8
6	K2	0.0835615	0.17	291.8
7	P1	0.0415526	0.16	256.3
8	SA	0.0001141	0.11	348.3
9	NU2	0.0792016	0.08	246.5
10	Q1	0.0372185	0.05	235.3



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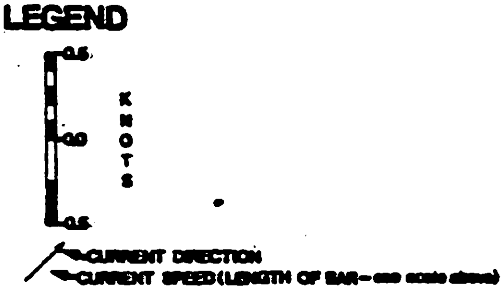


NOTES

SOURCE: HEAT, 1975

Figure 3.3-9

PRINCE RUPERT HARBOUR CURRENT MEASUREMENT TAKEN AT STATION 4, OCTOBER 24 AND 25, 1964

PETROCHEMICAL TERMINAL

toward the mouth of the inlet because of fresh water in Chatham Sound. The reduced salinity layer is generally less than 15 m deep. Dissolved oxygen concentrations indicate that the deep waters of Prince Rupert Harbour are isolated from replenishment at the surface. The low concentrations of dissolved oxygen appear to result from limited mixing.

A study of circulation in Prince Rupert Harbour was made in 1977 by Associated Engineering Services Ltd. (AESL) as part of a long range plan for sewage disposal in the harbour (AESL, 1977). In addition to deploying surface drifters, vertical profiles of water properties were made at several stations, and a current meter was deployed 0.8 m above the bottom of the harbour for a 10-day period beginning July 4. Harmonic analysis of the current meter record showed that the constituent with the largest amplitude was the M2 (8 cm/s), while the next largest was the shallow water constituent M4 (2.1 cm/s). Shallow water constituents arise from non-linear interactions resulting from bottom friction. The fact that the M4 constituent was larger than the K1 indicates the strongly non-linear character of the flow, which results from high current speeds and large shear. On average, it was found that the times of zero current speed preceded high and low water by 2 hours and 0.1 hours, respectively. High frequency oscillations observed in the current meter record were hypothesised to have come from a seiche motion set up, presumably, by surface wind stress.

During the AESL study, 62 drogues were released in five groups to measure the current within 1.5 m of the surface. Average flood tide currents up to 90 cm/s were observed within the harbour, although more typical current speeds ranged from 15 to 46 cm/s. Although the observed surface currents tended to be in phase with the tides, some observations suggest that other forcing mechanisms may be important inside the harbour. Northeast currents of up to 36 cm/s were observed during ebb tide. AESL speculates that these may have been due to the intrusion of Skeena River water into the harbour from Chatham Sound.

The mean current within Prince Rupert Harbour is very small: 0.7 cm/s at a depth of 35 m and 1.0 cm/s at 15 m. The maximum instantaneous current measured at 35 m is 20 cm/s (Akenhead, 1992).

In a recent study of circulation and water quality in Prince Rupert Harbour and approaches (Stucchi, 1993), salinity, temperature, dissolved oxygen, and nutrient concentrations (nitrate, nitrite, and silicate) were measured from May through early September of 1992 at up to 6 stations. The southern most station was near Barrett Rock; three were within Prince Rupert Harbour; and two were in Tuck Inlet to the north of the harbour. In addition, a lone current meter mooring was installed off Douglas Point near the middle of the harbour. Two Aanderaa RCM4 current meters were deployed: one at 17 m depth, and the other at 41 m depth. Unfortunately, the deeper of the two current meters failed immediately, and the other stopped after 63 days of the 119 day deployment. In addition to measuring current, each instrument also sampled temperature, conductivity, and pressure at a 15 minute sampling interval.

Analysis of the current meter record from 17 m depth shows the principle axis of motion to be approximately aligned with the harbour, that is, from northeast to southwest (45° to 225°). Maximum speeds along this axis approached 26 cm/s with the mean speed directed out of the harbour (toward the southwest) at 1.9 cm/s. Currents across the harbour reached speeds of 12 cm/s, with a mean cross-harbour current of 0.4 cm/s toward the southeast. These results agree with those from the much shorter record obtained by AESL (AESL, 1977).

Harmonic analysis of the current meter record was performed and the ten largest constituents have been listed in Table 3.3-4. As with the AESL study the shallow-water constituent M4 was second largest after the semi-diurnal M2. Comparing the Greenwich phase angles of the current with the surface elevation shows that they are nearly in quadrature, that is, their phases are nearly 90° apart. This results in slack water occurring near times of minimum and maximum surface elevation.

Table 3.3-4

LARGEST HARMONIC CONSTITUENTS FOR CURRENT VELOCITY (17 m) IN PRINCE RUPERT HARBOUR

RANK	CONSTITUENT	FREQUENCY (cph)	MAJOR SEMI-AXIS (cm/s)	MINOR SEMI-AXIS (cm/s)	ELLIPSE INCLINATION (° from E)	GREENWICH PHASE (°)
	Z0		1.961	0.000	42.3	180.0
1	M2	0.0805114	11.251	-0.599	29.6	181.7
2	M4	0.1610228	1.895	0.031	38.1	102.8
3	K1	0.0417808	1.833	0.005	34.2	182.0
4	N2	0.0789993	1.717	-0.233	25.2	182.2
5	MSF	0.0028219	1.610	0.009	22.8	294.4
6	S2	0.0833333	1.477	-0.389	16.7	257.0
7	MS4	0.1638447	1.340	-0.180	23.6	164.0
8	MU2	0.0776895	1.245	0.339	15.9	284.2
9	L2	0.0820236	1.043	0.267	22.1	152.4
10	O1	0.0387307	0.938	0.322	9.8	150.0

Stucchi observed low-frequency currents that persisted for several days during the current meter record. These reached magnitudes of 5 to 10 cm/s and were oriented along the harbour axis. An examination of wind records collected at the same time did not suggest a mechanism to explain these currents. Low-frequency fluctuations in sea level were also observed. The latter, while correlated with the wind, are not correlated with the low-frequency currents.

Vertical temperature and salinity profiles were measure by AESL at several stations within Prince Rupert Harbour and at Barrett Rock on July 7, 8, and 11, 1977. The combination of summer heating and lighter winds than at other times of the year results in strong near-surface gradients of temperature and salinity. A rapid increase in salinity and decrease in temperature is observed during summer months over the upper 20 m in Prince Rupert Harbour.

Time-series of salinity were harmonically analyzed (Stucchi, 1993) to identify the correspondence with the astronomical tide. It was found that a strong fortnightly signal is present in both the salinity and temperature signals. In the case of salinity the MSF was the largest constituent followed by the M2. For temperature, the MM and MSF were the two largest constituents followed by the M2. The strong fortnightly signal reflects the importance of tidally-driven turbulent mixing in the dynamics of the harbour. Since the rate of dissipation of turbulent kinetic energy is proportional to the current speed raised to the third power, it is expected to find that significant variations in current speed would have profound effects on mixing rates, and hence on stratification.

Larger salinities at 17 m are associated with weaker neap tides (less mixing), while smaller salinities are associated with stronger spring tides (more mixing). Greater turbulent energy is available in the case of the spring tides to mix surface waters downward, thereby lowering the salinity and increasing the temperature. In other words, the strength of the summer pycnocline undergoes a fortnightly modulation in concert with the current. Restratification occurs during neap tides because of the constant influx of fresher water and surface heating.

Flushing of near-bottom waters in Prince Rupert Harbour was evident in the time-series record as increased salinity due to an influx of higher salinity water from Chatham Sound. The time-scale for this replacement was approximately 12 days. There is some evidence that water replenishment is modulated on a fortnightly period by the spring and neap tides. During the relatively weak neap tides turbulent mixing at the entrance to the harbour is at a minimum and denser, more saline water may enter the harbour relatively unaltered. It then proceeds to move downward, where it replaces the resident bottom water. During the time of spring tides, on the other hand, turbulent mixing is enhanced and the character of the incoming water is significantly modified. In particular, the salinity will be lowered by mixing with the resident water mass and consequently its density will decrease. This will affect the depth to which the incoming water will sink, and hence the volume of water that will be displaced.

In a preliminary survey, Stokes (1953) (Hoos, 1975; Goyette et al, 1976) was the first to report dissolved oxygen levels of less than 5 mg/l in Wainwright Basin and Porpoise Harbour. Although recording an average of 8.4 mg/l in Chatham Sound, he suggested that the effects of the mill wastes on the environment were minimal.

More recent measurements of DO in Prince Rupert Harbour and in the main entrance channel near Barrett Rock (Stucchi, 1993) revealed summer oxygen concentrations that did not fall below the lowest tolerable level (level C) for maintaining fish health. In his discussion Stucchi uses the three level classification scheme for DO introduced by Davis (1975). In this scheme level A affords the safest level for fish, while at level B some stress may be observed. At level C some portion of the fish population may be adversely affected. Lowest DO values were recorded in the deeper waters of the harbour and suggest a longer residence time than for locations outside the harbour. Lowest levels usually occur during the fall.

In a series of oceanographic surveys by Waldichuk (1961 to 1967), it was apparent that the degree of pollution in the vicinity of the pulp mill had increased substantially since Stoke's work. Dissolved oxygen values at some stations were less than 0.5 mg/l at various depths in Porpoise Harbour and Wainwright Basin (Waldichuk, 1962a). A level of 5 mg/l is considered the minimum required for fish habitation (Alderdice and Brett, 1957). Waldichuk (1966), attributed the general decrease in dissolved oxygen with an increase in spent sulphite liquor concentration and he investigated rates of deoxygenation. The dissolved oxygen level was restored to nearly normal concentration after a week of no waste discharge in July 1962. Oxygen levels declined to pre-shutdown concentrations in about 30 days after discharge was recommenced. Water samples from Wainwright Basin and Porpoise Harbour showed lower pH values (6.9 to 7.1 respectively) than those taken in Chatham Sound (around 8.0).

Water quality in the Prince Rupert Harbour area was considered as "fairly good" in the Drinnan and Webster study, despite the location of 12 domestic sewage outlets, 11 fish processing discharges, and several marinas and log booming grounds in the area. Slightly elevated faecal coliform bacterial counts were found at some stations when compared to stations in Chatham Sound.

An earlier study (Pollution Control Branch, 1964) reported that Prince Rupert Harbour sewage, although completely untreated, had nutrient suspended solid, TOC and oil levels below that of "typical" sewage, being higher only in pH and total solids.

Oceanographic surveys of Prince Rupert Harbour and Port Simpson (Lee Doran Associates Ltd, 1975) indicated that the waters of Prince Rupert Harbour exhibited a reverse "salt wedge" in which the surface salinity decreased towards the mouth of the inlet owing to dilution effects of the Skeena River. The inlet displayed a stratified profile in which the layer of reduced salinity was generally less than 10 m deep. A general decrease in dissolved oxygen concentration in the deeper waters of the inlet towards its head (8 mg/l) confirmed trends observed by Waldichuk et al (1968). This was attributed to limited mixing and was possibly influenced by the presence of organic wastes and, hence, rapid bacterial oxygen consumption along with high turbidity which reduces photosynthesis by shading.

Measurements made by Stucchi (Stucchi, 1993) revealed nitrate concentrations in the harbour that exhibited a similar pattern to those taken by Drinnan and Webster (1974). Surface concentrations measured in July, 1993 were low, while concentrations closer to the bottom were significantly larger. The surface nitrate depletion and super-saturated oxygen are a clear indication that a healthy plankton bloom was underway during the summer of 1992. Although phosphate measurements were not made, it is possible to infer from the low levels of nitrates that biological processes in this area are nitrogen limited.

Porpoise Harbour - Wainwright Basin - Morse Basin

Porpoise Harbour, Wainwright Basin and Morse Basin form a chain of partially enclosed marine embayments separating Ridley and Kaien islands from the northern mainland coast of British Columbia. Porpoise Harbour is suitable for navigation by deep sea ships, having midchannel depths of 12 to 24 m (Waldichuk, 1962). The large amplitude tides of the more open areas of the coast are strongly attenuated by the constricted passages leading to the inner basins; hence, tidal flushing of the basins is also limited. Consequently, the waters of Porpoise Harbour and Wainwright Basin have been degraded because of the confinement and the presence of individual waste discharges (Waldichuk, 1968).

Within the three main basins, the water is observed to be fairly still, despite strong currents which occur in the entrance channels. Turbulence, particularly in Zanardi Rapids between Porpoise Harbour and Wainwright Basin, causes thorough mixing and therefore a decrease in stratification (Waldichuk, 1966). Consequently, the physical and chemical characteristics vary little with depth in both Wainwright and Morse basins, in contrast to the marked gradients in Porpoise Harbour, the embayment nearest the sea. The water column in Porpoise Harbour exhibits moderate density stratification as a result of the introduction of fresh Skeena River water through Porpoise Channel during tidal exchanges (EVS Consultants Ltd, 1980). The degree of stratification is affected somewhat by the seasonal fluctuations in the flow rates of the Skeena River (Packman, 1977, 1979). In a study of effluent dispersion in Wainwright Basin, Waldichuk (1966) concluded that the removal of waste occurs seaward through Porpoise Harbour by a combination of advection and turbulent diffusion associated with the tides. It was also suggested that the water in Morse Basin may be exchanged through Butze Rapids to the north.

Water quality measurements have been made in Porpoise Harbour and Wainwright Basin by Hatfield Consultants Ltd. for Skeena Cellulose as part of the ongoing Environmental Effects Monitoring (EEM) process. This is a joint federal and provincial program directed toward monitoring the quality of waters directly affected by the pulp mill discharge. Until recently, intertidal macroalgae and benthic sampling programs were carried out annually. Water quality (including: dissolved oxygen, salinity, temperature, lignin, and tanin) was also monitored at a set of standard stations on an irregular schedule throughout the year. At present the regulations governing the EEM are being reviewed and a new monitoring program will be developed for implementation in the coming year.

<u>Site of Proposed Terminal Development</u>

The proposed terminal development is located on the southwest tip of Kaien Island, immediately north of Prince Rupert Grain Terminal No. 2. The area surrounding the terminal site is characterized by an intertidal zone comprised of a series of sand deposits, mudflats, and rock outcroppings. This region extends for about 1 km north of the grain terminal, and for a maximum distance of about 0.4 km offshore. The total area covered by the flats is 20.3 ha, of which approximately 35% is intertidal rocky foreshore; 55% intertidal mud/sand flats; and 10% cobble/shingle beach. The maximum elevation in the tidal flats region is 1.9 m above chart datum, while immediately to the west the depth increases rapidly to more than 60 m. During high tide most of the region, with the exception of Bishop Island, is flooded; while during lowest tides all of the area is exposed, except for a small embayment at the south end.

Recent studies of the oceanographic and coastal processes pertinent to the proposed development site have been undertaken by Hay & Co Consultants (Hay & Co, 1993). These studies included reviews of wave and wind climate in the area, sedimentation processes and measurements of surface currents over a two day period using three drifters.

a) Wind and Waves

The terminal site is positioned due east of the south tip of Digby Island, at the entrance to the channel which leads to Prince Rupert Harbour. It is exposed to winds and waves from the south quadrant, although a series of small islands and rocks, including the Kinahan Islands, Kestrel Rock, Falcon Rock, and Georgia Rock, afford some protection from the southwest. Heights and periods of waves incident on the terminal site depend on the strength and duration of the wind, together with the length of water, or fetch, over which the wind blows. A bivariate histogram showing the distribution of wind speed versus direction over an 18 year interval (1969 to 1987) at Lucy Island is presented in Table 3.3-5. The dominant wind direction and largest wind speed during this period were from the southeast.

The wind data were used to prepare a deep water wave hindcast for the terminal site using the modified SMB approach detailed in the Shore Protection Manual (1984) (Table 3.3-6). Significant wave height (Hs) and the spectral peak period (Tp) are listed under Height and Period, respectively, for five different return periods. The largest waves originate from the south, which has the largest wind speeds; and from the southwest,

Table 3.3-5

WIND SPEED VERSUS DIRECTION AT LUCY ISLAND
(% OF OBSERVATIONS FROM 1969 TO 87)

DIR	WIND SPEED CLASS (km/h)								TOTAL (%)	MEAN (km/h)
	1-9	10-19	20-30	31-42	43-55	56-69	70-84	85-100		
NE	1.52	1.29	0.28	0.08	0.01				3.2	11.0
E	2.87	2.29	0.84	0.34	0.05				6.4	12.5
SE	4.93	7.90	7.92	10.46	6.05	3.06	0.90	0.09	41.3	30.8
S	2.40	1.66	1.14	1.06	0.57	0.22	0.09	0.01	7.2	20.9
SW	3.52	2.17	0.21	0.08	0.03	0.01			6.0	9.2
W	5.00	7.16	3.01	1.34	0.16	0.01			17.5	15.6
NW	3.06	3.39	1.56	0.65	0.08				8.7	14.5
N	2.91	3.47	1.20	0.55	0.13	0.02			8.3	14.3
Calm									1.4	
Total	26.21	29.33	16.95	14.56	7.07	3.33	0.98	0.09	100.0	21.1

Table 3.3-6

HINDCAST WAVE PROPERTIES FOR VARYING INCIDENT DIRECTIONS AND RETURN PERIODS

DIRECTION	FETCH (km)	ANNUAL		5 YEAR		25 YEAR		50 YEAR		100 YEAR	
		Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)	Hs (m)	Tp (s)
S	19.0	2.3	5.1	2.9	5.5	3.2	5.6	3.2	5.6	3.3	5.7
SW	23.0	0.9	3.0	1.6	4.3	2.4	5.1	2.7	5.4	3.2	5.7
W	2.8	0.6	2.4	0.7	2.5	0.8	2.6	0.9	2.7	0.9	2.7
NW	3.0	0.6	2.3	0.6	2.4	0.6	2.4	0.6	2.4	0.6	2.4
SE	8.0	1.8	4.0	2.0	4.2	2.0	4.2	2.1	4.2	2.1	4.2

Table 3.3-7

WAVERIDER MOORINGS NEAR THE TERMINAL SITE

MOORING	LATITUDE	LONGITUDE	START	FINISH	LENGTH (d)
88	54 ° 14' 12"	130 ° 20' 17"	April 9, 1976	July 23, 1976	95
104	54 ° 11' 09"	130 ° 30' 06"	Sept 28, 1972	June 13, 1973	258

which has the greatest fetch. Hs is less than or equal to 3.3 m, and wave periods are less than 6 s for all hindcast directions and return periods.

Only limited measurements of wave properties have been made near the terminal site. Waverider buoys were deployed very near the terminal site for 95 days in 1972-73, and at a location further offshore for 258 days in 1976 by AES Environment Canada. The location and deployment period for each site are given in Table 3.3-7.

An analysis of data from the Waverider mooring furthest from the terminal site (No. 104), in position during the winter and spring of 1972 to 1973, yields 0% exceedence levels for significant and maximum wave height of 1.9 m and 2.9 m, respectively; and 50% exceedence levels for these quantities of 0.3 m and 0.5 m, respectively. The distribution of Hs with Tp at this station is indicated by the bivariate histogram provided in Table 3.3-8.

The frequency spectrum at Station 104 is bimodal, with peaks at 2 to 3 s and at 9 to 10 s. The latter is associated with swell coming into Chatham Sound from further offshore. The dominant source of wave energy during this period is from locally generated seas, however.

An analysis of data from the Waverider mooring nearest the terminal site (No. 88), in position for 95 days during the spring and summer of 1976, yields 0% exceedence levels for significant and maximum wave height of 0.7 m and 1.3 m, respectively; while 71% of the record corresponded to calm seas. The bivariate histogram presented in Table 3.3-9 shows the distribution of Hs with Tp at this station.

The frequency spectrum at station 80 contains much less energy than at Station 104. This is primarily due to the different times of the year during which the two moorings were in place, since spring and summer winds are generally much less energetic than

Table 3.3-8

DISTRIBUTION OF Hs VERSUS Tp FOR STATION No. 104
(% of 1598 observations)

SIGNIFICANT WAVE HEIGHT INTERVAL (m)	PEAK PERIOD INTERVAL (s)														
	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-20	CALM	TOTAL %
1.75 - 2.00			0.06 0.06												0.06
1.50 - 1.75			0.06	0.06	0.06										0.06
1.25 - 1.50		0.06	0.56												0.63
1.00 - 1.25		0.94	1.06	0.19	0.19	0.06									2.44
0.75 - 1.00		3.75	0.25	0.31	0.19	0.50 0.06							5.07		
0.50 - 0.75	3.50	5.57	0.69	1.25	0.88	0.56	0.69	0.75	0.13	0.13	0.06	0.06			14.27
0.25 - 0.50	15.58	1.81	2.38	4.38	1.56	1.91	3.63	4.38	1.88	1.00	0.88	1.06	0.63		41.11
0.00 - 0.25	3.51	0.75	2.63	2.25	0.69	2.07	3.13	3.00	1.25	0.8	1.63	0.56	0.88		25.16
Calm														11.08	11.08
Total Percent	24.59	12.89	7.70	8.45	3.57	3.25	7.45	8.20	3.25	1.94	2.57	1.69	1.50	11.08	100.00

Table 3.3-9

DISTRIBUTION OF Hs VERSUS Tp FOR STATION NO. 88
(% of 691 observations)

SIGNIFICANT WAVE HEIGHT INTERVAL (m)	PEAK PERIOD INTERVAL (s)														
	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	14-20	CALM	TOTAL %
0.75 - 1.00			0.14												0.14
0.50 - 0.75		0.10													1.10
0.25 - 0.50	6.37	3.18	0.72			0.14	0.14								10.56
0.00 - 0.25	12.74	1.88	1.45	0.58		0.29		0.14		0.14					17.22
Calm														71.06	71.06
Total Percent	19.1	6.08	2.32	0.58		0.43	0.14	0.14		0.14				71.06	100

during winter. In addition, the inshore location of mooring 80 is afforded more protection from swell, and from waves arriving from outside the south quadrant.

The results of the Waverider analysis are consistent with the wave hindcast based on observed winds. Wave heights at both moorings were less than the calculated extreme annual value for Hs of 2.3 m (from the south).

b) Currents

Currents in the vicinity of the terminal site are driven primarily by the mixed, semi-diurnal tide, the wind, and by runoff from the Skeena River, which tends to turn north after passing over Flora Bank due to the Coriolis effect. The relatively high influx of fresh water in the region results in highly stratified conditions, thus creating an energy barrier to vertical mixing. Consequently, conditions for estuarine circulation are present, and currents should exhibit a strong vertical dependency. Under conditions of strong winds or large runoff the effects of either would be expected to dominate the flow.

The direction of the current north of the terminal site is constrained by the local bathymetry to an approximately north-south orientation; with northward and southward flowing currents resulting on the flood and ebb tides, respectively. South of the terminal site the waters open up into Chatham Sound and current directions are free to vary in direction. Values given in the Sailing Directions (1991) for the surface current during a strong flood and ebb are 2.8 km/h and 4.6 km/h, respectively. The larger value cited for the ebb tide is due to the shape of the local coastline. Water issues from Prince Rupert Harbour on an ebb tide through a fairly narrow channel into the broad expanse of Chatham Sound. Upon initially leaving the constriction the water forms a jet which maintains its high speed. Eventually, however, it broadens as it enters Chatham Sound, and in doing so slows down. On the flood tide the reverse takes place. Water from Chatham sound funnels into the channel leading to Prince Rupert Harbour where it gains speed. Initially, however, the water will be travelling slower than during an ebb tide because there is no corresponding jet.

During the AESL study of Prince Rupert Harbour (AESL, 1977) three drogues were released 400 m north of Barrett Rock on July 12, 1977. The three drogues were released at approximately one hour intervals during the latter half of a flood tide. The first drogue moved rapidly north-eastward toward Prince Rupert Harbour at speeds up to 70 cm/s. Drogues released later (closer to high tide) exhibited much more erratic movement, with significant lateral motion. One drogue was observed to traverse the channel between Kaien and Digby Islands at speeds up to 87 cm/s.

Recent drogue studies have been undertaken in order to obtain additional information on surface currents in the immediate vicinity of the proposed development site (Hay & Co, 1993).

Surface drifters were deployed during August 2 and 3, 1993 in order to obtain additional information on surface currents adjacent to the terminal site. Drogues were released at various phases of the tide and at locations that resulted in them being advected by the current within the vicinity of the proposed terminal development. Winds during the study were weakly onshore and had little effect on the movement of the drogues. Discharge from the Skeena River was normal for the time of year.

Current strength generally increased towards the centre of the channel, with peak mean speeds of 88 cm/s on the ebb tide and 62 cm/s on the flood tide. Near shore velocities were considerably weaker, especially over the shallows east of Barrett Rock, where weak flow reversals were sometimes observed, especially towards the end of an ebb tide. The study confirmed that during much of a tidal cycle the currents adjacent to the terminal site follow the local bathymetry and are oriented in a roughly north-south direction. Currents in the section of the channel west of Barrett Rock have considerably larger speeds due to the deeper water and decreased influence of bottom friction.

As part of the ongoing EEM process for Skeena Cellulose a dye tracer study was conducted in Porpoise Harbour and Chatham Sound (Hatfield Consultants, 1990). Near high tide on March 31, 1990, rhodamine dye was injected into the diffuser at the Skeena Cellulose Inc. pulp mill and monitored over the following 30 hours. The ensuing spatial distribution of dye concentration provides some insight into the circulation and turbulent diffusion that can occur in this area. Although the initial release took place within Porpoise Harbour, the ebb tide advected the dye into the waters west of Ridley Island, and thus within the area of interest for the present development.

Upon entering Chatham Sound through Porpoise Channel the dye was well mixed throughout the water column by turbulence. It then became trapped at a depth corresponding to water of the same density. At this time the dye occupied a layer which extended downward approximately 15 to 20 m from the surface. The patch of dye subsequently dispersed into a plume approximately 4 km across and began to move northward with the ensuing flood tide. During the next five hours the leading edge of the dye plume had reached the south entrance to the channel between Digby and Kaien Islands; a distance of approximately 4 km. Due to the finite extent of the plume it was not possible during this study to determine the instantaneous distribution of dye. Numerous transects were required over several hours to identify the lateral and vertical extent of the plume. For this reason, it is difficult to estimate the speed of the plume as it moved northward through Chatham Sound. However, a rough estimate based on the horizontal displacement of the plume edge, and the time intervals over which concentrations were measured, yields a value on the order of 20 cm/s.

Vertical profiles of water temperature and salinity were made coincident with measurements of dye concentration. These revealed a complex vertical structure in the region with elevated temperatures at several depths. The dye patch tended to be contained within a thin sheet near the surface of the water column, constrained to this level by the ambient density structure. This structure results from the combined effect of fresh water discharged from the Skeena River and the turbulent mixing which results from the strong tidal currents. Dilution ratios due to turbulent mixing of 103:1 after 5 h and greater than 104:1 after 18 h were calculated for Porpoise Channel and Chatham Sound.

c) Water Properties

Measurements of water properties made near Barrett Rock in the summer of 1977 provide information on the vertical structure of the water near the terminal site (AESL., 1977). Table 3.3-10 lists vertical profiles of temperature (T), salinity (S) and density (sigma-t) at various depths just north of Barrett Rock.

Due to enhanced heating of surface waters and reduced wind speeds, stratification is most intense during summer. This can be seen in the profile as a relatively rapid increase in salinity and density, and rapid decrease in temperature with depth over the upper 40 m, followed by a much more gradual change down to 140 m. This illustrates the formation of a pycnocline during summer months which tends to inhibit mixing near the surface.

The large runoff from the Skeena River during the June and July snowmelt combined with low precipitation during these months tend to produce colder and fresher surface waters near Barrett Rock than further north in the harbour off Prince Rupert. In October, when rainfall is at its peak and runoff has decreased significantly, surface waters in Prince Rupert Harbour tend to be fresher than near Barrett Rock (AESL., 1977).

Near surface DO levels measured during the summer of 1992 near Barrett Rock (Stucchi, 1993) were all at protection level B. Highest near surface concentrations were found in July. Ho (1978) analyzed a seven year time-series of DO from a station near Barrett Rock and found a seasonal dependence in DO with a minimum occurring in the fall which he attributed to wind-induced upwelling. Such upwelling events occur when

Table 3.3-10

VERTICAL SECTION NEAR BARRETT ROCK
July 11, 1977
(54° 14'46" N, 130° 20'52" W)

DEPTH (m)	TEMPERATURE (° C)	SALINITY	DENSITY (sigma-t)
0	11.68	20.33	15.35
10	11.49	22.28	16.88
20	10.98	25.19	19.21
40	9.98	29.77	22.92
60	9.50	30.85	23.84
80	9.38	31.08	24.04
100	9.34	31.25	24.18
120	9.34	31.32	24.23
140	9.22	31.41	24.32

surface waters are driven offshore and compensating upward transport raises oxygen depleted water from below to be mixed with near surface waters.

d) Flushing

The region immediately adjacent to the proposed development site contains extensive tidal flats which are connected to Chatham Sound via narrow and shallow openings through the many outcroppings of rock found in the area. If a causeway is built across these flats and outcroppings it will modify the circulation in the area by dividing the flats into two new embayments. The issues concerning the present state of tidal flushing in the region, and the impact on the flushing rate of a causeway have been addressed by Hay & Co (1993b). A model developed by Sanford et al (1992) is applied in this report to the present state of the tidal flats, and to the state after construction of a causeway. The study concludes that the tidal flats region is presently well flushed by tidal currents, and that the residence time is now of the order of one to two semi-diurnal tidal cycles. The flushing times in the two new embayments created by a proposed causeway were not found to differ significantly from this value.

3.3.2 Marine Biology

Chatham Sound

a) Plankton

Information on nearby coastal waters influenced by the discharge of the Skeena River have been used to prepare a description of the existing Chatham Sound environment. Oceanographic conditions in the nearshore waters of Queen Charlotte Sound and Hecate Strait generally favour a net increase in algal standing crop during the period of April to November (pigment values of 0.8 to 4.0 mg chlorophyll a/m^3) over values recorded in December, January and February. The standing crops of marine phytoplankton on Chatham Sound is likely similar to those measured in Hecate Strait. Maximum zooplankton standing crops of 134 to 246 mg wet wt/m^3 have been encountered in northern coastal waters in May and minimum quantities (0.4 to 45 mg wet wt/m^3) in March (Parson, 1965). In the Kitimat area, relatively high levels of primary production (1 mg c/m^3/hr); phytoplankton standing stock (greater than 7 mg chlorophyll a/m^3) and zooplankton abundance (17,000 mg wet wt/m^3) have been measured in the water of Principe Channel. Biological production in the more northern water of Douglas Channel and north of the Queen Charlotte Islands (Duval and Packman) is thought to be somewhat lower than in Principe Channel.

Higgins and Schouwenburg (1973) and Kilke et al (1979) provide data on the occurrence and abundance of zooplankton in Chatham Sound. Zooplankton species (excluding crustaceans) identified by Dilke et al were ctenophores, molluscs and their larvae, cnidaria, echinoderm larvae, turnicates, chaetocera and polychaetes and their larvae. Crustacean zooplankton were dominated by copepod species. Calanoid copepods were abundant throughout the area, and exhibited the highest species diversity. Of these, *Acartia longiremus* and *Pseudocalanus minutus* were prominent at most stations at most times. Calanoid copepods were also noted to be a major component in the gut contents of juvenile chinook and sockeye salmon, whereas *Pseudocalanus minutes* and *Cirripedia cypris* were a major food source for herring and needlefish.

The Flora Bank area of Chatham Sound south of Ridley island is a region of relatively high primary and secondary production (NEAT, 1975). Flora Bank supports approximately 50% to 60% of the total eelgrass production in the Skeena estuary (Figure 3.3-10) (Fisheries Services, 1972 as cited in Hoose, 1975). Eelgrass beds are an important component of estuarine ecosystems because their high rate of biomass production supports epiphytic algae and invertebrate communities. The Flora Bank eelgrass beds are known to provide food and shelter for juvenile fish populations which rear in brackish waters (Hoos, 1975). The presence of eelgrass on Flora Bank is thought to be due to the unique substrate which has a higher median substrate size (0.032 mm) and higher sand content (35%) than other Chatham Sound sites (NEAT, 1975).

b) Invertebrates

Data collected in conjunction with port development studies indicate a lower species diversity, but substantially high abundance of benthic invertebrates on Flora Bank and Horsey Bank in comparison to other sites samples in Chatham Sound. The lower species diversity and high abundance is typical of highly productive estuarine environments. Polychaetes, both mobile and sedentary, were the most frequently gathered benthic organisms and exhibited the largest number of taxa. An abundance of amphipods and isopods were found only in the Flora Bank region of Chatham Sound and are probably associated with the eelgrass beds. Amphipods and isopod crustaceans are an important dietary component of juvenile salmon (Goodman and Vroom, 1972; Gerke and Kaczynski, 1972).

c) Salmon

Many of the larger coastal streams in the vicinity of the proposed liquids terminal support populations of Pacific salmon. Statistics on escapements to these streams, including Denise, Diana, Prudhomme Creeks and Skeena, Ecstall and Kloiya rivers are listed in Table 3.3-11. There are no data defining the level of present or past use by salmon of individual streams flowing into Morse Basin. Comparison of salmon escapement data from all coastal streams in Statistical Area 4 indicate that all the sockeye and chinook salmon and 41% of coho salmon came from Morse Basin streams.

Recent attempts have been made through the Salmonid Enhancement Program to provide enhancement facilities for chinook on Kloiya River and Diana Creek (SEP Annual Report, 1979). Egg survival in the first year of operation was poor but future attempts are planned. The Kloiya River also supports a population of steelhead trout.

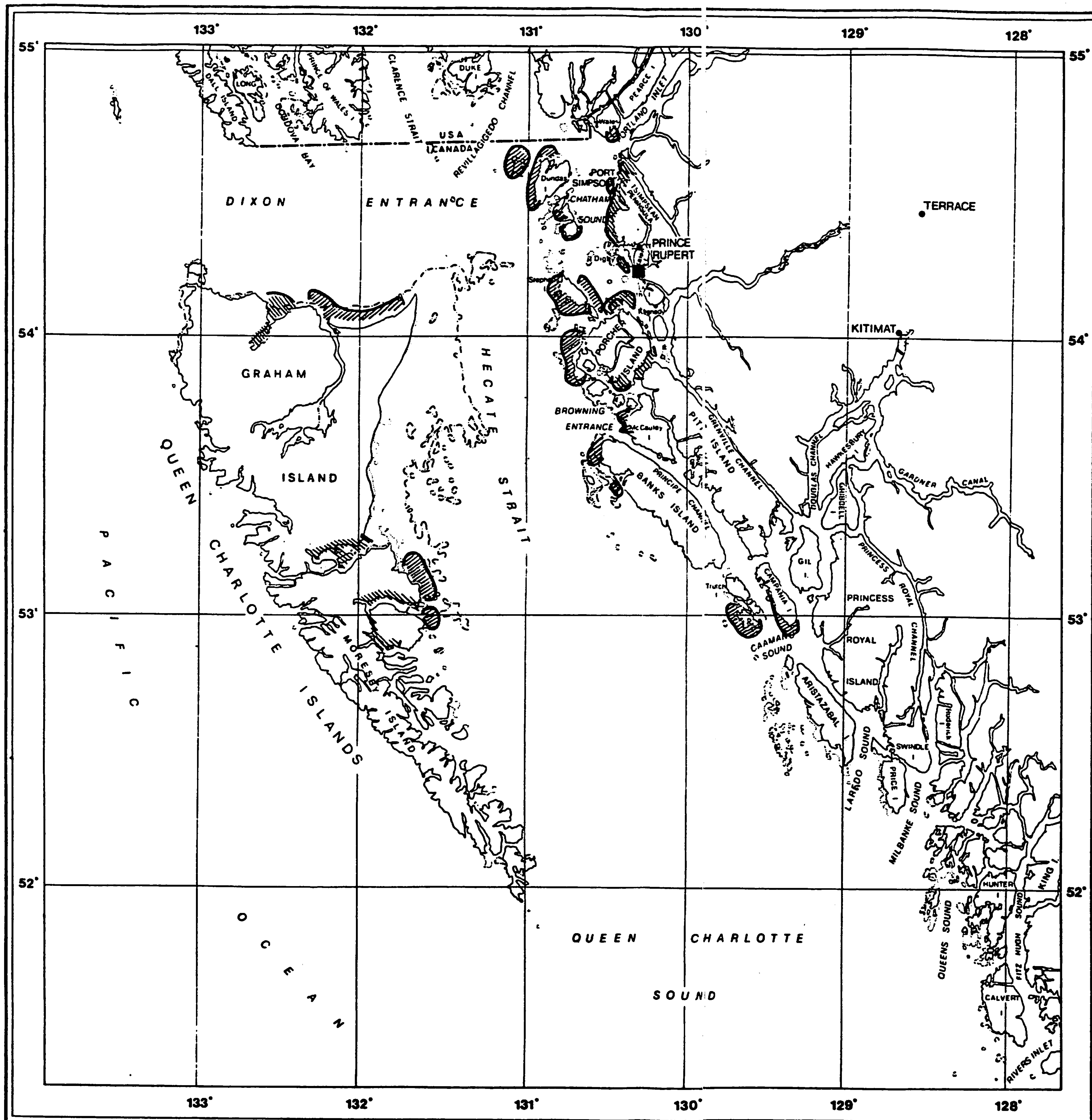


Figure 3.3-10

KELP BEDS AND HERRING SPAWN AREAS OF THE BRITISH COLUMBIA NORTH COAST

PETROCHEMICAL TERMINAL

LEGEND

KELP BEDS

HERRING SPAWN AREAS

NOTE: DEPTH IN FATHOMS.

KILOMETRES

20 0 20 40 60 80

Table 3.3-11

ESCAPEMENT SUMMARY FOR SALMON SPECIES FOR SELECT STREAMS

	SOCKEYE	COHO	PINK	CHUM	CHINOOK
SKEENA RIVER					
Mean Escapement	-	-	284000[3] 101700[2]	3168[1]	520[1]
Maximum Escapement	-	-	500000[3] 400000[2]	20000[1]	-
ECSTALL RIVER					
Mean Escapement	206[1]	10500[1]	15600[3] 7500[2]	14950[1]	2005[1]
Maximum Escapement	1400[1]	10000[1]	35000[3] 20000[2]	75000[1]	3800[1]
KLOIYA RIVER					
Mean Escapement	-	60[1]	560[3] 685[2]	-	228[1]
Maximum Escapement	-	200[1]	2000[3] 2000[2]	-	400[1]
DIANA CREEK					
Mean Escapement	1467[1]	266[1]	-	-	1[1]
Maximum Escapement	3200[1]	450[1]	-	-	10[1]
PRUDHOMME CR					
Mean Escapement	506[1]	38[1]	-	-	-
Maximum Escapement	1000[1]	50[1]	-	-	-
DENISE CREEK					
Mean Escapement	-	17[1]	21[3] 170[2]	5[1]	-
Maximum Escapement	-	50[1]	70[3] 600[2]	30[1]	-

LEGEND:
PERIOD OF RECORD: 1 = 1980-1989; 2 = 1980-1988; 3 = 1981-1989

Wolf Creek, which drains into the B.C. Timber waste treatment lagoon, historically supported runs of steelhead trout, coho salmon and cutthroat trout. Industrial activity and effluents from the sulphite process formerly used at the pulp mill have eliminated these runs. The results of a survey by the Federal Department of Fisheries and Oceans in the summer of 1980 indicated that little suitable fish habitat remains in Wolf Creek, although small populations of resident rainbow trout and Dolly Varden char continue to inhabit the mid-reaches.

The most comprehensive data available on fish utilization of the Chatham Sound area has been collected by Fisheries and Marine Services. The data includes the catch frequency and distribution of juvenile salmon (5 species *Onchorhynchus*), herring (*Clupea pallas*), needlefish (*Ammodytes hexapterus*) and surf and longfish smelts (*Hypomesus pretiosus* and *Spirinchus dialtus*). A complete list of fish species captured during their investigation is provided in Table 3.3-12.

Figures 3.3-11 to 3.3-14 depict commercial finfish and shellfish grounds and areas in Chatham Sound, Hecate Strait, Dixon Entrance and Queen Charlotte Sound.

An assessment of fish utilization of the Skeena River estuary and shallow waters of southeastern Chatham Sound has been completed by Higgins and Schouwenburg (1973). The results of their investigations suggested that juvenile salmon are present in channels and embayments on the east side of Chatham Sound from April 12 to August 11 each year. Sampling in Inverness Passage, Flora Bank and DeHorsey Bank produced the greatest mean captures per net set. The high variance in the numbers of fish captured encountered in these areas relative to the other sampling areas is indicative of captures of schools of fish.

The data suggest that out-migration of pink salmon (*O. gorbuscha*) fry peaks in the third week of May and is usually over by mid-June. Pink salmon juveniles are fish captured in Inverness Passage as they migrate outward from the mouth of the Skeena, followed a week later by the appearance of large numbers in the Flora Bank and DeHorsey Bank area.

The initial migration and peak abundance of sockeye salmon (*O. nerka*) fry appears to occur in the last week of May at the mouth of the Skeena, closely followed by peaks in the Flora Bank and Kitson Island area. By the first week in July, most sockeye juveniles have moved out to open waters adjacent to the estuary area (Higgins and Schouwenburg, 1973).

The migration into the Skeena River estuary of coho salmon (*O. kisutch*) juveniles is known to commence in the third week of June. Netting results indicate that they are present in the shallow waters of sand banks in Inverness Passage and the seaward side of Lelu and Ridley islands until the end of July each year (Higgins and Schouwenburg, 1973).

Chinook salmon (*O. tshawytscha*) juveniles are known to be present in Inverness Passage and shallow waters of the east shore of Chatham Sound from the third week in May until mid-August each year. Higgins and Schouwenburg (1973) found the overall peak abundance occurred at various times from mid-June in areas sampled, such as Flora Bank, DeHorsey Bank, Inverness Passage, Ridley Island and offshore Chatham Sound.

Chum salmon (*O. keta*) juveniles are not usually abundant in the estuary at the mouth of the Skeena River, but remain in small numbers in Inverness Passage between June and August. The peak abundance in shallow waters of Chatham Sound appear to occur in the second week of July (Higgins and Schouwenburg, 1973).

Coho, chinook and chum salmon juveniles exhibit a considerably longer residency time in the estuary channels and in the shallow waters of eastern Chatham Sound than do pink and sockeye salmon. The lengthy residency time of chinook and coho in estuaries

Table 3.3-12

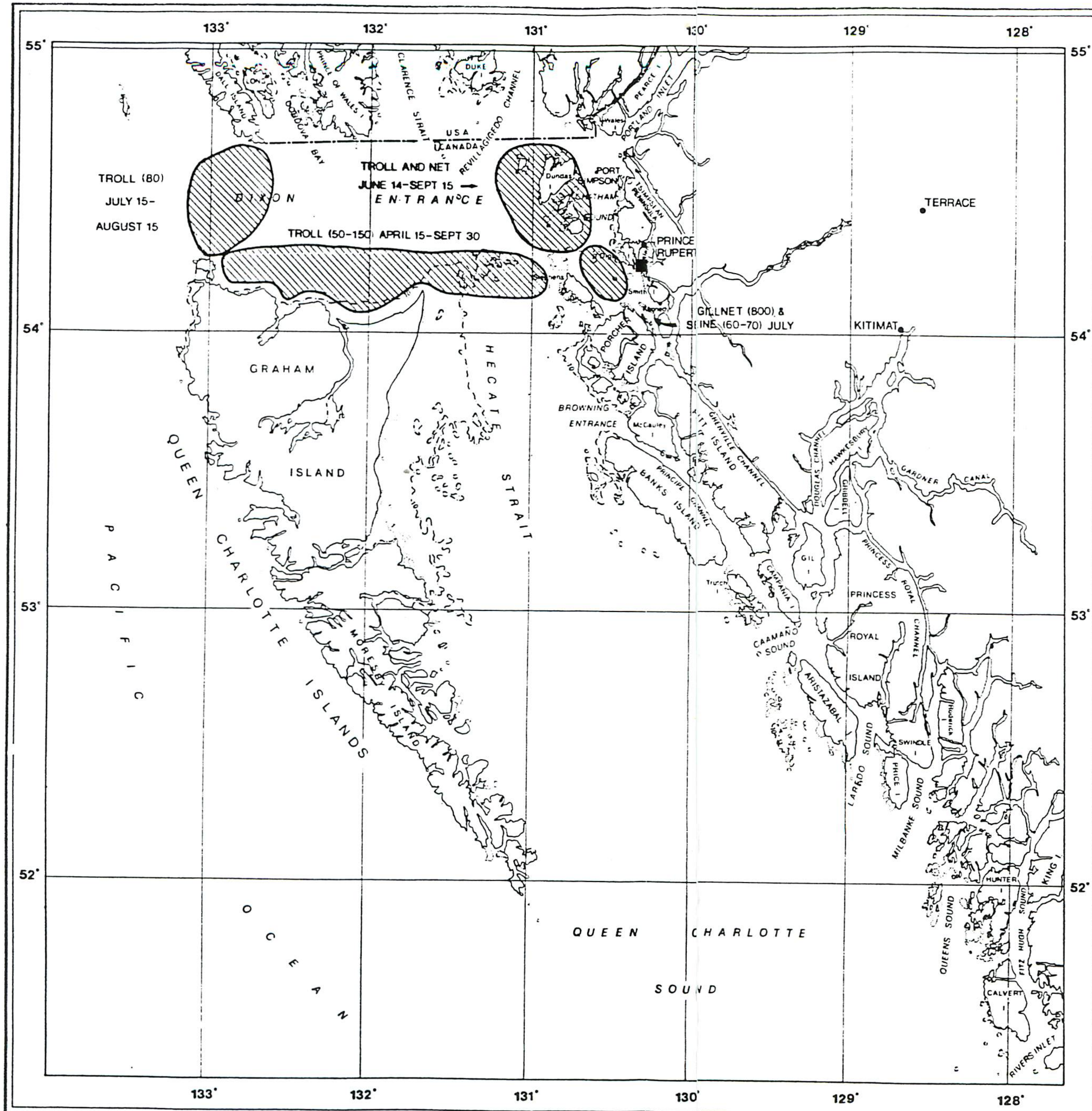
LIST OF FISH SPECIES CAPTURED IN PURSE SAINE
APRIL 23 TO AUGUST 11, 1972
(from Higgins and Schouwenberg, 1973)

Pink salmon	Onchorhynchus gorbuscha
Sockeye salmon	Onchorhynchus nerka
Coho salmon	Onchorhynchus kisutch
Chinook salmon	Onchorhynchus tshawytscha
Chum salmon	Onchorhynchus keta
Pacific lamprey	Entosphenus tridentatus
Eulachon	Thaleicthys melanostictus
Capelin	Mallotus villosus
Sand sole	Psettichthys melanostictus
Lemon sole	Parophrys vetulus
Butter sole	Isopsetta isolepsis
Starry flounder	Platichthys stellatus
Sandfish	Trichodon trichodon
Spinynose sculpin	Radulinus taylori
Padded sculpin	Artedius fenestralis
Buffalo sculpin	Enophrys bison
Staghorn sculpin	Leptocottus armatus
Grunt sculpin	Rhanphocottus richardsoni
Deep pitted poacher	Bothragomus swanii
Sturgeon poacher	Agonees acipenserinus
Spiny lumpsucker	Eumicrotremus orbis
Tadpole snailfish	Nectoliparis pelagicus
Threespine stickleback	Gasterosteus aculeatus
Whitebarred prickleback	Poroclinus rothrocki
Red brotula	Brosmophycis marginata
Flathead clingfish	Gobiesox masandricus

Figure 3.3-11

SALMON FISHING FLEET ACTIVITY IN THE PRINCE RUPERT REGION

PETROCHEMICAL TERMINAL



Source Jaltema (Pers Comm)

LEGEND

(80) NUMBER OF VESSELS

FLEET ACTIVITY AREA

NOTE: DEPTH IN FATHOMS.

KILOMETRES

20 0 20 40 60 80

Figure 3.3-12

MAJOR TRAWL AND HALIBUT FISHING GROUNDS

PETROCHEMICAL TERMINAL

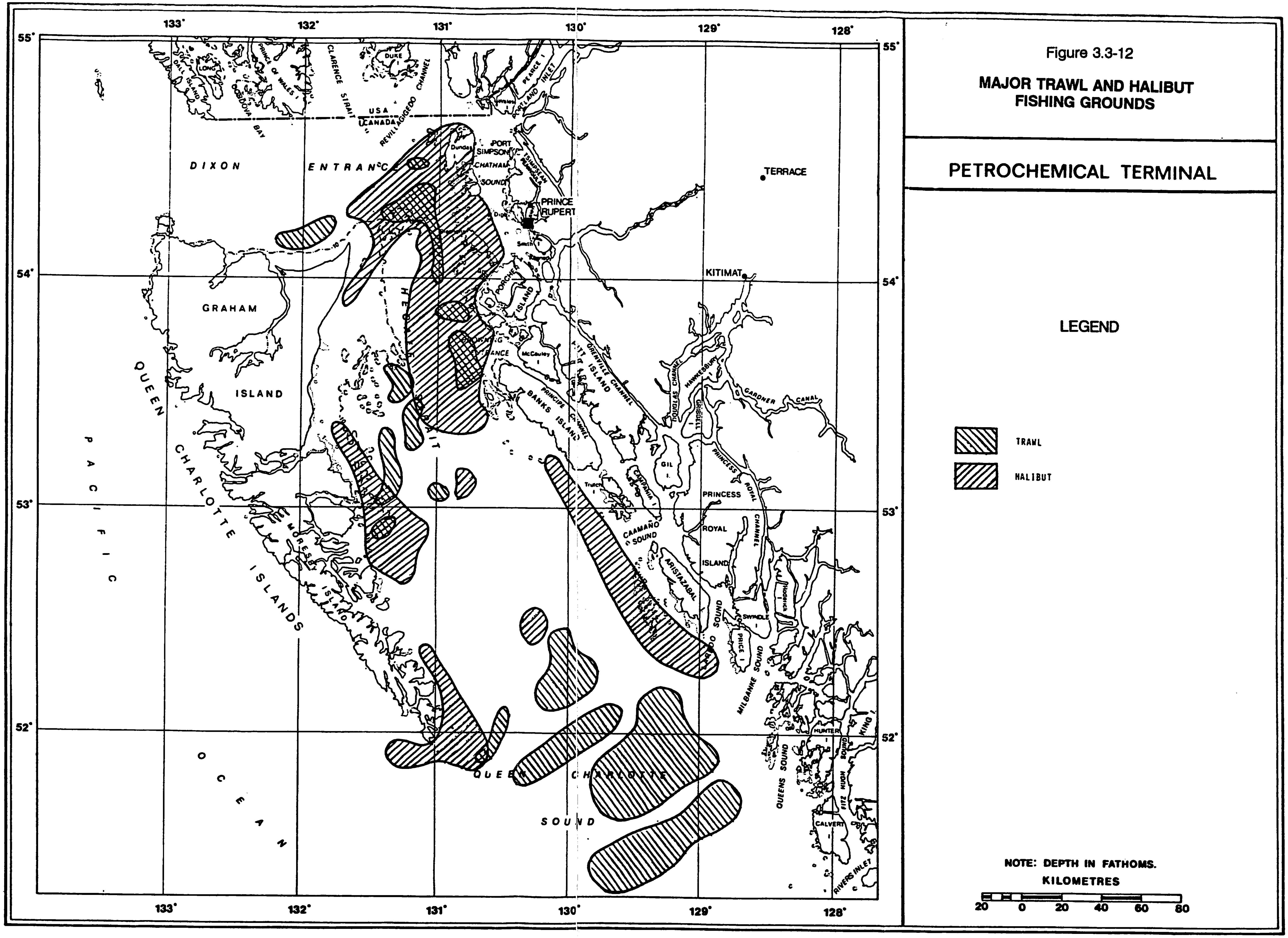
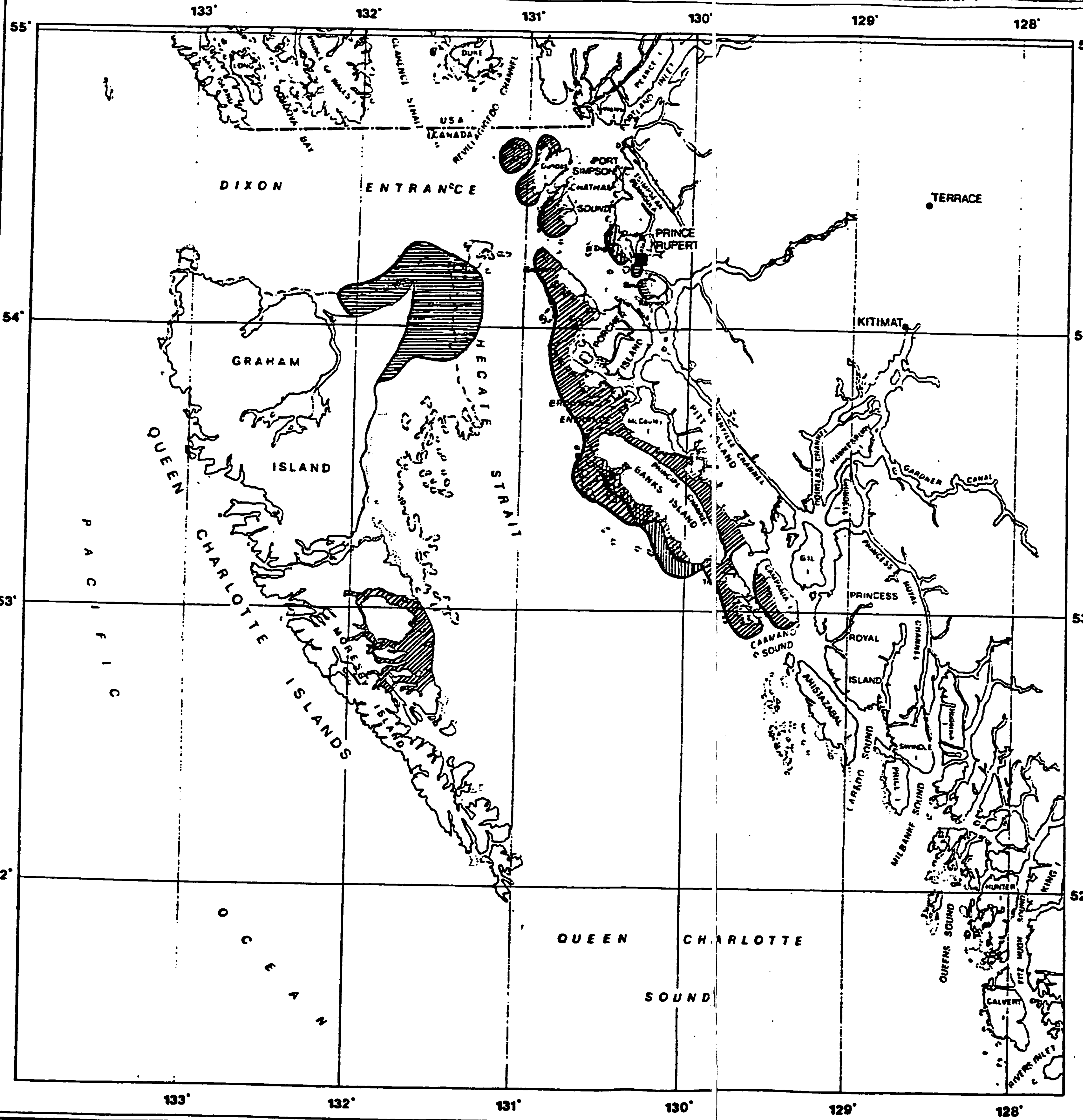


Figure 3.3-13

SHELLFISH (DUNGENESS CRABS, SHRIMPS, ABALONES AND URCHINS) RESOURCES OF THE B.C. NORTH COAST

PETROCHEMICAL TERMINAL



LEGEND

■ TERMINAL SITE

DUNGENESS CRABS

SHRIMPS

ABALONES & URCHINS

NOTE: DEPTH IN FATHOMS.

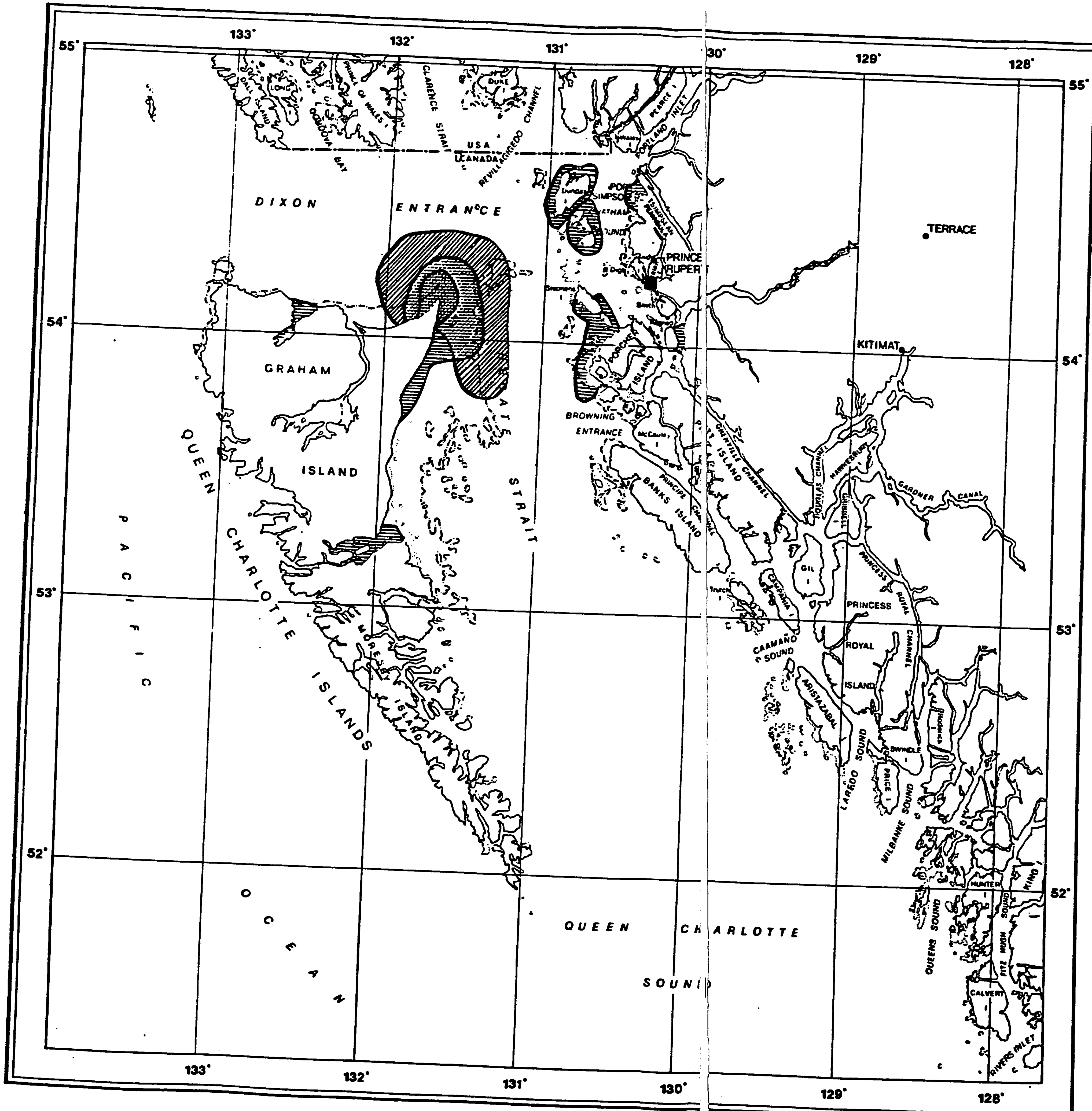
KILOMETRES

20 0 20 40 60 80

Figure 3.3-14

SHELLFISH (BUTTER CLAMS, RAZOR CLAMS, WEATHERVANE SCALLOPS) RESOURCES OF THE B.C. NORTH COAST

PETROCHEMICAL TERMINAL



LEGEND

■ TERMINAL SITE

BUTTER CLAMS

RAZOR CLAMS

WEATHERVANE SCALLOPS

NOTE: DEPTH IN FATHOMS.

KILOMETRES

20 0 20 40 60 80

has also been demonstrated in other estuarine environments such as the Columbia and Sixes estuaries in the state of Oregon (Sims, 1970; Reimers, 1971).

The results of surveys by Higgins and Schouwenburg (1973) indicate that the greatest number of salmon juveniles occur in Inverness Passage, followed by Flora Bank and DeHorsey Bank. These areas exhibited a large variance in numbers with time which suggests that salmon juveniles remain in schools after leaving the mouth of the Skeena River. The highest variance in mean capture per net set seen at Flora Bank indicates larger schools congregate in this area before their seaward migration and subsequent dispersal. The low variance in numbers encountered in samples collected off Ridley Island suggests that the schools may have dispersed somewhat by the time the juveniles have passed by the seaward side of Ridley Island.

A large portion of the outward migrating juvenile Pacific salmon from the Skeena system appear to pass through Inverness Passage and Flora Bank in schools which disperse upon reaching the open waters of Chatham Sound. The data for individual species also suggest that pink and sockeye salmon juveniles exhibit a short residency time, whereas coho, chinook and chum salmon exhibit a long residency time along the beaches of channels and islands north of the Skeena River.

d) Herring

Pacific herring are known to utilize the eastern portions of Chatham Sound in the Prince Rupert area for spawning, nursing and rearing, although their abundance and, hence, distribution has varied considerably from year to year (Figure 3.3-10). Herring eggs are considered to be euryhaline and stenothermal. The eggs are tolerant of a wide salinity range (12% to 26%) with maximum survival in the 13% to 19% range (Alderdice and Velsen, 1971). Most spawn deposition (80%) occurs at depths shallower than -1.5 m datum on various types (kelps, seaweed and eelgrass) of aquatic vegetation (Hourston and Haegle, 1980).

Following a 2-week incubation period, the herring eggs hatch, and after approximately 6 days the larvae are able to swim and feed on small zooplankton. Metamorphosis to the adult form starts about 10 weeks after hatching and takes about 3 weeks (Houston and Haegle, 1980).

The juvenile herring grow quickly the first summer, gathering in increasingly large schools (Taylor, 1964; Houston and Haegle, 1980) and feeding on copepods, amphipods and euphasids (Outram and Humphreys, 1974). The juveniles begin their outward migration from shallow to deeper waters (150 to 200 m) in September.

The feeding ground for north coast herring is in Hecate Strait. The adults mature in 3 years and begin their migration to shallow nearshore spawning grounds between October and December (Figure 3.3-10). When spawning is completed, the adults feed voraciously and begin their migration back to the offshore feeding grounds (Houston and Haegle, 1980).

In a recent investigation (Fisheries and Marine Services, 1977), no significantly large herring populations were encountered near Ridley Island or in Chatham Sound, although the commercial fishery produced large catches. The data suggest that the high volume of Skeena River water discharging into Chatham Sound may lower the surface salinity to a point that spawning herring largely avoid the brackish waters in the vicinity of Flora and DeHorsey banks.

The catch frequency distribution of mature herring in Chatham Sound suggests that the fish enter Chatham Sound in large schools but avoid the brackish water of the Skeena estuary (Higgins and Schouwenburg, 1973).

Although Flora Bank is not a documented fishing area for herring spawn, it does provide an ideal nursing and rearing area for juvenile herring. Juvenile herring are known to migrate from the immediate spawning area to nearby nursing and rearing grounds (Taylor, 1974; Houston and Haegle, 1980).

Wainwright Basin - Morse Basin - Porpoise Harbour

Prior to establishment of the Skeena Cellulose Inc pulp mill complex (1951) in Porpoise Harbour, the embayment, including Wainwright Basin and Morse Basin, was reported to be highly productive especially with respect to Pacific herring (Packman, 1979). The potential herring production in this area, despite the 10-year presence of the pulp mill, is suggested by statistics from the 1960 to 1961 fishing season when landings from Morse Basin contributed to as much as 18% of the total British Columbia catch.

The Skeena Cellulose Inc pulp mill complex formerly discharged most of its wastewaters into a shallow inlet at the western edge of Wainwright Basin. The woodroom effluent was discharged directly into Porpoise Harbour. Following the conversion from a sulphite to a kraft process (1977), a waste effluent diffuser was installed in Porpoise Harbour and a pipeline was constructed to discharge spent sulphite liquor wastes into Chatham Sound. Pipeline ruptures resulted in the discharge of red liquor into Porpoise Harbour. In the early 1980's, this outfall was decommissioned. Effluent is currently treated in a bioreactor complex. Two small independent fish processing plants discharge organic waste effluents via submerged outfalls (5 to 10 m depth) into Porpoise Harbour from the east shore.

Biological investigations carried out to date in Wainwright Basin have been largely qualitative, having considered the relative abundance of species between selected sites. The results of studies indicate a recent increase in dissolved oxygen concentrations from previously low levels caused by decaying organic wastes in Porpoise Harbour and Wainwright Basin (Packman, 1977; EPS, unpublished data). Although an increase in secondary production was also expected following removal of the mill waste discharge to the seaward side of Ridley Island, this increase was not evident in the results of more recent biological investigations (Drinnan, 1977). On the contrary, the results of this work in 1977 showed a marked decrease in algal species and number in Wainwright Basin compared to Morse Basin and Porpoise Harbour. The data on the distribution of benthic macro-invertebrates and algae determined in 1977 indicates that Wainwright Basin supports sparse populations, whereas Porpoise Harbour and Chatham Sound support greater numbers.

3.3.3 Intertidal and Subtidal Biology

The marine waters of South Kaien Island in the region of the proposed causeway have been affected by the pulp mill in the past. However, the outfall into Chatham Sound has been terminated, and the general marine conditions are improving. The shallow water marine and intertidal area at the Southwestern tip of Kaien Island out to Bishop Island and Northwest of Porpoise Harbour is an area of moderate productivity. Some eelgrass occurs in the mud flats but very little of this eelgrass is within the fill area of the proposed causeway.

The site of the proposed causeway is 8 km North of Flora Bank. Flora Bank is a shallow region of extremely high value to the rearing of salmon on their seaward migration, and of importance to crab and shellfish. Predominant currents from the proposed site are to the north away from Flora Bank and therefore chances of adverse impact on Flora Bank from this development are minimal. However, the high resource value of the Bank and the waters further South to the Skeena River mouth (generally the Skeena River Estuary) dictate some sensitivity in this area.

The foreshore of South Kaien Island in the vicinity of the proposed causeway development is an area of mud flats interrupted by large rock outcroppings or "reefs". The stable rock formations provide anchorage for seaweeds and protection for marine life. Near the low tide line, protected areas of the mud flat support patchy eelgrass growth. The upper intertidal area and supralittoral fringe of South Kaien Island consist mainly of scattered boulders, loose rock and gravel, but at some points this upper area is reduced due to a steep rock bank.

A number of distinct habitat zones can be identified throughout the general area of the proposed causeway development. These are as follows:

- intertidal rocky foreshore
- intertidal mud/sand flats
- sub-tidal habitat

Figure 3.3-15 illustrates the location of the conceptual footprint of the proposed causeway with respect to the South Kaien Island shoreline, the CN rail line, and the existing Prince Rupert grain structures on Ridley Island. The main areas occupied by each of the habitats outlined above is also diagrammed in Figure 3.3-15 to illustrate their relationship to the proposed development. As can be seen from the causeway footprint, the direct impacts of this proposed causeway will be mainly within the rocky intertidal area and along the edge of the mud flat. Some small patches of eelgrass within the mud flat area also fall within the direct impact area. Most of the discussion that follows, will deal with these areas of direct impact, but where sensitive regions such as eelgrass patches, and kelp habitat border on the direct impact area, they will be included in the calculations.

The area in the proposed causeway fill area occupies an intertidal and sub-tidal area of 2.02 ha. The intertidal portion of this is 1.31 ha and the sub-tidal portion is 0.72 ha. The area occupied by each habitat within the proposed fill area is as follows.

- intertidal rocky foreshore 0.49 ha
- intertidal mud/sand flats 0.82 ha
- sub-tidal habitat 0.71 ha

* The intertidal mudflat within the causeway footprint includes some small patches of eelgrass totalling approximately 0.055 ha.

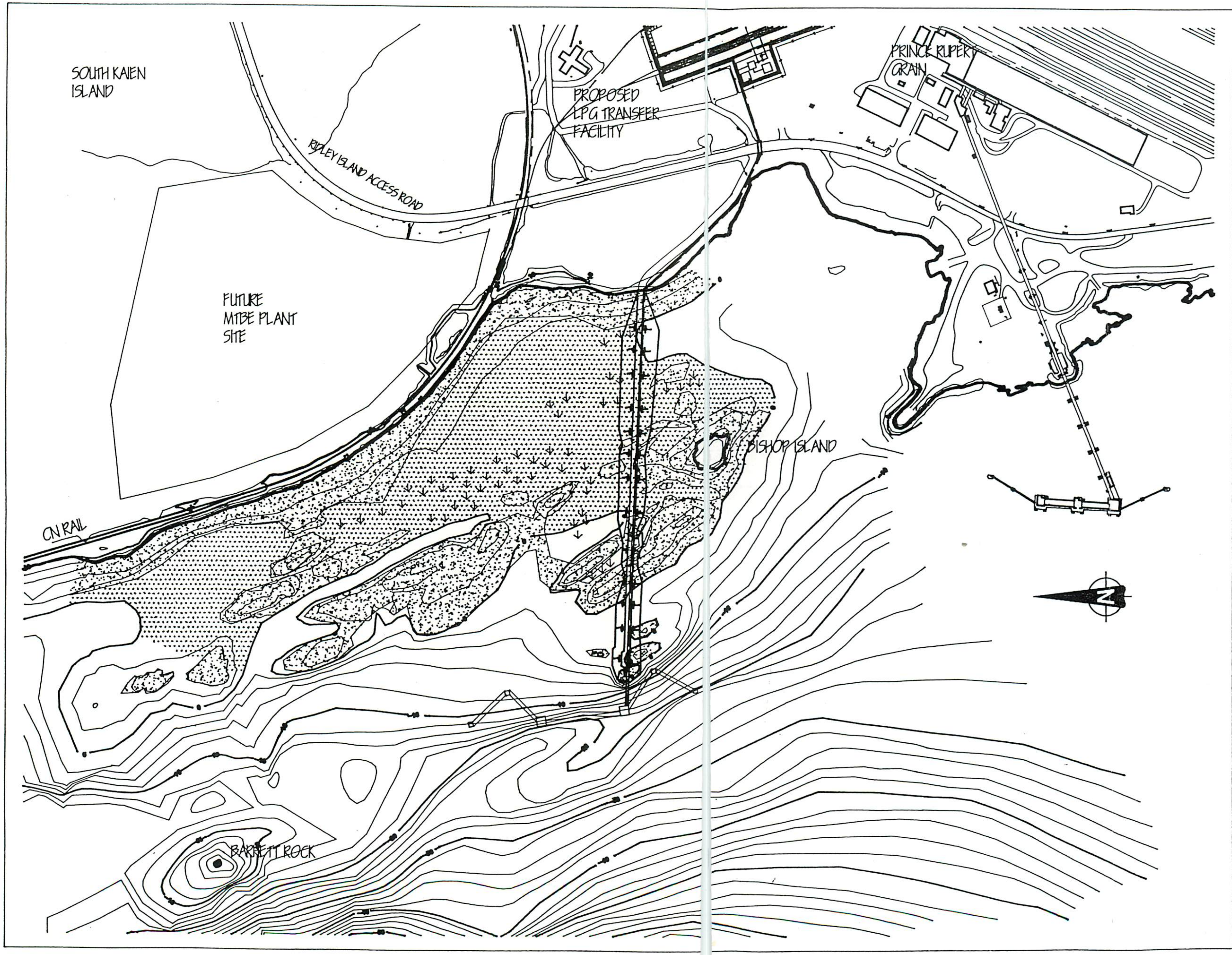
The regions of the proposed causeway fill area occupied by each of the identified habitats listed above is outlined in Figure 3.3-16. Figure 3.3-16 is a longitudinal profile of the causeway showing the changes in elevation through the intertidal and sub-tidal areas that the proposed causeway will pass. The habitat zones associated with the various elevations are also outlined in Figure 3.3-16. Each habitat zone has been studied with respect to the dominant organisms and its relation to the tidal level. Whenever possible, quantitative documentation of dominant species abundance has been carried out. All descriptive documentation of the intertidal habitats is supported by a photographic survey (Appendix A).

The Intertidal Rocky Foreshore

As can be seen from Figure 3.3-16, one of the most conspicuous intertidal regions in the proposed causeway fill area is the rocky intertidal foreshore, which occupies about 0.49 ha of the total proposed fill area. Taking into account the slope and contours of the rocky intertidal zone as well as the irregular nature of the rock formations, this converts to approximately 0.6 ha surface area for growth and attachment of marine life.

The nature of the rocky foreshore in the fill area varies from large rock outcroppings or "reefs" down to boulders and loose rock (0.3 m diameter). Most of the rocky intertidal is a productive area for seaweed growth.

As stated above, the profile shown in Figure 3.3-16 depicts an imaginary line along the centre line of the causeway showing changes in elevation and corresponding changes in habitats along the length of the causeway. This figure serves to illustrate the fundamental nature of the marine rocky intertidal habitat in that all rocky intertidal habitat



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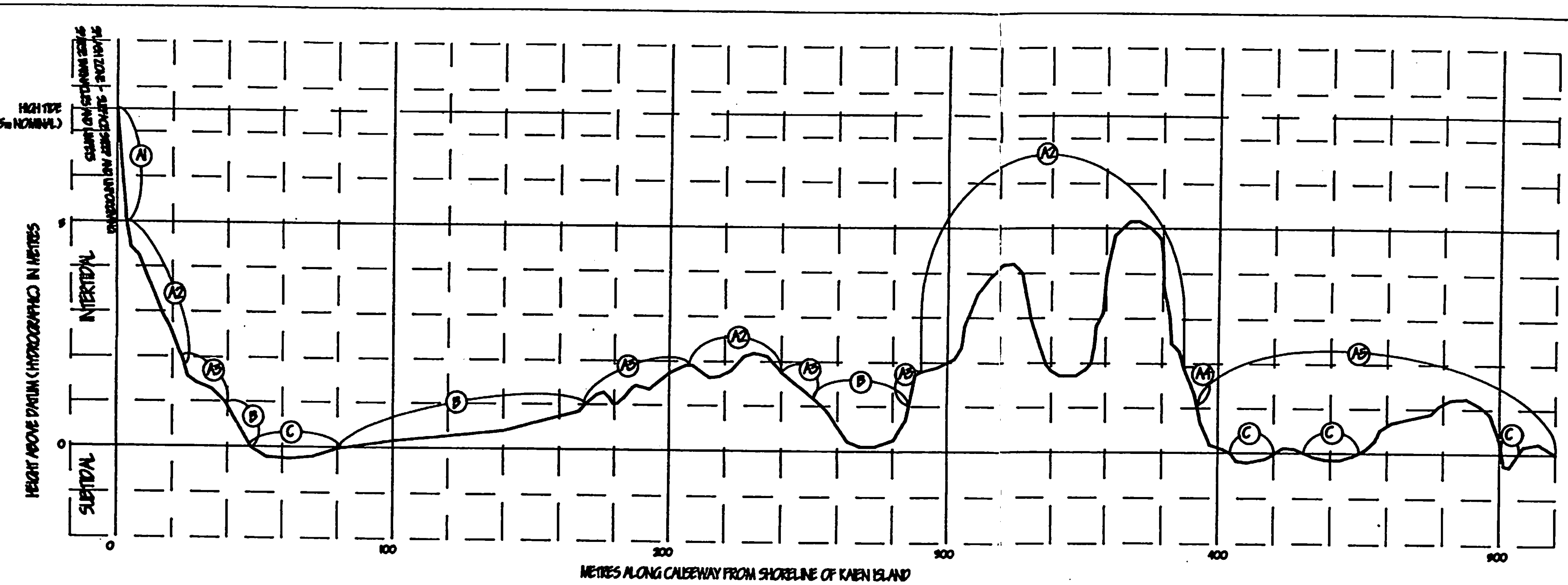
REVISIONS

PRINCE RUPERT PORT CORPORATION
110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :
Figure 3.3-15
PROPOSED FORESHORE FILL AREA
HABITAT AREAS

Designed	JS	Project No.	LPG-1	Drawing No.
Drawn	PS	Scale	1:5000	
Checked	JS	Date	93/10/20	of



CONCEPTUAL CAUSEWAY LONGITUDINAL PROFILE ILLUSTRATING ELEVATION CHANGES ALONG THE LENGTH OF THE CAUSEWAY AS WELL AS THE MAIN HABITAT ZONES THROUGH WHICH IT WILL PASS

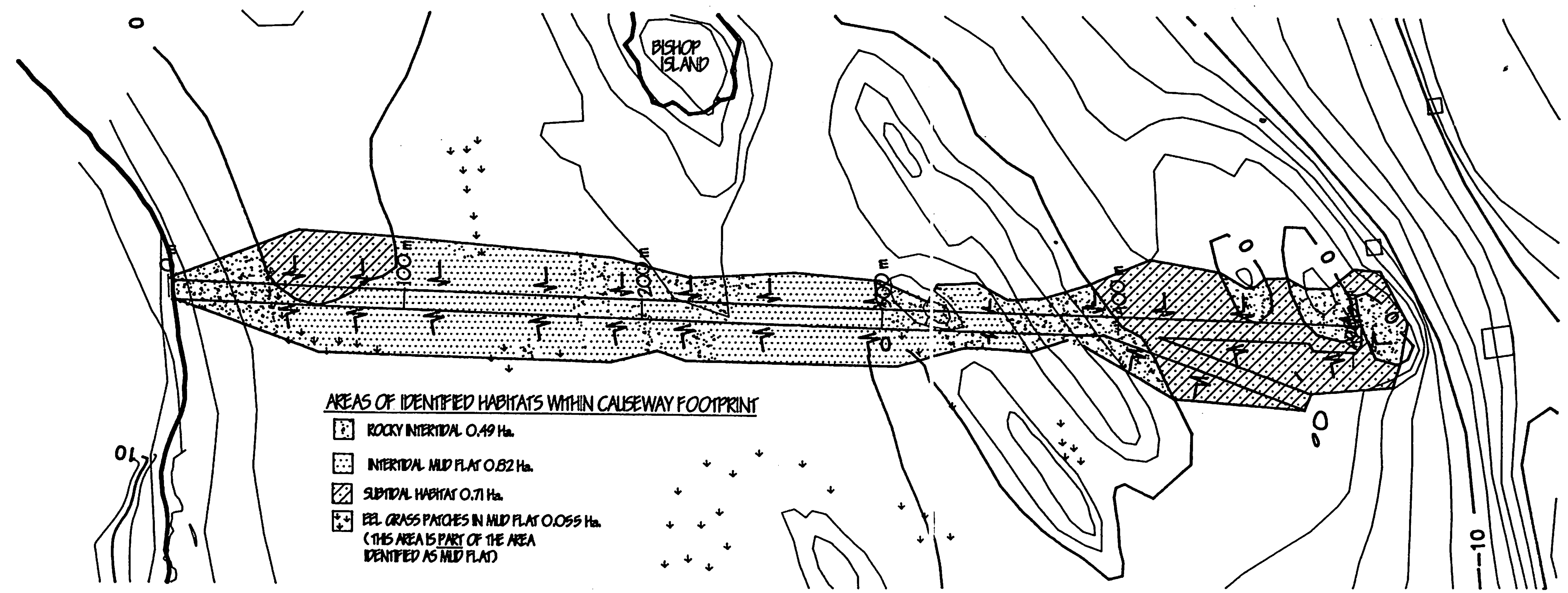
HABITAT ZONES

A : ROCKY INTERTIDAL
INCLUDES :
A1 : BARNACLE / LIMPET ZONE
A2 : FUCUS ZONE
A3 : ULVA/ BARNACLE ZONE
A4 : ALARIA/ HALOSACCION ZONE
A5 : KELP ZONE *

B : MUD FLAT

C : SUBTIDAL

* KELP ZONE EXTENDS TO SUBTIDAL AS WELL AS LOWER ROCKY INTERTIDAL



CONCEPTUAL CAUSEWAY PLAN SHOWING AREAS OF THE CAUSEWAY OCCUPIED BY EACH OF THE MAJOR HABITAT ZONES

TOTAL CAUSEWAY FILL AREA = 2.02 Ha.

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PRINCE RUPERT PORT CORPORATION
110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K3
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

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Figure 3.3-16

CAUSEWAY PLAN/PROFILE
STA. 0+00 TO STA. 4+98.5

Designed		Project No.	LPO-1	Drawing No.
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is divided into a number of zones or horizontal regions according to the degree that each is covered and uncovered during the tidal cycle. Since the environment is different in each of these zones, each is dominated by distinct organisms. Various names may be used to describe each of these zones but perhaps the simplest and most easily recognizable method for naming the zones, is to label them according to the most conspicuous organism(s) in each horizontal zone. This format will be adopted here in the descriptions of the rocky intertidal zones in the proposed causeway fill area.

The degree of exposure of the specific shore to sunlight, wind and wave action also affects the dominant species found. In the region of the South Kaien Island proposed causeway fill area, the outer or seaward facing slopes of the rocky foreshore areas are more exposed to wave action than some of the inward or shore facing rocky shores and therefore have somewhat different species.

The zones of the Rocky Intertidal Habitat of the Proposed Development Area are as follows (Figure 3.3-17):

- Kelp Zone: The lower intertidal zone extending to the sub-tidal (<1.5 m above datum);
- Ulva/Barnacle/Polysiphonia Zone: The lower to mid intertidal area (1.5 m to 3 m above datum) in more sheltered areas;
- Alaria/Halosaccion Zone: The lower to mid intertidal area (1.5 m to 3 m above datum) on more exposed rocks;
- Fucus Zone: The mid to upper intertidal area (2.5 m to 5.5 m above datum);
- Limpet/Barnacle Zone: The upper intertidal zone (5.5 m to 6.5 m above datum); and
- Algae/Lichen Zone: The extreme upper intertidal or fringe zone (6.5 m to 7 m above datum).

* All levels above datum are approximate and will vary slightly from one area to another throughout the fill area.

a) Kelp Zone

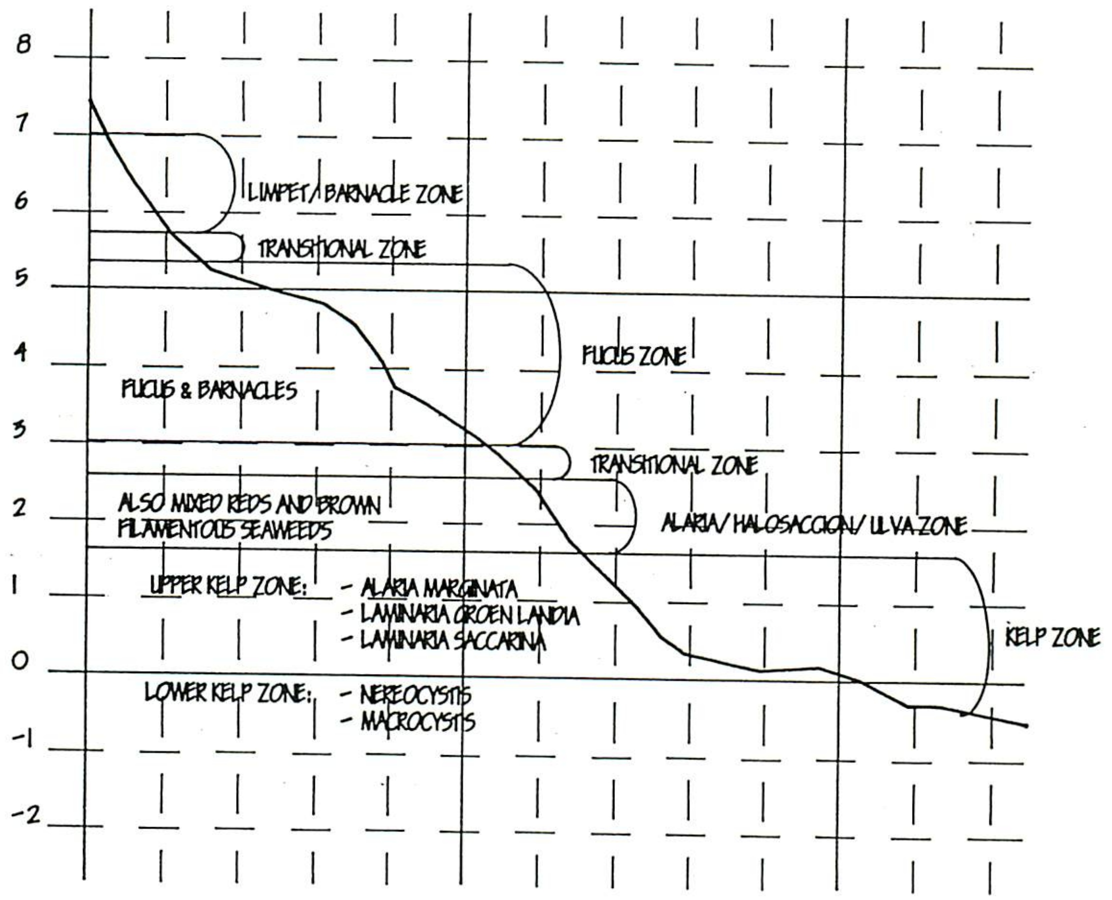
In areas of rocky intertidal habitat where the rocks extend down to the 0 tide line and below, growth of large brown seaweeds (Phyopaeta) generally referred to as kelp, predominates in the 0 m to the 1.5 m range. The most extensive kelp formations are to be found on the outer or seaward sides of the "reef" formations, but kelp is also present in other areas. The kelp zone forms a productive marine habitat providing food and shelter for numerous marine invertebrates and fish. Figure 3.3-18 outlines the areas of kelp growth and lists the main species of kelp found. Mixed red seaweeds are also found in the "kelp" zone and the main species found in this area are also listed in Figure 3.3-18. The area occupied by the kelp band is approximately 0.12 ha, compared to the total of 0.49 ha for the whole rocky intertidal area.

An initial quantitative analysis of kelp growth in this zone was carried out for the purposes of future comparison. This involved the counting of viable kelp stipes per metre square and the measurement of the length and width of the individual blades of each of the kelp stipe. This was repeated in 20 randomly chosen locations within the outlined "kelp zone" (Table 3.3-13).

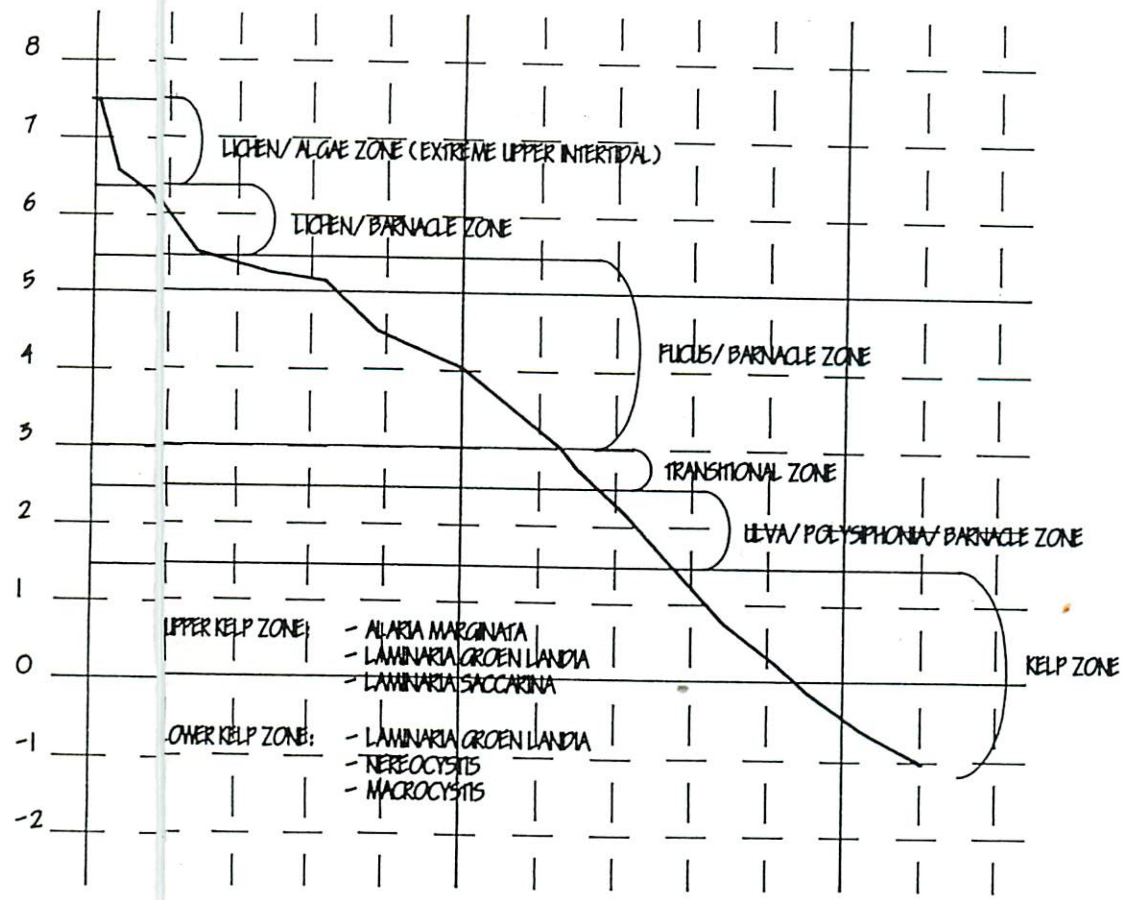
In Appendix A, Section 1a, Photographs i through x, illustrate the kelp zone of the rocky intertidal zone. The approximate locations where these photographs were taken are indicated on Figure 3.3-18.

b) Ulva/Barnacle/Polysiphonia

In areas of the rocky intertidal zone which are slightly sheltered from wave action, the rocky surfaces tend to be covered by Ulva (sea lettuce) and Barnacles as well as the



A) MORE EXPOSED ROCK FACES



B) MORE SHELTERED ROCK FACES

SCHEMATIC REPRESENTATION OF HORIZONTAL HABITAT ZONES OF THE ROCKY INTERTIDAL REGIONS AT THE PROPOSED CAUSEWAY

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PRINCE RUPERT PORT CORPORATION

110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :

PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :

Figure 3.3-17

ROCKY INTERTIDAL REGIONS
HORIZONTAL HABITAT ZONES

Designed		Project No.	LPO-1	Drawing No.
Drawn	PS	Scale	N.T.S.	
Checked	JS	Date	93/10/21	of

Table 3.3-13

QUANTITATIVE MEASUREMENTS OF KELP IN THE KELP ZONE OR ROCKY INTERTIDAL AREA

GRID NO	MEASUREMENTS OF BLADE SIZE IN CM				
	# STRIPES per m^2	LENGTH	VARIATION (+/-)	WIDTH	VARIATION (+/-)
1	8	83	20	42	12
2	12	75	25	53	14
3	9	90	19	49	15
4	7	85	27	50	11
5	10	75	15	49	8
6	10	85	19	44	9
7	8	79	29	49	16
8	11	81	19	53	14
9	13	88	20	48	12
10	10	86	21	45	13
11	8	70	16	33	11
12	9	77	21	46	10
13	11	83	18	45	7
14	14	89	17	47	9
15	12	75	15	45	13
16	9	81	20	47	14
17	10	73	24	38	14
18	8	86	23	52	15
19	7	84	22	48	12
20	9	76	21	44	9
MEAN	10	81	21	46	12
SD	1.9	5.6		4.7	
SE	0.9	2.8		2.4	

Note: Dominant species - Laminaria groenlandica was measured
Measurements made in ledge of seaward facing sloper or outer

filamentous algae such as Polsiphonia. Ulva or sea lettuce is a bright green thallus formed in almost transparent flat sheets. It is a common food for many invertebrate grazers. Figure 3.3-19 outlines the areas where the Ulva/Barnacle/Polysiphonea zone predominates.

This zone covers approximately 0.07 ha out of the total 0.49 ha for the rocky intertidal zone.

In Appendix A, Section 1b, Photographs i through vii illustrate the Ulva/Barnacle/Polysiphonia zone of the rocky intertidal zone. The approximate locations where these photographs were taken are indicated on Figure 3.3-19.

c) Alaria/Halosaccion Zone

This zone tends to occupy approximately the same horizontal level as the Ulva/Barnacle/Polysiphonia level and there is some overlap between the two "zones". The Alaria, Halosaccion band also contains a number of smaller red and brown seaweeds as well as barnacles. It tends to occur on the seaward or more exposed rock slopes and covers approximately 0.02 ha of the rocky intertidal zone in the proposed causeway fill area (Figure 3.3-19).

In Appendix A, Section 1c, Photographs i through iv, illustrate the Alaria/Halosaccion zone of the rocky intertidal zone. The approximate locations where these photographs were taken are indicated on Figure 3.3-19.

d) Fucus Zone

This is by far the most extensive of the rocky intertidal zones occupying about 0.27 Ha of the total 0.49 ha of rocky intertidal zone in the proposed causeway fill area. When the tide is out, the Fucus often forms a thick coverage across the entire surface area in this

KELP ZONE: DOMINANT SPECIES LIST

PHAEOPHYTA

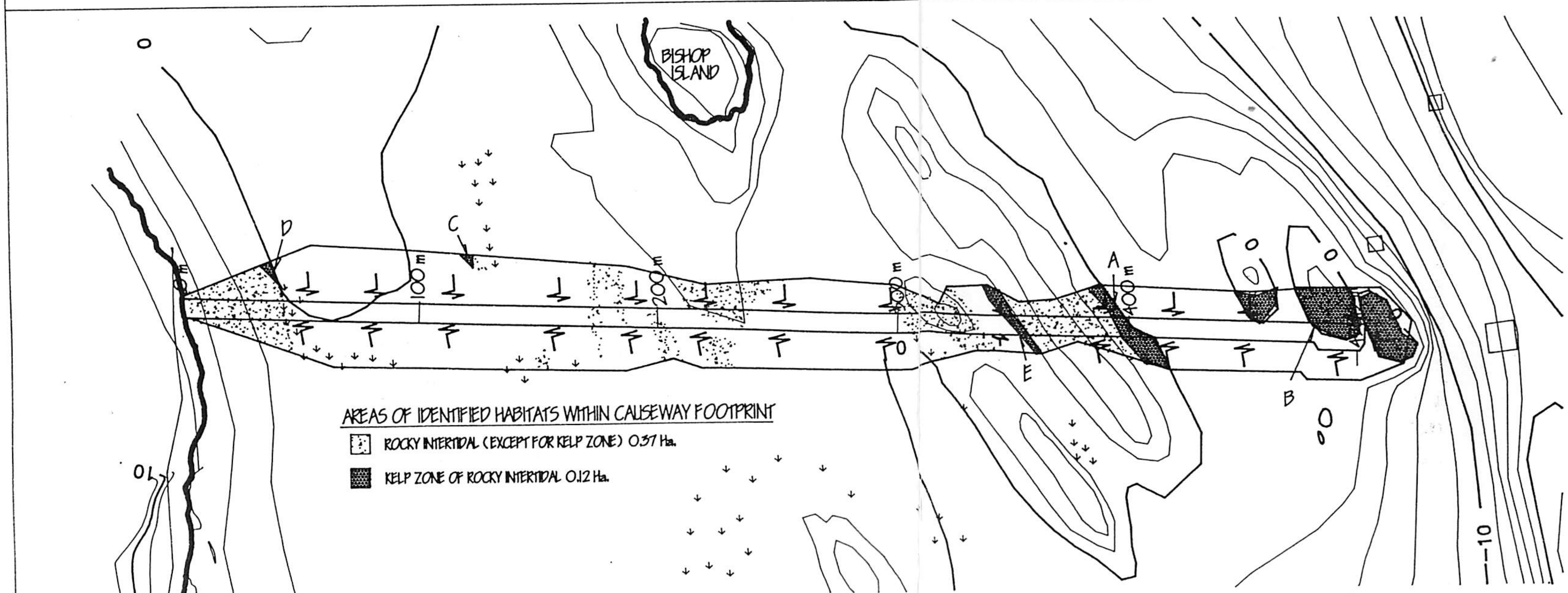
- LAMINARIA GROEN LANDIA
- LAMINARIA SACCHARINA
- MACROCYSTIS INTEGRIFOLIA
- CYMANTHERE TRIPLICATA
- ALARIA MARGINATA

RHODOPHYTA

- LESSINIOPSIS LITORALIS
- PLOCAMIUM COCCINEUM
- PALMARIA PALMATA
- GIGARTINA
- IRIDEA CORDATA

PHOTOGRAPHIC SURVEY

AREAS	PHOTOGRAPHS – APPENDIX A SECTION IA
A	I, II, III, IV
B	V, VI
C	VII, VIII
D	IX
E	X



KELP ZONE OF THE ROCKY INTERTIDAL

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PRINCE RUPERT PORT CORPORATION
110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
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LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :
Figure 3.3-18
KELP ZONE OF THE ROCKY INTERTIDAL
AREA OF CAUSEWAY FOOTPRINT

Designed		Project No. LPC-1		Drawing No.
Drawn	PS	Scale	1:2000	
Checked	JS	Date	93/10/20	of

PHOTOGRAPHIC SURVEY: APPENDIX A
SECTION IB – ULVA/ BARNACLE / POLYSIPHONIA ZONE

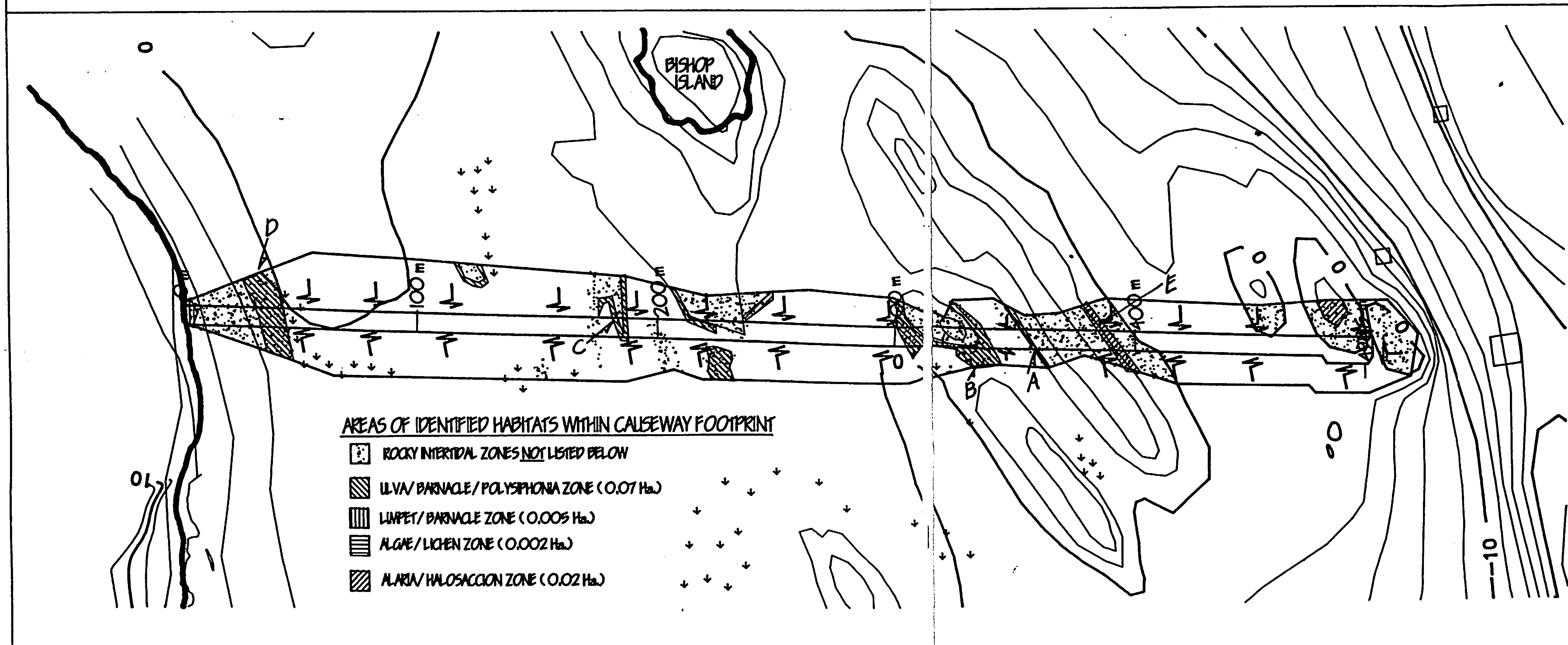
AREA	PHOTOGRAPH
A	I,II
B	III
C	IV,V
D	VI,VII

SECTION IC – ALARIA/ HALOSACCION ZONE

AREA	PHOTOGRAPH
E	I,II,III,IV

ROCKY INTERTIDAL ZONES

- ULVA/ BARNACLE/ POLYSIPHONIA ZONE
- LIMPET BARNACLE ZONE
- ALGAE / LICHEN ZONE
- ALARIA/ HALOSACCION ZONE



NO.	DESCRIPTION	DATE	BY

REVISIONS

PRINCE RUPERT PORT CORPORATION
110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :
Figure 3.3-19
CAUSEWAY PLAN/PROFILE
ROCKY INTERTIDAL ZONES

Designed		Project No.	LPG-1	Drawing No.
Drawn	PS	Scale	1:2000	
Checked	JS	Date	93/10/24	of

zone (Appendix A, Section 1d). In addition, when the Fucus is lifted aside, there is usually extensive coverage of the rock surface underneath the Fucus by barnacles and other small invertebrates. Fucus grows well on any relatively stable substrate, natural or man made, in the 2.5 (or 3) m above datum to approximately 5.5 m above datum zone. The result is the formation of an extensive dynamic habitat supporting many marine organisms. Tide pools are often formed within the Fucus zones by depressions in the rock formations. These pools support typical tide pool life such as sculpins, gunnels, limpets, periwinkle, etc. Figure 3.3-20 shows areas of Fucus coverage within the proposed fill zone.

In Appendix A, Section 1d, Photographs i through xii, illustrate the Fucus zone of the rocky intertidal zone. The approximate locations where these photographs were taken are indicated on Figure 3.3-20.

e) Limpet/Barnacle Zone

This is the upper region of the intertidal foreshore. It is occupied only by the hardiest of the marine intertidal organisms and surface coverage of the rocks by these organisms is low. Similarly, the surface area of rock at this 5.5 m to 6.5 m level within the proposed fill area is small, only about 0.005 ha (Figure 3.3-19 and Appendix A, Section 1D, Photograph i).

f) Algae/Lichen Zone

This region of the rocky intertidal zone occupies the area of the extreme upper limits of the tides and it is above all but the highest tides. Organisms found in this zone are not truly marine but are capable of withstanding the effects of being submerged from time to time. There is only a very small surface area in the proposed fill zone (0.002 ha) that falls in this category (Figure 3.3-20).

The Intertidal Mud/Sand Flats

The intertidal mud/sand flat is a dominant part of the ecology of the general area for the proposed fill. However the surface area of mud flat that will be directly required for the proposed causeway fill is relatively small being approximately 0.82 ha (see Figure 3.3-15) since the alignment of the causeway has been chosen to make best use of existing stable rock formations in the area. Within the identified areas of mud/sand flat patchy eelgrass growth occurs as shown in Figure 3.3-16.

The total eelgrass coverage in the immediate area of the causeway fill has been calculated to be 0.055 ha.

Quantitative measurements of the eelgrass patches were made and the sites of these measurements are shown in Figure 3.3-16. For these counts, a metre square was used, and the number of shoots per metre square was counted for 20 squares in each of the three separate areas (labelled "A", "B", and "C"). Average shoot length was also tabulated. Results of these measurements are shown in Table 3.3-14.

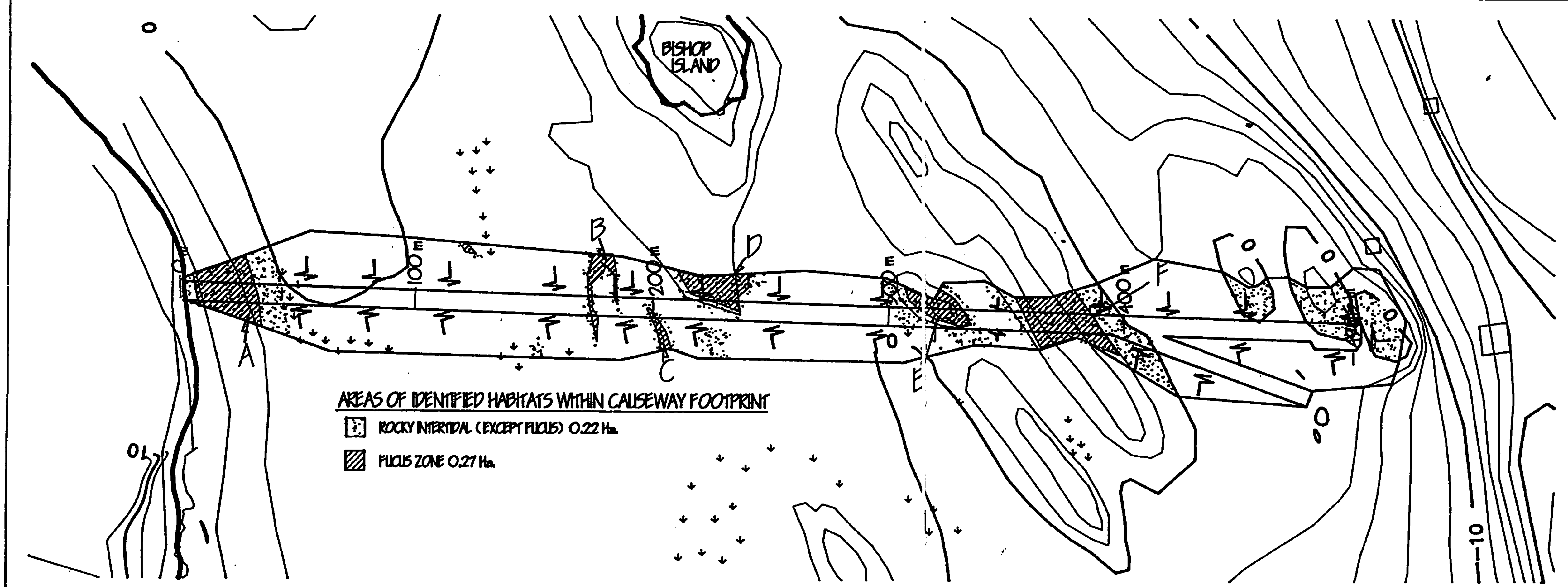
In Appendix A, Section 2a, Photographs i through vii, illustrate the eelgrass patches in the intertidal mud flat.

The eelgrass patches appear healthy and relatively free from epiphytes. The patchy nature of the eelgrass growth in this area may be explained in part by the varying elevation of the mud flat with the eelgrass more abundant in the lower intertidal regions. The patchy nature of the eelgrass growth may also be partly due to competition for space with burrowing marine invertebrates. The extensive burrowing of organisms such as the ghost shrimp, Callianassa, would likely disrupt the delicate rhizomes of young eelgrass plants (Harrison, 1985; Suchameti, 1983).

PHOTOGRAPHIC SURVEY: APPENDIX A
SECTION ID – FUCUS ZONE

AREA	PHOTOGRAPHS
A	I,II
B	III,IV
C	V,VI,VII
D	VIII
E	IX
F	X,XI,XII

FUCUS ZONE OF THE ROCKY INTERTIDAL



FUCUS ZONE OF THE ROCKY INTERTIDAL

NO.	DESCRIPTION	DATE	BY
	REVISIONS		

PRINCE RUPERT PORT CORPORATION
110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :
Figure 3.3-20
CAUSEWAY PLAN/PROFILE
FUCUS ZONE OF ROCKY INTERTIDAL

Designed		Project No.	LPO-1	Drawing No.
Drawn	PS	Scale	1:2000	
Checked	JS	Date	93/10/24	of

Table 3.3-14

EELGRASS COUNTS FROM EELGRASS PATCHES IN OR NEAR PROPOSED CAUSEWAY FOOTPRINT
(Areas Identified in Figure 6.3-2)

GRID NO	AREA "A" PATCHES TOTAL COVERAGE (.015 ha)		AREA "B" PATCHES TOTAL COVERAGE (.017 ha)		AREA "C" PATCHES TOTAL COVERAGE (0.13 ha)	
	# SHOOTS/m^2	SHOOT LENGTH	# SHOOTS/m^2	SHOOT LENGTH	# SHOOTS/m^2	SHOOT LENGTH
1	16	60	44	65	40	110
2	28	65	52	70	76	98
3	96	70	108	110	32	101
4	52	55	104	85	92	85
5	84	45	136	95	30	91
6	60	60	132	115	42	77
7	36	75	96	100	61	88
8	60	80	104	95	62	90
9	99	95	100	88	40	81
10	86	80	120	90	54	77
11	102	90	96	75	84	64
12	92	75	88	110	72	91
13	80	85	76	95	41	58
14	54	65	160	85	33	65
15	152	72	64	70	85	45
16	59	81	68	75	56	60
17	92	61	52	74	65	71
18	62	55	48	80	74	40
19	74	73	88	91	96	60
20	88	89	48	70	35	70
MEAN	74	72	89	87	59	76
SD	29.7	12.9	32.0	14.3	20.8	18.1
SE	14.9	6.5	16.0	7.2	10.4	9.1

As indicated above, in most areas of mud flat without eelgrass, burrowing invertebrates dominate. The larger of these include Nereis (clam worm), Callianassa (ghost shrimp), Macoma, Cockles (Clinocardium nutalli), and littleneck clams (Protothaca staminea). The mud flat provides food and habitat for marine invertebrates such as starfish and crabs as well as fish such as the sand sole, and sculpins. In addition, migratory Canada geese were observed feeding on the mud flat in late August.

Productivity varied from area to area within the mud flats and quantitative counts of population densities were made in 20 locations using a metre square and digging to a depth of approximately 1.5 feet. Dominant species were counted as the number of organisms per metre square. The results of these digs are shown in Table 3.3-15.

The mud supports a fairly large population of microscopic invertebrate life as well as diatoms and other small algae. A small area identified as sand/mud flats is at a higher elevation than the main mud flat and is largely a sand/gravel area with small gamarids being the main life in the area.

Sub-Tidal Habitat Zone

The area of the proposed causeway fill includes three different sub-tidal portions totalling approximately 0.71 ha. Two of these are small sub-tidal areas adjacent to mud flats which are very shallow and represent sub-tidal extensions of the mud flat (Figure 3.3-16). The ecology of these areas is very similar to that of the mud flat described above except for the fact that the mud flat here "dries" only during sub-zero metre tides. The eelgrass shown at points "B" and "C" extends slightly below the zero tide mark or into the "Sub-tidal Habitat", but this eelgrass was included in the 0.055 Ha of eelgrass already discussed. Random bottom samples in these two areas revealed a muddy base similar to the intertidal mud flat but did not produce any macroscopic invertebrates.

Table 3.3-15

QUANTITATIVE MEASUREMENTS OF MARINE INVERTEBRATES IN THE MUD/SAND FLAT ZONE

GRID NUMBER	MARINE INVERTEBRATE				
	COCKLES	MACOMA	NEREIS	OTHER "WORMS"	GHOST SHRIMP
1	2	0	2	0	1
2	0	2	6	3	0
3	0	4	3	4	0
4	4	1	4	3	0
5	4	0	1	2	0
6	3	2	3	1	2
7	1	1	5	3	0
8	0	1	8	1	1
9	0	0	6	4	2
10	3	4	0	6	0
11	3	1	3	2	3
12	2	2	3	2	0
13	0	1	2	1	1
14	0	0	0	1	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	2	1	1	3	2
19	1	3	7	1	1
20	1	0	5	2	1
MEAN	1.3	1.15	2.95	1.95	0.7

In the third and largest sub-tidal area (0.58 ha) on the seaward side of the rock reefs (Figure 3.3-14), the intertidal kelp zone extends down into the sub-tidal zone which extends out to the outer rocks marked by the red can buoy. This is a relatively shallow sub-tidal region averaging less than 2 m below datum. As shown in Figure 3.3-17, when kelp habitat extends below datum the dominant species gradually change. In this case, Macrocystis and Nereocystis dominate below the 0 tide mark and more red seaweeds (Rhodophyta) become evident. The sub-tidal kelp area is an important habitat for many marine invertebrates and fish providing an abundance of both food and shelter.

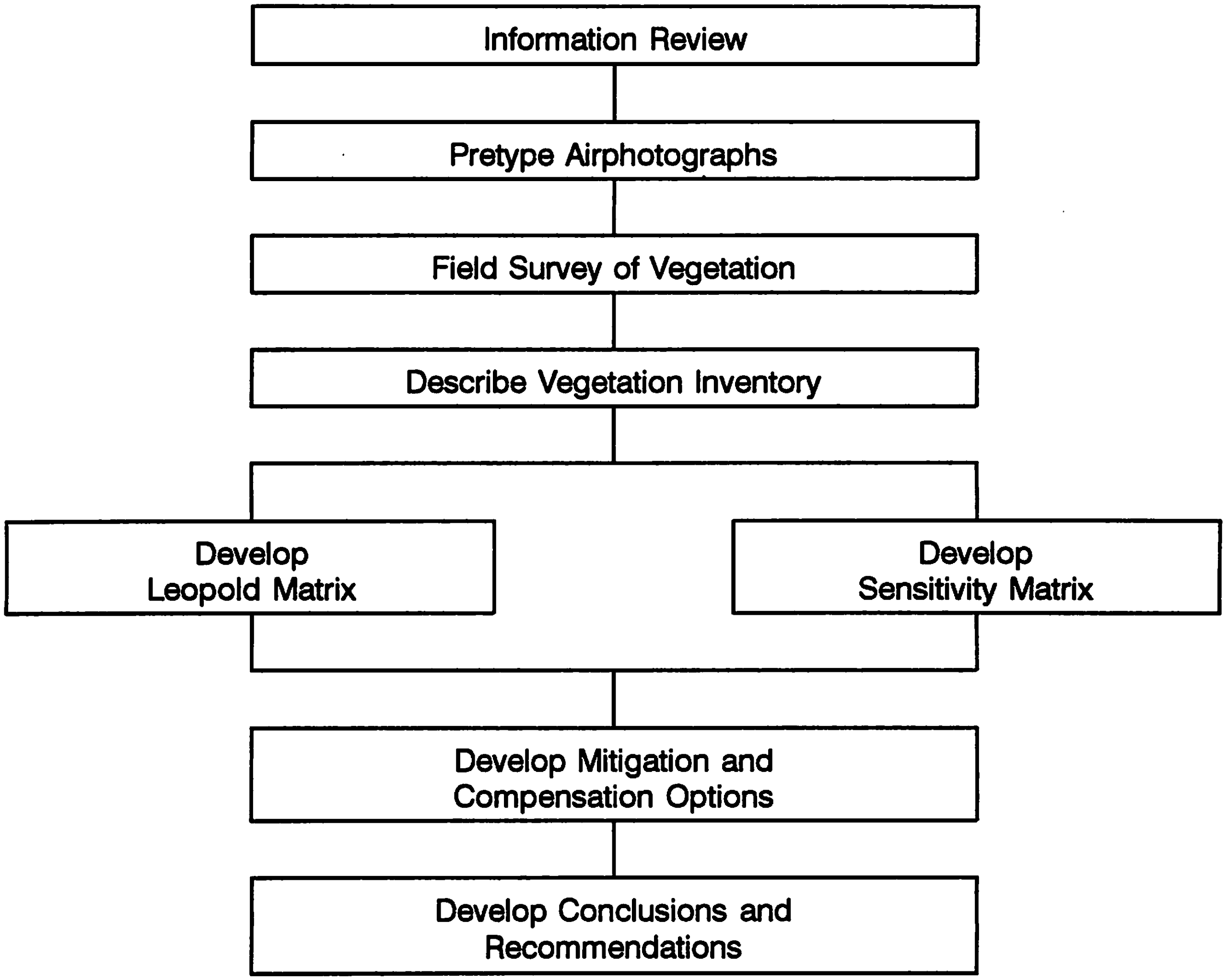
3.4 Terrestrial Resources

3.4.1 Vegetation

The native vegetation of a region is a reflection of the climate, topography and soil, while the type, density and distribution of native vegetation are important determinants of the quantity and quality of water, wildlife and visual resources. This section describes, therefore, those aspects of the vegetation which are relevant to an effective evaluation of the stability of the biophysical resources.

The vegetation flowchart (Figure 3.4-1) indicates the procedure which was followed to arrive at a development strategy which would minimize resource impacts. The vegetation of the study area was assessed during August of 1993. A 1:20,000 forest cover map (map sheet 103J 029, 1990) from the Ministry of Forests and 1:5,000 aerial photographs (#1366-0 R305 L52-01-05) taken in 1991 and obtained from MacElhenney Geosurveys Ltd. in Vancouver were used to map the vegetation of the study area. These tentative vegetation types were then groundtruthed with the placement of sample plots in each vegetation type. For descriptive purposes, the vegetation types were also classified according to the Canadian Vegetation Classification System (National Vegetation Working Group, 1990).

Figure 3.4-1
VEGETATION METHODOLOGY FLOWCHART



Regional Vegetation

The entire coast of British Columbia below 900 m in the south and 300 m in the north lies in the Coastal Western Hemlock (CWH) biogeoclimatic ecological zone, indicating that coastal western hemlock is the tree species expected to dominate undisturbed, moist mid-slope sites in this area. Mild temperatures and high rainfall make the abundant coniferous forests of this area the most productive in Canada. In the Prince Rupert area the CWH zone extends to approximately 500 m elevation, above which is the Mountain Hemlock zone (Jones and Annas, 1978). On Kaien Island the Mountain Hemlock zone is encountered only on the upper slopes of Mount Hayes.

The CWH zone is comprised of ten subzones distinguished along gradients of continentality and precipitation. The Prince Rupert region (which includes the study area) is located in the very wet hypermaritime subzone, the mildest and wettest of the CWH subzones (Meidinger and Pojar, 1991). A variety of coniferous and deciduous tree species dominate the landscape, the particular species or mixture of species on a site depending primarily on the age and history of the stand, and the site's elevation and hydrologic characteristics. The stands are typically dense and have poorly developed shrub and herb layers, although they support heavy growth of terrestrial and arboreal mosses and lichens. Salal, huckleberry and false azalea are the most frequent shrub species. On disturbed sites, red alder and various shrubs, including salmonberry, are common (TERA Environmental Resource Analysts Ltd, 1975; 1982).

Local Vegetation

Vegetation within the study area consists of native trees, shrubs, ferns, herbs, mosses and lichens typical of the wettest CHW subzones. Vegetated areas (approximately 44 ha) have been divided into four vegetation types including: young deciduous forest (9 ha), mature coniferous forest (20 ha), shrub (4 ha) and mature deciduous forest (11 ha) (Figure 3.4-2 and Table 3.4-1).

LEGEND

VEGETATION		ECOLOGICAL VALUE
YD	YOUNG DECIDUOUS	LOW-MOD
MC	MATURE CONIFEROUS	HIGH
MD	MATURE DECIDUOUS	MOD
SH	SHRUB	LOW

NO.	DESCRIPTION	DATE	BY

REVISIONS

PRINCE RUPERT PORT CORPORATION

110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :

PROPOSED
LIQUID BULK EXPORT FACILITY
SOUTH KAIEN ISLAND

DRAWING TITLE :

Figure 3.4-2

VEGETATION

Designed	Project No. LPG-1	Drawing No. 04
Drawn PS	Scale 1:5000	
Checked HH	Date 93/10/24	of 4

Table 3.4-1
AVERAGE PERCENT COVER VALUES FOR VEGETATION OBSERVED IN RELEVÉ SAMPLING ON PRINCE RUPERT LPG/MTBE SITE

		VEGETATION TYPE			
		YOUNG DECIDUOUS	MATURE CONIFER	SHRUB	MATURE DECIDUOUS
TREES					
Red alder	Alnus rubra	70	5		70
Yellow-cedar	Chamaecyparis nootkatensis	1	15		2
Sitka spruce	Picea sitchensis		2		
Lodgepole pine	Pinus contorta		5		5
Western red-cedar	Thuja plicata		20		
Western hemlock	Tsuga heterophylla		35		
SHRUBS					
Sitka alder	Alnus sinuata	10		60	
Salal	Galtheria shallon		1		
False azalea	Menziesia ferruginea		10		
Salmonberry	Rubus spectabilis	10	5	20	50
Elderberry	Sambucus racemosa	5	2	10	20
Alaskan blueberry	Vaccinium alaskaense		10		
Red huckleberry	Vaccinium parvifolium		14		
FERNS AND ALLIES					
Deer fern	Blechnum spicant		4		
Spiny wood fern	Dryopteris expansa	5	5		40
Horsetail	Equisetum sp.			40	
GRASSES AND SEDGES					
Pacific reedgrass	Calamagrostis nutkaensis	35			1
Common rush	Juncus effusus			20	
Small-leaved bulrush	Scirpus microcarpus	1			
FORBS					
Bunchberry	Cornus canadensis		1		
Cow parsnip	Heracleum lanatum	5	1		
Skunk cabbage	Lysichitum americanum	2	5		2
False lily-of-the-valley	Maianthemun dilatatum	1	20		
--	Potentilla sp.		1		
False Solomon's seal	Smilacina racemosa		1		5
MOSSES AND LICHENS					
Step moss	Hylocomnium splendens		10		
Knight's plume	Ptilium crista-castrensis		1		
--	Rhizomnium glabrescens		5		
Lanky moss	Rhytidiadelphus loreus		20		
False polytrichum	Timmia austriaca	5	1		

a) Young Deciduous Forest (Alder-Salmonberry) (YD)

Pure stands of red alder, classified as 'short, closed, deciduous tree vegetation' in the Canadian Vegetation Classification System (National Vegetation Working Group, 1990), have regenerated along the roadsides of Ridley Island access road in the study area. (Photo 3.4-1). These homogenous stands are approximately 6 years old, 5 cm in diameter and 5 m tall. There is a thick layer of the grass Calamagrostis in the understorey. The dense composition (approximately 8000 stems per hectare) of the forest makes passage through and within these stands difficult. Slightly older and less dense pure alder stands containing vigourous salmonberry are also present on both sides of the CNR line for approximately 100 m on either side of the bridge.

b) Mature Coniferous Forest (Hemlock-Red-cedar) (MC)

Three stands of mature coniferous forest exist in the study area (with the exception of the alder on the roadside). These stands are classified as 'very tall, closed, evergreen tree vegetation' (National Vegetation Working Group, 1990) (Photo 3.4-2). The largest stand occupies the 20 m tall knoll west of the access road, while the other two cover the slope and the bottomland east and west of the CNR bunkhouse. Many of the attributes recognized in 'old growth' forests are present in these stands, e.g. old trees (sample cores of two large cedar trees indicate 190 and 260 years of age), a variety of tree sizes (some trees achieving 35 m in height and 1.2 m in diameter), many strata, gaps, abundant fallen logs and snags and high species diversity. Western hemlock and western red-cedar are the dominant conifer species, although lodgepole pine, sitka spruce and yellow-cedar become frequent on water-receiving sites and in depressions. In such areas skunk cabbage and false lily-of-the-valley are also common. A variety of mosses cover the abundant fallen logs and decaying organic material on the forest floor.

Photo 3.4-1
Dense red alder stand forming Young
Deciduous Forest

Photo 3.4-2
Mature Coniferous Forest containing high species and spatial diversity

Photo 3.4-3
Dense sitka alder shrub regenerating naturally on reclaimed lowland

c) Shrub (Alder-Horsetail) (Sc)

West of the railway exists a flat 4.4 ha alder site classified as 'intermediate, open, deciduous shrub vegetation' (National Vegetation Working Group 1990) (Photo 3.4-3). The alder present here is sitka alder (*Alnus sinuata*), a shrub species which grows in clumps and seldom exceeds 10 m, as opposed to red alder (*Alnus rubra*), the tree species which is dominant on the roadside and in the clearings made around the World War II military installations. Giant horsetail is profuse beneath the alder. Both species occur frequently on reclaimed sites and can withstand prolonged flooding.

d) Mature Deciduous (Alder-Salmonberry) (MD)

Nearly pure stands of red alder, up to 30 m tall and 40 cm in diameter, have regenerated on this upland site (Photo 3.4-4). Self-thinning has reduced the density of the stands to approximately 500 stems/ha, allowing the natural establishment of occasional sitka spruce and western red-cedar under the alder canopy on the wetter micro-sites. The coniferous component of these stands would be expected to increase over the next 2 to 4 decades as the alder degenerates and the conifers gradually succeed.

Ecological Reserves

British Columbia's ecological reserves are areas set aside for preservation under the administration of the Parks Branch of the B.C. Ministry of Environment. To the end of 1990 there were 136 ecological reserves scattered throughout British Columbia, the closest of which is the Skeena River Floodplain Islands (E.R. 63) located 80 km east of Prince Rupert. No ecological reserves are planned for the Prince Rupert area (Derek Maseleck, pers. comm.) revealed that no provincial ecological reserves have been established or are proposed near Prince Rupert.

The only known site being preserved for its ecological significance is a lowland bog (property 91) owned by Nature Trust and located on the north end of Smith Island, approximately 10 km south of the study area.

Land tenure data from the B.C. Lands Registry office indicate that no other reserves or natural areas that might protect vegetation exist in the project area.

Rare or Endangered Species

Eight species of vascular and non-vascular plants have been identified by the BC Conservation Data Centre as either 'imperiled' (S2) or 'critically imperiled' (S1) (both formerly classified as 'red listed' species) within 10 km of Kaien Island. These species and an additional seven species classified as 'rare or endangered' in the Prince Rupert Forest District are being tracked for changes in distribution or frequency. Table 3.4-2 describes the observation location, endangered status, and expected habitat (Hitchcock and Cronquist, 1973; Taylor and McBride, 1977; Klinka et al, 1989) of the identified plants. None of the rare or endangered plant species identified by the Conservation Data Centre were observed during the field survey.

3.4.2 Wildlife

The term wildlife in this report refers to birds and mammals. Species of interest or "focus" species (and their habitats) include those which are economically, aesthetically or ecologically important, including rare or endangered species. These focus groups are colony-nesting seabirds, waterfowl, raptorial birds, marine mammals, furbearing mammals and ungulates. These species groups have the highest sensitivity and greatest potential for impact from development of the port facility.

Photo 3.4-4
Mature Deciduous Forest comprised of 25 m
tall red alder stand

Table 3.4-2
RARE AND ENDANGERED PLANT SPECIES FOUND IN THE PRINCE RUPERT AREA
(Source: B.C. Conservation Data Centre, 1993)

COMMON NAME	SCIENTIFIC NAME	HABITAT	LOCATION[1]	STATUS[2]
Plains small reedgrass	Calamagrostis montanensis	grassland, benchland	PR	S2
Water-starwort	Callitriche anceps	aquatic, wetland	PRFD	S3
Clustered sedge	Carex glareosa	wetland	PR	S1
Gmelin's sedge	Carex gmelinii	herbaceous	PR	S2
Gray-leaved witlow-grass	Draba cinerea	herbaceous	PRFD	S3
Kamchatka spike-rush	Eleocharis kamtschatica	herbaceous, wetland	PR	S1
Bob adder's-mouth orchid	Hammarbya paludosa	herbaceous, wetland	PR	S1
Arctic rush	Juncus arcticus spp. alaskanus	herbaceous, wetland	PR	S2
Couille's rush	Juncus covillei	herbaceous, wetland	PRFD	S3
	Juncus stygius	herbaceous, wetland	PRFD	S3
Marsh peavine	Lathyrus palustris	marsh	PRFD	S3
Arctic daisy	Leucanthemum arcticum	herbaceous	PRFD	S3
Flowering quillwort	Lilaea scilloides	herbaceous, aquatic	PRFD	S3
Northern Jacob's ladder	Polemonium boreale	herbaceous	PRFD	S3
Menzies' burnet	Sanguisorba menziesii	bog, marsh	PR	S2

[1] LOCATION CODES:
PR = observed in Prince Rupert
PRFD = observed in Prince Rupert Forest District

[2] STATUS CODES:
B.C. Conservation Data Centre ranking system uses 5 levels for subnational (S) or provincial ranking:
S1 = critically imperilled ($\leq$5 extant occurrences of few ndividuals)
S2 = generally imperiled (6-20 extant occurrences)
S3 = rare or uncommon (21-100 occurrenced)

Wildlife populations are often abundant at the interface or "ecotone" of terrestrial and marine environments, including shorelines, intertidal and estuarine habitats, shallow inshore waters and small islands. Use of these areas, although sporadic and seasonal in nature, can be critical to certain species migratory patterns. Thus, it was considered appropriate to carry out a regional review of wildlife occurrence and specifically in the project area. It should be noted that the most significant wildlife features in the area are dependent on marine rather than terrestrial ecological systems which are dealt with in Section 3.3 of this report.

In determining the approach to this section, it was anticipated that wildlife impacts could result in two ways: from habitat loss or other disturbances associated with construction or operation of the liquids terminal or from tanker groundings or spills in the offshore environment. Thus, wildlife background material considers both a relatively small area of terrestrial environment and shoreline at and near the proposed tidewater facility, and a much larger marine area. A review of available data sources yielded a paucity of information.

The marine area wildlife information is subdivided into Chatham Sound, a relatively protected, shallow marine environment for which considerable wildlife information was available, and the more extensive Hecate Strait-Dixon Entrance area for which information is presented at a more generalized level. In the following sections, existing local conditions in the vicinity of south Kaien Island are discussed, and regional conditions in Chatham Sound, Dixon Entrance and Hecate Strait are reviewed.

South Kaien Island

South Kaien Island, including the study site, contains generally pristine areas with some areas of high sensitivity. The study area is found with the Coast Forest Biotic Area (Cowan and Guiget, 1978). This area extends from the southwest corner of B.C. north above Prince Rupert. Subspecies of note within this biotic area and the Prince Rupert

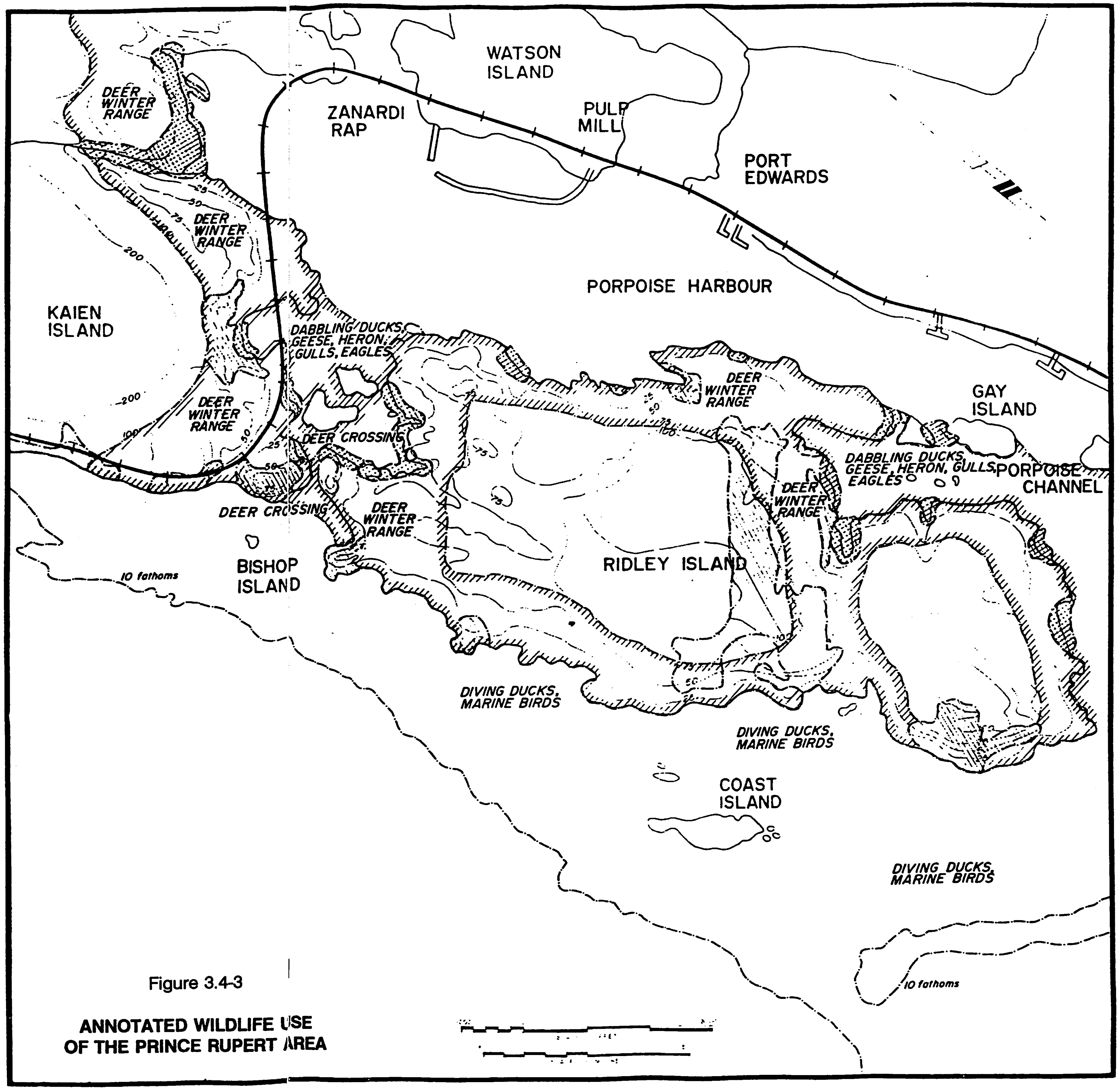


Figure 3.4-3

ANNOTATED WILDLIFE USE OF THE PRINCE RUPERT AREA

region include Columbia blacktail deer (*Odocileus hemionus* columbianus), redbacked vole (*Clethrionomys gapperi* caurinus), white-footed mouse (*Peromyscus maniculatus* austerius, cinereus shrews (*Sorex cinereus* streatori) and wandering shrews (*Sorex vagrans* longicaudus).

A study in 1982 (PRPC, 1982) shows the presence of blacktailed deer winter range on the western boundary of the study area and presumably the lowland. This is shown on Figure 3.4-3. In addition, deer crossing areas (wildlife movement corridors) are also shown within the project site on the southern boundary. Other species of interest include black bear, known to frequent estuarine areas as food/forage areas. An adult wolf was observed in June of 1993 within the study area which was very acclimatized to the presence of people and most probably a lone stray.

The upland vegetation communities, described in Section 3.4.1, were used as the basis for a description of the wildlife habitats. These were assessed as to their wildlife supportive capability and importance and are described below.

a) Young Deciduous Forest (Alder-Salmonberry)

This young, seral vegetation community is typical of coastal forest biotic areas (Cowan and Guiget, 1978) and is generally succeeding to a coniferous dominated forest. The dense nature deciduous tree species composition of this habitat make it of low value to deer as winter range for both browse and thermal cover. This area would be used on a seasonal basis both by deer and black bear. Species found within the Prince Rupert region that typically use young alder forests include longtailed voles, porcupine, western flycatcher, Swainson's thrush, ruffed grouse, downy woodpecker and long-toed salamander. It is of low importance to wildlife.

b) Mature Coniferous Forest

This habitat is the most important upland habitat within the project site. It has high horizontal and vertical stratification and vegetation species diversity. This yields a corresponding high abundance and diversity of wildlife species. This area is a typical climax coniferous forest found within the Coast Forest Biotic Region (Cowan and Guiget, 1978). This area has a high abundance of songbirds and small mammals with predators of these species, such as great horned owl and other raptors. There are reports of feral dogs in the area (Terry Chow, Ministry of Forests, pers. comm.).

There are abundant snags in this area with approximately 25% being in excess of 25 m in height and 1.2 m in diameter. Approximately 50% are between 5 to 25 m in height and 30 to 70 cm in diameter. There are large veteran snags, both alive and dead, extending above the canopy layer. Deer tracks were observed within this area, as well as black bear scat. Black bear would be attracted to the abundant *Vaccinium* berries and skunk cabbage within the area. *Vaccinium* spp. are also a preferred deer browse species. This area is of high importance to raptors as a resting, feeding and breeding area.

c) Mature Deciduous Forest

This forest is approximately 30 to 40 years of age and is of moderate value to wildlife. The older, decaying alder is an excellent source of snags for cavity nesters such as downy woodpeckers. This is also a prime breeding and feeding habitat for porcupine. A dead porcupine, apparently killed by vehicular traffic, was found within the mature deciduous forest. Other species typically using this forest include American robin, cedar waxwing, orange-crowned warblers, pine siskin, porcupine and deer mice. This area is of moderate importance to both deer and raptors.

d) Shrub

The shrub wildlife habitat is an early seral stage of red alder and coniferous forest habitats. The majority of this habitat is located adjacent to the road and railway rights-of-way and maybe the result of disturbance to the mature coniferous forest habitat. This habitat, although quite monotypic in nature, is important to species groups such as songbirds and small mammals. Deer and bear will use these areas where the shrub thickets are not extremely dense. This area is of moderate value to wildlife.

Typical species found in the Prince Rupert region using this area include blue grouse, chipping sparrow, common nighthawk, hermit thrush, blacktailed deer, white footed mouse and porcupine.

Chatham Sound

a) Waterfowl

Canada Land Inventory mapping designates most of the east shoreline of Chatham Sound as Class 3M; that is, habitat of importance for migrating and wintering waterfowl. Other parts of the Sound did not receive a migration/wintering rating, and are presumably of lesser importance for this purpose. Waterfowl production in this area is very low.

Swans are consistently seen wintering in the Chatham Sound area, but usually in low numbers. Small numbers have been observed at the mouth of the Skeena River, in Porcher Inlet and Porcher Peninsula (Savard, 1979), and at Pearl Harbour, Dinina Island and Big Bay (Canadian Wildlife Service, 1980).

The migration route of Pacific Flyway Canada geese follows Chatham Sound, which is thought to be an important wintering area for the species. Big Bay appears to be the most important area to the geese with over 500 birds being counted there at one time (Savard, 1979). Salt marshes at the heads of Scott Inlet and Pillsbury Cove are also used by feeding geese and many rest on sandbars at Metlakatla Bay at low tide (Canadian Wildlife Service, 1980). A resident population of Canada geese is known to exist at Moore Cove, the only true estuarine marsh at the mouth of the Skeena River. During the aerial survey on February 24th, 1981, 710 Canada geese were counted, of which 500 were at Big Bay and 138 at Pearl Harbour (Table 3.4-3).

White-fronted and snow geese also migrate through the area in spring. There is no evidence that they stop in significant numbers, although one flock of 150 snow geese was reported at Big Bay in April of 1975. During recent Canadian Wildlife Service surveys, either few or no brant geese have been observed in Chatham Sound. However, "a considerable proportion of the entire continental population" of brant is said to migrate through the Sound (Canadian Wildlife Service, 1980).

Four species of dabbling ducks (mallards, pintail, American wigeon and green-winged teal) have been reported to winter in the area. Dabbling ducks appear to be more abundant in shallow inlets and bays than along other shorelines (Savard, 1979). The mallard is the most common wintering duck (Canadian Wildlife Service, 1980) and the only species known to breed in the area (Hoos, 1975). Big Bay appears to be the most important habitat for dabbling ducks, followed by Kitkatla Inlet on Porcher Island. During the February survey, 241 dabblers were counted along the east shoreline of Chatham Sound, 77 of which were at Big Bay (Table 3.4-3).

Sea ducks reported to winter in the area are the greater scaup, Barrow's goldeneye, common goldeneye and bufflehead. These species generally prefer inlets and bays but are also often seen along rocky or sandy shorelines. Bufflehead are the most abundant and widespread bay ducks during the winter (Savard, 1979). Big Bay is one of the most important habitats for bay ducks, although good wintering habitat occurs throughout the Chatham Sound area.

Table 3.4-3

BIRD OBSERVATIONS MADE DURING AERIAL SURVEY OF EAST SHORELINE OF CHATHAM SOUND

February 24, 1981

SPECIES GROUP	NUMBER SEEN	COMMENTS
Loons	10	one identifed as common loon
Grebes	1	small; probably horned grebe
Cormorants	33	mostly double-crested; few pelagic
Herons	13	all great blue herons
Swans	6	probably trumpeters
Geese	710	all Canada geese
Dabbling Ducks	241	virtually all mallards; five teal
Bay Ducks	455	mostly scaup; some bufflehead; three goldeneye
Sea Ducks	679	mostly surf scoters and oldsquaw; few harlequins and black scoters
Unidentified Bay/Sea Ducks	308	mostly sea ducks; scoters and oldsquaw probably
Fish-eating Ducks	299	mostly common mergansers; some red-breasted mergansers
Gulls	660	all identified were mew and glaucous-winged gulls
Alcids	17	all were common murres
Raptors	25	all bald eagles (mostly adults); two nest located
Crows	200+	all presumed to be northwestern crows

Five species of sea ducks (surf, white-winged and black scoters, oldsquaw and harlequin duck) were recorded by Savard (1979) and Canadian Wildlife Service (1980). These ducks generally prefer exposed shorelines and open water; Kitkatla Inlet, Freeman Passage and Browning Entrance are the most important areas for wintering sea ducks. Big Bay and Kitkatla Inlet appear to be important spring staging areas, and flocks of scoters numbering up to 300,000 (mostly surf scoters) were seen there in April of 1975.

Three species of fish-eating ducks (common, red-breasted and hooded merganser) were identified in the area by both Savard (1979) and Canadian Wildlife Service (1980).

Red-breasted mergansers, the most common species, were most often found along the open seacoasts and bays; hooded mergansers in sheltered bays and inlets (often with buffleheads); and common mergansers in sheltered inlets and shallow passages with strong tidal currents.

During the February 1981 survey, diving ducks were observed to be spread out in small groups all along the Tsimpsean Peninsula coast of Chatham Sound. Groups of 100 or more included: 300 surf scoters near Frederick Point; 200 oldsquaw near Grassy Point; a couple of flocks of over 100 scaup in Dodge and Casey coves, 100 mergansers in Wainwright Basin, and a group of 150 common mergansers in Butze Rapids. Bufflehead were common in small groups along most shorelines. Other diving ducks seen included black scoters, goldeneyes and harlequin ducks.

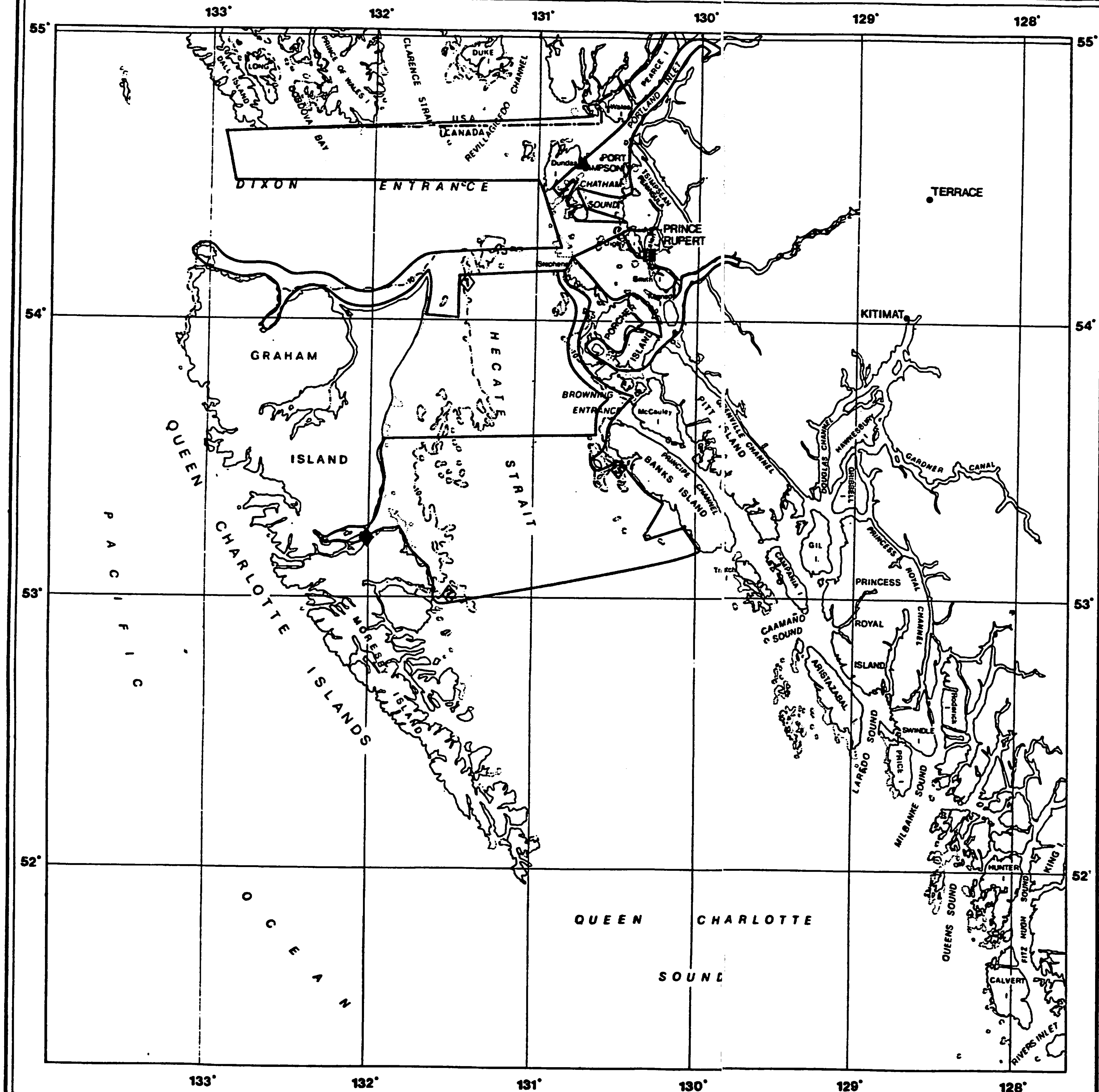
b) Colonial and Other Seabirds

A number of nesting sites of alcids, gulls or cormorants occur in and around Chatham Sound. Most are on the outer side of Dundas and Stephens islands or in the southern part of Chatham Sound. Lucy Island is probably the most significant site. These nesting islands are used by local seabird populations from late March until July or August.

Figure 3.4-4

LOCATION OF SURVEY LINES AND BIRD CONCENTRATIONS THROUGHOUT HECATE STRAIT

PETROCHEMICAL TERMINAL



Source Savard, 1979

LEGEND

■ TERMINAL SITE

SURVEY LINES

SCOTERS

WESTERN GREBES AND BRANTS

SHEARWATERS

NOTE: DEPTH IN FATHOMS.

KILOMETRES

20 0 20 40 60 80

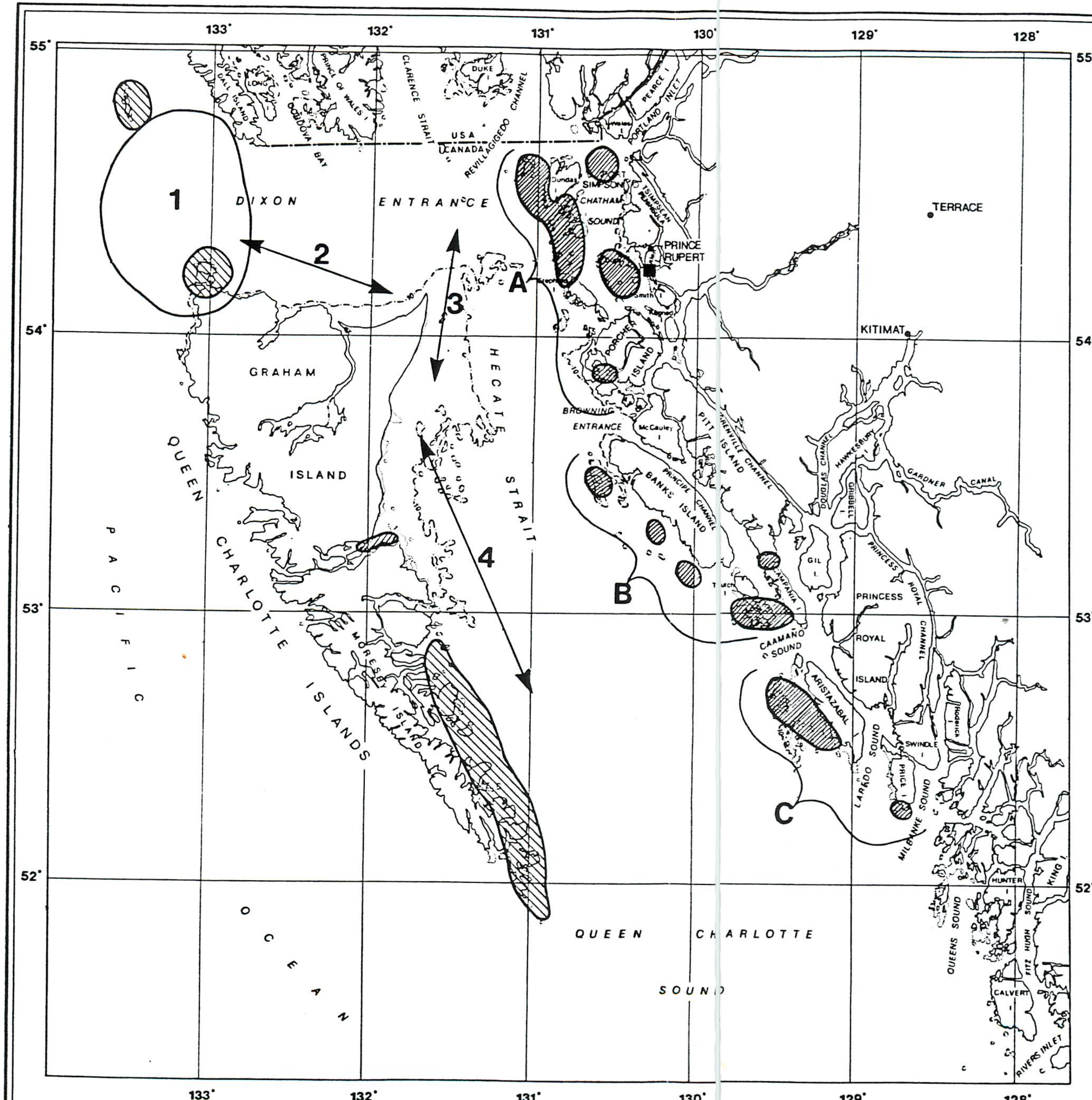


Figure 3.4-5

COLONIAL AND OTHER SEABIRD OCCURRENCE DIXON ENTRANCE/HECATE STRAIT

PETROCHEMICAL TERMINAL

LEGEND

SEABIRD NESTING COLONIES*

- LARGE NUMBERS
- MODERATE TO LOW NUMBERS

OTHER SEABIRD OCCURRENCE

1. LARGE ALCID CONCENTRATIONS
2. SUMMERING AREA — COMMON MURRE AND BLACK-LEGGED KITIWAKE
3. SUMMERING AREA — SOOTY SHEARWATER
4. ARCTIC LOON AND NORTHERN PHALAROPE MIGRATION ROUTE

* MOST PEREGRINE FALCON NESTING IS IN SAME AREAS, PARTICULARLY QUEEN CHARLOTTE AND FORRESTER ISLANDS

NOTE: DEPTH IN FATHOMS.

KILOMETRES

20 0 20 40 60 80

Other seabirds which nest in the area are the marbled murrelet and red-throated loon. The marbled murrelet is believed to nest inland in tall trees, but specific sites were not known. Red-throated loons nest on small islands in muskeg ponds on coastal islands and peninsulas, and forage on nearby saltwater areas during the nesting season.

Four species of loons have been recorded in the area. The common and red-throated loons breed locally and are present year-round. The yellow-billed loon has been recorded in the area and may winter along parts of the British Columbia coast. Arctic loons are abundant migrants through the area and moderate numbers winter here.

Savard (1979) and Canadian Wildlife Service (1980) recorded three species of grebes (western, red-necked and horned) in Chatham Sound during the winter of 1977-78. Concentrations were noted near Freeman Passage, Duncan and Big bays, and Tuck, Porcher and Kitkatla inlets.

Shearwaters are common in Chatham Sound, and large concentrations have been observed near Green Island (Hart, 1978) and Dundas Island (Savard, 1979).

The glaucous-winged gull is the most abundant wintering gull in the area. This species along with mew, herring and Bonaparte's gulls are common migrants and winter visitors to the area. They are usually found along shores and bays of the inland waters and coast, and are especially common in the Metlakatla Bay, Tugwell Island and Prince Rupert Harbour areas (Canadian Wildlife Service, 1980).

Black-legged kittiwakes are another common winter visitor but prefer the more open waters of Hecate Strait. Their favourite habitats in Chatham Sound appear to be around Edith Harbour (south end of Dundas Island), Hudson Bay Passage and Goose Bay (north end of Dundas Island) (Canadian Wildlife Service, 1980). In addition, Hoos (1975) lists the glaucous gull, Sabine's gull and Arctic tern as having been recorded in the area. During aerial and ground surveys in February 1980, gulls were frequently observed along the entire Tsimpsean Peninsula coast, especially on mudflats and beaches. The Big Bay/Pearl Harbour area was the most popular area, with about 300 gulls observed feeding along the mudflats there. All those identified were either mew or glaucous-winged gulls.

Double-crested, Brandt's and pelagic cormorants all occur in the area, the pelagic being the most abundant in winter (Canadian Wildlife Service, 1980). During the February 1981 surveys, both double-crested and pelagic cormorants were observed in the Zanardi Rapids area.

Savard (1979) observed about 35 to 45 alcids, mostly murres, per 100 km of shoreline in Chatham Sound in winter. Most of the alcids which nest in this area in summer migrate south for the winter. The only alcids observed during the February 1981 survey were common murres.

c) Raptorial Birds

In Chatham Sound the important marine-oriented raptorial birds are the bald eagles and peregrine falcon.

Bald eagles are common in the area year-round, but neither nesting or wintering inventories have been carried out. Good (1978) rated bald eagles as abundant in the Prince Rupert area in summer. During surveys in February 1981, 25 bald eagles and 2 nest sites were observed. The nest sites were at Butze Rapids and on the mainland near the south end of Swamp Island.

Three active eyries of the peregrine falcon have been reported to occur on offshore islands in Chatham Sound (NEAT, 1975) although no locations are given. Likely nesting sites may occur on the west coast of the Dundas Islands group and a single peregrine falcon has been reported near Simpson Rock on Melville Island of that group (Campbell, 1976).

d) Other Birds

As many as 28 species of shorebirds are recorded as migrants or winter visitors in the area (Hoos, 1975; Canadian Wildlife Service, 1980). These birds are usually found along beaches, exposed sand and mudflats or on rocky islets where they forage for food. Two species are known to nest in the area. The spotted sandpiper commonly breeds on the estuary (Hoos, 1975) and the black oyster-catcher has been found nesting on small rocky islets in the Sound (Campbell, 1976; Cannings, 1979).

Great blue herons reside year-round in Chatham Sound, and prefer sheltered mudflats and open beaches. Rookeries have not been reported, although some may exist in the area (Savard, 1979). Sandhill cranes may also breed locally (Hoose, 1976; Canadian Wildlife Service, 1980). During February 1981, herons were noted at scattered locations along the Tsimpsean Peninsula, and a large concentration was seen at Zanardi Rapids.

Other residents of the area include kingfishers, crows and ravens.

e) Marine Mammals

Harbour seals are widespread throughout Chatham Sound and are locally abundant, particularly in the main channels of the Skeena River estuary. The bars of Smith and DeHorsey Islands are favoured haul-out ground and 200 to 300 seals have been observed hauled out include Gnarled Islands, Hodgson Reefs, Jap Point and Galloway Rapids (Canadian Wildlife Service, 1980).

The steller sea lion has been observed infrequently in the vicinity of Prince Rupert Harbour and the Skeena Estuary, although a few have been observed on Dundas Island, in Kitkatla Inlet and off Freeman Passage.

Killer whales are reported to be erratic visitors to Chatham Sound during the winter months. No definite data regarding dates and numbers are available, but reliable reports indicate their presence.

The harbour porpoise appears to be a resident of, or regular visitor to, the Chatham Sound area. Harbour porpoises have been regularly observed off Ridley Island (NEAT, 1975) and have also been recorded in Chismore Passage (Canadian Wildlife Service, 1980). They are relatively inconspicuous and may be more abundant than the records indicate. The harbour porpoise is more estuarine in preference than the dall porpoise, which is frequently seen close to Chatham Sound and may enter it periodically.

f) <u>Rare and Endangered Species</u>

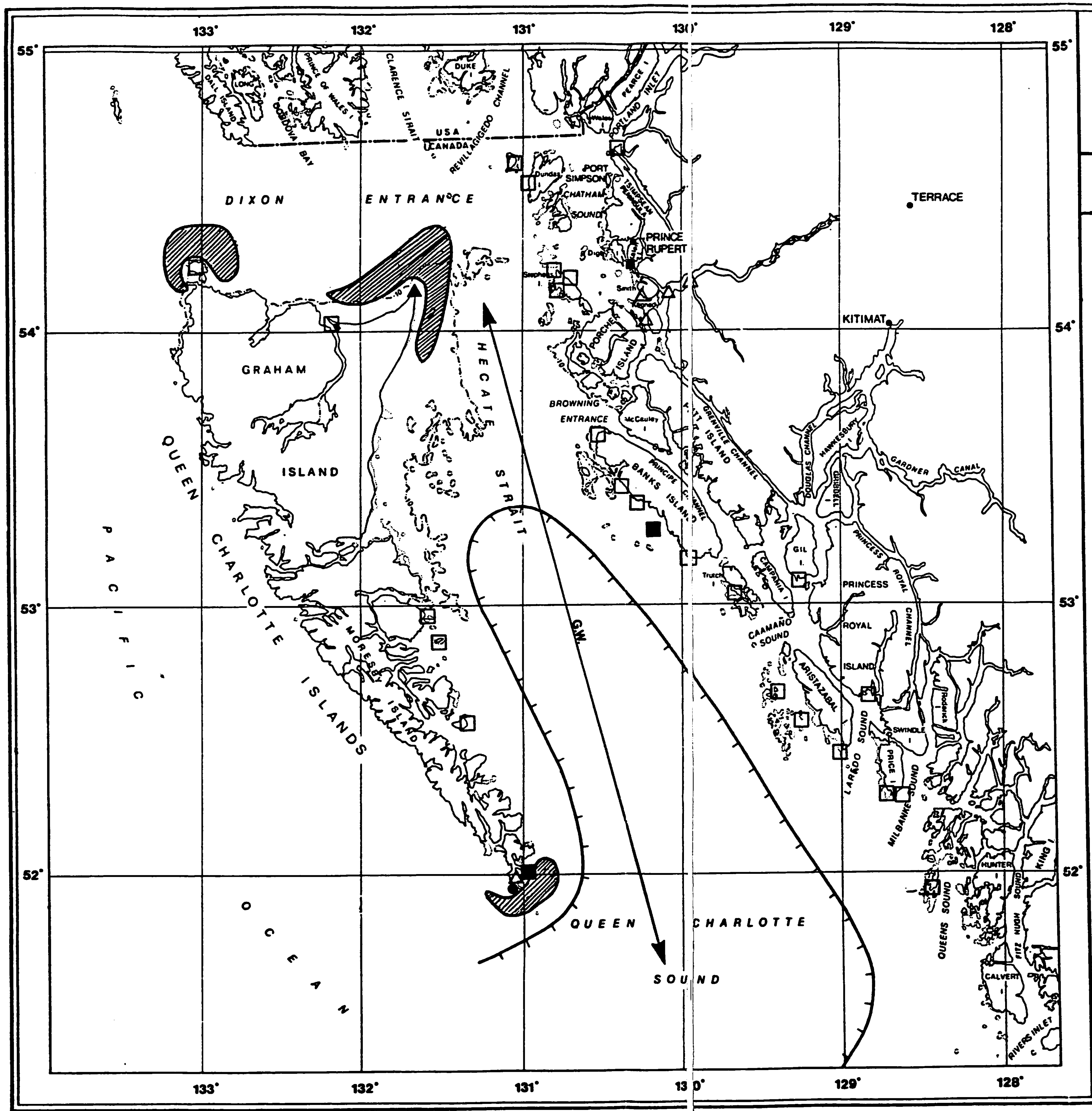
The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) presently includes five species of birds that are likely to occur in the Chatham Sound area in its list of rare, threatened or endangered species. No mammals on the list occur in this area. A "rare" species is one that for any reason exists in low numbers or in very restricted areas in Canada, but is not a threatened species; a "threatened" species is one that is likely to become endangered in Canada if the factors affecting its vulnerability are not reversed.

The trumpeter swan is listed as "rare", though its numbers have been steadily increasing due to its protected status. Trumpeter swans are regular but uncommon migrants in Chatham Sound (Savard, 1979; Canadian Wildlife Service, 1980). Occasionally, some birds winter in the area, but most move further south along the coast and to Vancouver

Figure 3.4-6

MARINE MAMMAL OCCURRENCE
DIXON ENTRANCE/HECATE STRAIT

PETROCHEMICAL TERMINAL



LEGEND

■ TERMINAL SITE

WHALES

LARGE WHALE DISTRIBUTION

GREY WHALE SIGHTINGS

GREY WHALE MIGRATION ROUTE

SEA LIONS

BREEDING COLONY

HAUL - OUT SITE

HARBOUR SEALS

HAUL - OUT SITE

SEA OTTER

SIGHTING

NOTE: DEPTH IN FATHOMS.

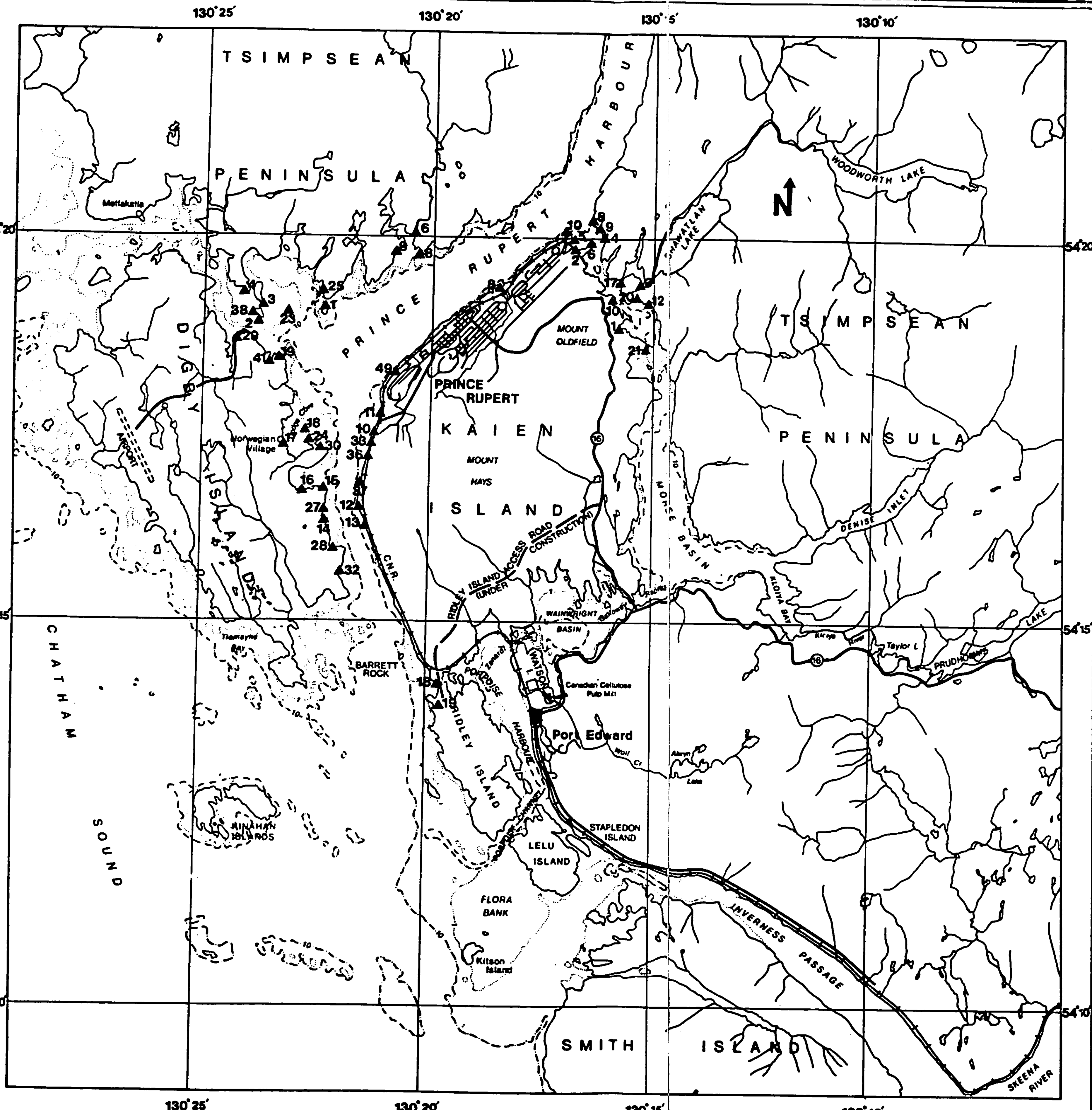
KILOMETRES

20 0 20 40 60 80

Figure 3.5-1

RECORDED HERITAGE SITES IN THE KAIEN ISLAND AREA

PETROCHEMICAL TERMINAL



LEGEND

■ TERMINAL SITE

▲ HERITAGE SITE

NOTE: DEPTH IN FATHOMS.

KILOMETRES

2 1 0 2 4

Island. Three pairs were seen on Georgetown Lake during the aerial survey in February, 1981 (Table 3.4-3).

The Peale's peregrine falcon is also listed as "rare" by COSEWIC. This bird is an uncommon resident, occasionally sighted along the shoreline. It is possible that a few birds may breed along the west coast of Dundas Island (Ascot, pers. comm.).

The tundra peregrine falcon is listed as "threatened" by COSEWIC. It nests in the Arctic and winters south of Canada and small numbers may pass through Chatham Sound during migration.

Greater sandhill cranes are included on the COSEWIC list as "not in any category". These cranes breed in the area, and have been observed at Serpentine Inlet and Chief Point (on Porcher Island) in spring and at Larsen Harbour throughout the summer (Canadian Wildlife Service, 1980).

Double-crested cormorants are also classified as "not in any category". They are widespread and locally abundant in Chatham Sound in the winter but do not breed in the area. The Canadian Wildlife Service (1980) reported a large concentration of double-crested cormorants in Wainwright Basin in February of 1978, and several were observed at Zanardi Rapids during the February 1981 survey.

Dixon Entrance and Hecate Strait

a) Waterfowl

The most complete data on waterfowl in Dixon Entrance and Hecate Strait are presented by Savard (1979) who surveyed the area and reviewed the earlier work of McKelvey (1977) and Robertson (1974). Savard found that the deep offshore waters of Dixon Entrance and Hecate Strait supported very few ducks during fall and winter, although shallow offshore waters had some concentrations. Open waters of Hecate Strait had much higher bird densities than those of Dixon Entrance and three large wintering concentrations of scoters were located in Hecate Strait (Figure 3.4-3). Scoters and harlequin ducks were abundant in all surveys, while goldeneyes, buffleheads and oldsquaws were not seen before November. Inlets and sandy shorelines had much higher densities of ducks than rocky shorelines. Inlets were characterized by the presence of scaups, Canada geese and dabbling ducks. Harlequin ducks preferred rocky shorelines, while scoters and goldeneyes were mostly found in inlets and along sandy shorelines. Most ducks leave the area for northern or inland nesting areas in spring and summer.

b) Colonial and Other Seabirds

Islands along the edges of Dixon Entrance and Hecate Strait are the sites of many large and small seabird nesting colonies (Drent and Guiget, 1961; Vermeer and Vermeer, 1976; Summers, 1974). The common species include petrels, murrelets, auklets and puffins. Many more colonies occur along Hecate Strait than Dixon Entrance. In Hecate Strait, the major colonies are along the east coast of Moresby Island (Queen Charlotte Islands) but colonies are also numerous in the Aristazabal-Moore Island area (Figure 3.4-5). Two very important sites, Langara and Forester islands (the latter in Alaska), occur at the western approach to Dixon Entrance, and sites are numerous (but smaller) in the Dundas Island area. Approximately 165,000 breeding pairs of ten species occur along Hecate Strait (south to Price Island) and 26,000 pairs of five species in the Canadian portio of Dixon Entrance.

These birds may be in attendance at nesting colonies as early as mid-March. Laying and incubating occur mostly from early April to early July, but some late species may remain in the nest site vicinity until August.

Seabirds found wintering in the area on open waters by Savard (1979) were shearwaters and alcids, concentrations of which occur in western Dixon Entrance. Loons, cormorants, grebes and gulls were found wintering in inlets and along shorelines (Savard, 1979).

c) Raptorial Birds

Two species of raptorial birds commonly nest along shorelines in this area, and depend on marine food chains for their sustenance. These are the Peale's race of the peregrine falcon and the bald eagle.

The major peregrine falcon nesting sites are on cliffs facing the sea at Langara and Forrester islands and along the southeast coast of Moresby Island (Beebe, 1960; Blood, 1968). A small number of additional sites occur on islands along the mainland coast. Peregrines nest in this area from April to July, but may be present at other times of the year. They feed mainly on small seabirds such as murrelets and petrels. The total number of active nest sites along Hecate Strait and Dixon Entrance is probably only 30 to 60.

Bald eagles commonly nest in trees along shorelines through the entire area. Nesting densities in good habitat are about 0.25 to 1.50 active nests/km of shoreline (Harris, 1978; Rosenthal et al, 1973).

d) Marine Mammals

The Steller sea lion is abundant sporadically, being found in summer on bare rocks exposed to the open ocean, and in winter dispersed widely in exposed and protected locations throughout the region (Pike and MacAskie, 1969). There are ten major haul-outs (Figure 3.4-6) in the Hecate Strait region, but only two of these, Cape Saint James and North Danger Rocks, are breeding grounds. The California sea lion does not breed here but is occasionally sighted along the coast, often in the company of Steller sea lions.

The harbour seal is abundant throughout the region in littoral waters and along shorelines. Major haul-outs occur at Rose Spit, where up to 300 seals haul out, and in the estuary of the Skeena River (Fisher, 1952; Figure 3.4-6). Other seals in the area include the elephant seal, a rare visitor, and the northern fur seal, a spring and fall migrant in open water.

Killer whales, which inhabit coastal waters, are common in the Hecate Strait-Dixon Entrance region, and are usually found travelling in pods of 5 to 20 individuals. Gray whales are generally rare, but are commonly sighted off Rose Spit. Gray whales have also been sighted off Cape Saint James, west Calvert Island and other coastal areas (Pike and MacAskie, 1969). Other whales occur primarily in a tongue of deep water which extends from the open ocean through Queen Charlotte Sound up into Hecate Strait (Figure 3.4-6). Occasional sightings have been made elsewhere, particularly of whales migrating through Hecate Strait and Dixon Entrance. Humpback whales have been observed east of Calvert Island. The whales observed in the region (Lee and Adkins, 1977) include: sperm whale (common, pelagic), dall and harbour porpoise (common, coastal), humpback whale (rare, coastal and pelagic), right whale (very rare, pelagic), blue whale (rare, pelagic), minke whale (common, coastal and pelagic) and fin whale (common, pelagic).

The sea otter is extremely rare. The only recorded sightings in the Queen Charlotte region occurred off Cape Saint James. The individual may have come south from the resident population in southeast Alaska or north from the group released at Checlesit Bay, Vancouver Island (Edie, 1973).

3.5 Cultural Resources

3.5.1 Land Use

The South Kaien Island site is presently undeveloped, containing only a railway line and the road to Ridley Island. A dormitory for the CNR is located in the southern part of the property. The site was utilized by the Department of National Defence as a defence installation during World War II. Industrial activity in the region includes a commercial fish processing plant, a pulp mill and the port terminal facilities for coal, grain and lumber.

The site is located within the City of Prince Rupert and is presently zoned, by the City of Prince Rupert, as port development. The land is currently owned by the Government of Canada, Prince Rupert Port Corporation. The closest municipality is the District of Port Edward, 2.5 km to the southeast, but the site is separated from that community by Porpoise Harbour and the Skeena Cellulose Inc pulp mill on Watson Island.

Road Transportation

The Yellowhead route of the Trans-Canada Highway connects Prince Rupert to the North American highway system. Other important roads include 730 R highway to Ridley Island and 686 R to Port Edward. Daily bus service to communities to the east and Vancouver is available. Local and charter bus services are also available.

Ferry System

Car and passenger ferry service is available to Port Hardy on Vancouver Island, Skidegate in the Queen Charlotte Islands and to Alaska. Privately operated ferries also provide passenger service to Dodge Cove and Metlakatla.

The City of Prince Rupert operates a car/passenger to link Prince Rupert with the Prince Rupert Airport.

Rail System

Prince Rupert is the terminus of CN Rail's northern line. The northern line was upgraded to handle large unit trains in the mid-eighties. The Canadian National Railway main line to Prince Rupert forms the southern boundary of the site. Rail yards are located at Fairview Bay, the Prince Rupert waterfront and on Ridley Island.

Rail passenger service to Prince George and Jasper is provided by Via Rail three times per week.

The Alaska Marine Highway terminal provides a barge service linking CN Rail to Alaskan railways.

Air Service

Daily jet service to Vancouver is provided by Air B.C. and Canadian Airlines from the Prince Rupert Airport on Digby Island.

Local and regional operators provide regular and charter fixed wing and helicopter service to communities on the north coast, Queen Charlotte Islands and south east Alaska.

A flight school is offered at the Digby Island Airport.

3.5.2 Recreation

Outdoor recreational opportunities in the Prince Rupert area are predominantly water-oriented and the lands of highest recreational capability occur in narrow strips along coastlines and around lakes. The area is considered to have a moderate capability for outdoor recreation. Suitable activities include camping, boating, family recreation, sport fishing, with some areas having scenic views and interesting rock formations.

Other recreational facilities available in the region include a performing arts centre, motion picture cinemas, a civic centre with gymnasium, squash courts, skating rink, meeting rooms, an aquatic centre, downhill and cross country skiing, curling rink, bowling alley, fitness centre, yacht club, tennis courts, golf course, track field and day parks.

3.5.3 Heritage Resources

The Prince Rupert region is rich in heritage resources as a consequence of continuous occupation over the past 5,000 years. This section reviews known information about the prehistoric and historic activities and sites and relates the distribution sites to the location of the bulk liquids terminal.

Prehistoric land use patterns in the Prince Rupert area reflect a primary marine/riverine association. The effects of isostatic depression and rebound of land surfaces as well as sea level changes (as related to Pleistocene glacial activity) are important aspects to consider in assessing the potential distribution of prehistoric sites.

Fladmark (1975a) reviewed the literature pertaining to relative sea level fluctuations subsequent to the close of the Pleistocene epoch and suggested that the present relatively sea level of the Prince Rupert area stabilized about 5,000 years ago. Previous to that time the relative regional sea levels were higher that at present by as much as 10m, 6,000 years ago; 14 m, 7,000 years ago; and 90 m, earlier than 8,000 years ago.

It is apparent from Fladmark's study that evidence of human activity prior to 5,000 years ago will likely be situated well above the present coastline.

Ethnography

The complex lies within the traditional territory of Coast Tsimshian peoples. Prior to 1830, the major population centre of the Coast Tsimshian was the Prince Rupert Harbour area, including Kaien Island and the north end of Ridley Island (MacDonald and Inglis, 1980; May 1979). The Coast Tsimshian followed a basic subsistence pattern involving occupation of areas with adequate fish food supplies. Their major, semi-permanent winter villages were located in Prince Rupert Harbour.

Early each spring, a major population shift was made to the Nass River where the Coast Tsimshian joined their linguistically related Tsimshian neighbours, the Gitksa and Nishga, at traditional eulachon fishing grounds, Following the eulachon fishing season in May, the Coast Tsimshain returned to winter village locations where they fished for herring and halibut. During the summer and fall they moved up the Skeena River to fish for salmon, again returning to the winter villages in November (MacDonald and Inglis, May, 1979).

Euro-Canadian History

The historic period began almost 200 years ago when initial contacts were made by early sea-based fur traders. In 1788, Captain Duncan of the trading vessel Princess Royal anchored in the mouth of the Skeena River and in 1793, the Skeena River estuary was examined by Mr. Widby of the Discovery. The first land-based full time contact occurred in 1831 with the establishment of Fort Nass near the mouth of the Nass River by the Hudson's Bay Company.

Fort Nass was later re-named Fort Simpson after its founder Captain Aemiluis Simpson, who died at the fort in 1931. Fort Simpson was moved to its present locality 40 km north of Prince Rupert in 1834 (Walbran, 1974). The establishment of Fort Simpson had dramatic effects upon native settlement, resulting in the virtual abandonment of traditional winter villages (MacDonald and Inglis, 1979).

In 1862, William Duncan persuaded nearly 200 people to return to the Prince Rupert Harbour area, at which time the village of Metlakatla was established. Fur trading was the primary Euro-Canadian interest until the 1870's when the Skeena River region was considered for rail access to the interior. In 1870, Robert Cunningham established a store near the mouth of the Skeena and in 1871, he pre-empted a large tract of land to establish the town of Port Essington. Port Essington may have been an outpost of Fort Simpson as early as 1835 or 1836, although the original survey notes do not mention existing buildings (Heritage Conservation Branch, undated).

Euro-Canadian activity on Kaien Island itself did not begin until 1900 when the Pacific Grand Trunk Railway, later to become the CNR, chose a site on the north end of Kaien Island as the western terminus of a trans-continental line. In 1905, the townsite of Prince Rupert was cleared and the rail grade begun. The rail grade passes through the terminal site. Prince Rupert was officially incorporated in 1910 and since that time has become the major industrial and transportation centre of coastal British Columbia north of Vancouver.

Prehistory/Archaeology

The prehistoric sequence of cultural developments within the Prince Rupert Harbour area as outlined by MacDonald and Inglis (1980) has been one of continuous occupation and growth over the past 5,000 years. Three major periods marking times of significant and measurable change have been identified. The first of these periods (3,000 B.C. to 1,500 B.C.) marks the earliest known occupation. This period is characterized by a tool inventory consisting of crude cobble tools, large chipped stone bifaces, boulder chip scrapers, knives, saws, bilaterally barbed bone harpoons with line holes or bilateral guards, geometric decorative motifs, shell adze blades and points, bone wedges/chisels, canine tooth pendants, beaver incisors, bird-bone tubes and beads, and a variety of bone awls and points. Some structural features suggest that houses of this early period were smaller than those of later periods, and that slab-lined hearths were utilized.

The middle period (1,500 B.C. to 500 A.D.) produced a rapid growth of midden deposits suggesting a substantial population increase. The tool inventory characteristic of the early period continues, although there is a decline in the frequency of chipped stone tools. Additional tool types also appear, including unilaterally barbed bone harpoons with multiple notched unilateral line guards, ground slate points, labrets, nephrite adze/chisel blades, pecked and ground stone tools, socketed points, red ochre pigment balls, and shaman mirrors. Obsidian and amber items, as well as dentalia shell beads appear, suggesting that external trade had been established. House features of the middle period are considerably larger than those of the early period and numerous burials with associated grave goods suggest that social status differentiation within communities had begun.

The late period (500 A.D. to 1830) marks the full appearance of the classic culture pattern observed in early historic times. massive and elaborate pecked and ground stone artifacts occur. Zoomorphic art appears commonly on both utilitarian and decorative items. House structures show definite size differentiations and other features, such as lowered floors, reflect ranked village structure. Chipped stone items continue, but in fewer numbers and new artifact types appear, including bone scrappers, composite toggling-harpoon valves, stone splitting adzes, mauls, clubs and bowls.

A total of 30 archaeological sites are recorded on portions of Kaien Island (Figure 3.5-1). The coastal portions under consideration for development have been surveyed and found to be devoid of heritage resources. The lack of evidence for cultural activity pre-

Table 4.3-1

HABITAT AREAS BALANCE SHEET

HABITAT TYPE	AREA OF FOOTPRINT OCCUPIED BY HABITAT (ha)	AREA AFTER ADJUSTMENT FOR CHANGES IN SLOPE (ha)	AREA OF MITIGATION BY CAUSEWAY (ha)	NET HABITAT LOST (ha)	NET HABITAT GAINED (ha)
ROCKY INTERTIDAL					
Kelp Zone	0.120	0.150	0.180		0.030
Ulva/Polysiphonia	0.070	0.090	0.120		0.010
Alaria/Halosaccion	0.020	0.020			
Fucus	0.270	0.330	0.390		0.060
Limpet/Barnacle	0.005	0.007	0.450		0.440
Algae/Lichen	0.002	0.002			
Total	0.490	0.600	1.180		0.540
INTERTIDAL MUD/SAND					
Eelgrass	0.055	0.055			
Mud Flat	0.765	0.765			
Total	0.820	0.820	0.000	0.820	
SUBTIDAL HABITAT					
Subtidal Mud Flat	0.136	0.136		0.136	
Rocky Subtidal (Kelp)	0.580	0.580	0.050	0.530	
Total	0.710	0.710	0.050	0.666	

dating 5,000 years ago may be more a function of the science of archaeology than a true picture of the nature and extent of such resources. All heritage sites known to exist are associated with the present shoreline but relative sea levels over 5,000 years ago were markedly different than at present. Conceivably, evidence of cultural activity during that time may exist at elevated inland locations. Archaeological studies in other parts of the north coast of British Columbia and southern Alaska have yielded cultural remains dating back 11,000 years (Ackerman, 1974; Apland, 1977).

Summary

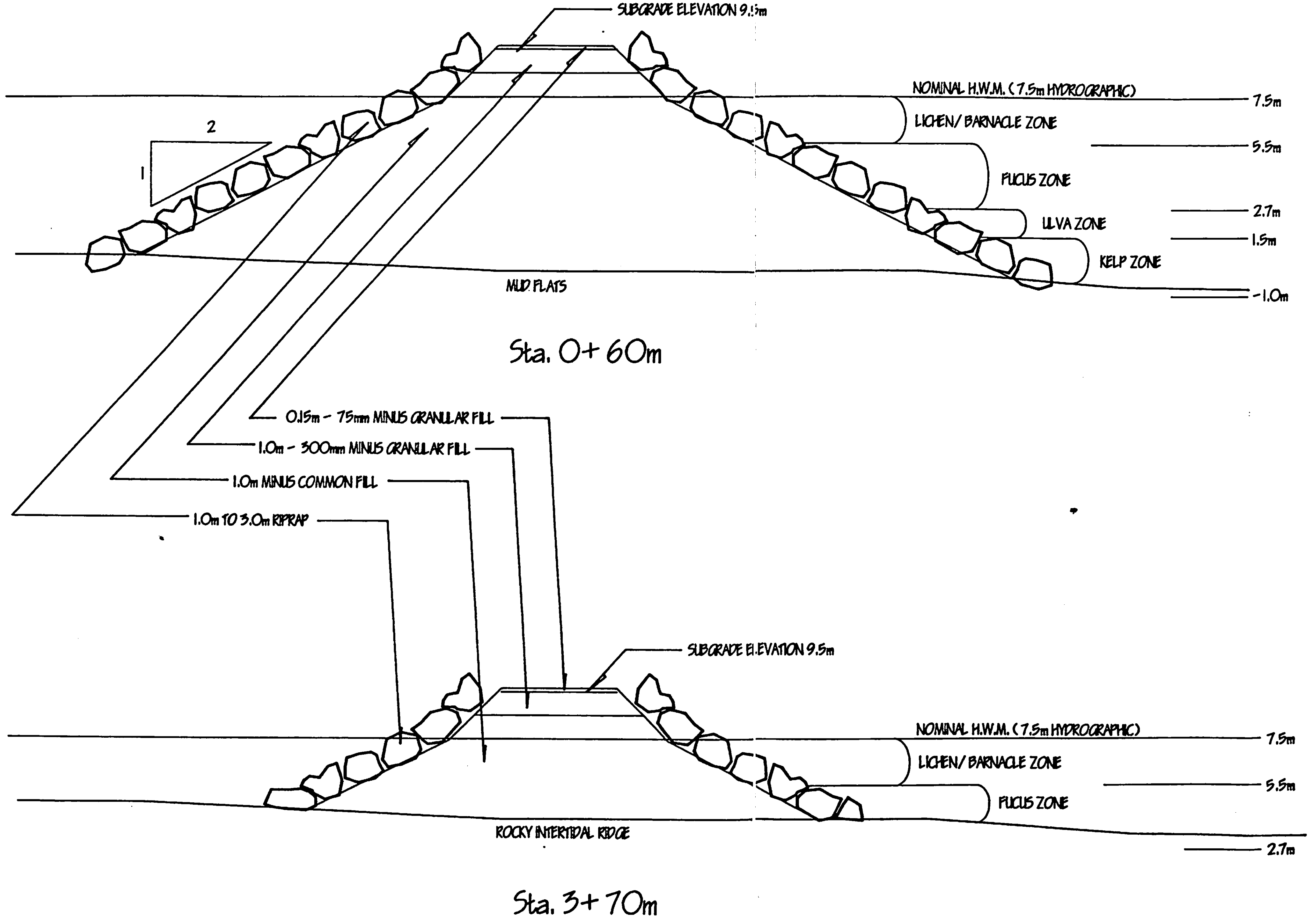
Two major development projects have been proposed for the south end of Kaien Island. One is a new transfer facility to handle the movement of liquid petroleum gas (LPG) from rail cars to deep sea vessels; the second is a production plant for the manufacture and shipping of methyl tertiary butyl ether (MTBE). Both projects will have extensive impact on the local landscape, and in view of this, a heritage impact assessment was carried out, results of which are included in Appendix B.

The assessment process involved four days of archival research and an initial two days in-field site survey. Following the initial assessment by heritage consultant David J.W. Archer an additional field investigation was carried out by a team made up of David Archer, Larry Valentin of Levelton Associates and Paige Smyth of the Prince Rupert Port Corporation.

As a result of the initial investigation, two archaeological sites were identified within the study area. A small shell midden was located at the southern tip of Kaien island. It falls within the area to be developed by the LPG project but has been completely destroyed in the early 1980's during construction of the Ridley Island Access road. There are no other potential heritage sites within the boundaries of the proposed LPG facility.

The initial investigation additionally identified an additional site within the area of the proposed MTBE site. A single stone artifact was identified in an old road bed constructed as part of a military installation used during the second world war. The initial assessment concluded that the artifact was not in it's original location but that it had been moved from another location on the site. Additional field investigation led to the conclusion that the material used for the road construction was imported by barge or rail from another site either along the Skeena River or from another site along the coast. In either case, the artifact discovered must be non local.

In conclusion, there is no need for any further action with regard to heritage sites within the area of the proposed LPG or MTBE sites. No regular monitoring or salvage excavations should be necessary.



AREAS OF REMEDIATED MARINE HABITAT WITHIN THE PROPOSED CAUSEWAY FOOTPRINT

TOTAL CAUSEWAY AREA	2.02 Ha.
LICHEN/ BARNACLE ZONE	0.45 Ha.
FUCUS ZONE	0.39 Ha.
ULVA ZONE	0.12 Ha.
KELP ZONE	0.23 Ha.
TOTAL REMEDIATED HABITAT	1.18 Ha.

NO.	DESCRIPTION	DATE	BY

REVISIONS

PRINCE RUPERT PORT CORPORATION
110 3rd AVE. WEST
PRINCE RUPERT, B.C.
V8J-1K8
TELEPHONE : (604)627-7545 FAX : 627-7101

PROJECT :
PROPOSED
SOUTH KAIEN ISLAND
LIQUID BULK TERMINAL

DRAWING TITLE :

Figure 4.3-1
TYPICAL SECTIONS
MARINE CAUSEWAY

Designed	PS	Project No.	LPG-1	Drawing No.
Drawn	PS	Scale	AS NOTED	
Checked	JS	Date	93/11/02	of

4.0 ENVIRONMENTAL IMPACT ASSESSMENT OF LPG TERMINAL

The environmental assessments has been divided into three phases:

- Phase 1 which includes the construction of the temporary LPG trans-shipment facility with floating LPG storage
- Phase 2 which involves the land-based tankage and LPG storage
- Phase 3 which will be the MTBE and other bulk liquid petrochemical terminal

The environmental assessment, in turn, is structured to provide an environmental impact assessment for Phases 1 and 2 of the LPG terminal, and an initial environmental evaluation for Phase 3 of the bulk liquids petrochemical terminal.

The components of site preparation, construction and operational activities have been identified and their impact on the socio-economic, physical and biological resources have been estimated and presented in a Leopold impact matrix (Leopold, 1971). The matrix was used as a working document and will be discussed in this chapter. The scores represents the combined effect of the magnitude and importance of the impact.

It is assumed that the export terminal design and construction will incorporate a high standard of environmental risk management. The Port will ensure that the facility is engineered and constructed to the highest standards attainable. All environmental and safety issues can be appropriately mitigated in the designs. The technology to be incorporated has a proven track record.

4.1 Atmospheric Resources

4.1.1 Climate

The relatively small scale of the proposed LPG terminal will not result in any adverse effects on the climate of the region. The compressors and refrigeration units for the LPG are powered by electricity or natural gas and cooling would be through air ventilation. Given the relative small size of the compressor unit, impacts on air resources will be very small.

4.1.2 Temperature and Precipitation

The relatively small scale of the proposed bulk liquids terminal will not result in any adverse effects on the synoptic seasonal weather patterns of the region. The effects, if any, on temperature and precipitation will be extremely localized and negligible.

4.1.3 Wind

The relatively small scale of the proposed bulk liquids terminal will not result in any adverse effects on the wind patterns of the region. Vapour dispersion has been discussed in Volume III on terminal risk. The effects, if any, will be extremely localized and negligible.

During construction dust control should be instituted by sprinkling dry soil, rock and construction aggregate.

4.1.4 Air Emissions

No emissions are anticipated from normal operations, except from hose disconnections in the rail receiving facilities which are considered negligible quantities. Gas emissions under certain emergency conditions may be experienced from pressure relief valves.

However, as discussed in Volume III of the document, these emissions potentially are mitigated in this facility design.

A gas vapour recovery system is provided to prevent emissions escaping to the atmosphere during transfer. Vapour air emissions would only occur during upset conditions (Volume III). Some emission potential is from tanks and vessels during product transfer. Monitoring should be instituted of vapour recovery.

4.1.5 Noise Emissions

Noise generation at the LPG terminal is confined to two sources which are the compressors at the LPG plant and the shunting trains. Given other industrial uses such as the CNR mainline, grain terminal and coal terminal, the additional noise levels are not expected to be significant.

4.2 Physical Resources

4.2.1 Bedrock Geology

Blasting and excavation of bedrock would result in pulverization of a significant portion of the friable schist which could result in sediment and dust release. Dust and sediment control is described in the drainage section.

4.2.2 Physiography and Landforms

Phases 1 and 2 involves the excavation of a small portion of the rocky knoll at the southwestern portion of the site. This is the proposed tank storage area of approximately 2.75 ha and would be excavated and blasted. This material would be used for the construction of the causeway through end-dumping. The remaining 3 ha of the site, which includes the process facility, would not involve rock excavation.

The landform of the proposed LPG terminal would be such that a rock wall will be maintained along the access road which would, in effect, make the tank storage invisible from the road. Some rock material would be placed along the high water mark to form a continuous platform from upland to causeway. For Phase 1, this rock material should not extend into the intertidal except at the causeway.

4.2.3 Drainage

The extremely low summer flow of the creek on the site would preclude the presence of fish during this season. This stream is not registered in the Department of Fisheries and Oceans' Stream Summary Catalogue Subdistrict #4A Lower Skeena (1991). During Phases 1 and 2, none of the site drainage would flow into this creek.

Some ditches and a pond located within the spill containment area of the refrigeration plant and flowing into Porpoise Channel via the small bay between the CNR mainline and the grain terminal marshalling yard would be altered. These ditches should be treated such as to comply with the guidelines for land development by the Department of Fisheries and Oceans and the Ministry of Environment, Lands and Parks (Chillibeck, 1993). This should include the provision of ponds and ditches with riparian buffers wherever possible. The introduction of silt and/or sediment from hard surfaces should be avoided through construction of proper retention systems including filter clothes and sand filters.

The runoff from the LPG storage tanks into Chatham Sound will also be collected through sumps, including appropriate settling basins before discharge.

4.2.4 Soils

Podzol soils are generally of poor to moderate nutrient status, depending on their depth, temperature, and the amount of leaching. Notwithstanding, large trees are able to develop on podzol soils because of the infrequency of fire, the long growing season and the excess of precipitation over evapotranspiration.

Organic soils, however, are almost invariably poorly productive due to their nearly constant saturation. In the Prince Rupert region they frequently develop into bogs which contain valuable wetland and aquatic habitat, and are evident in areas of stunted lodgepole pine and yellow cedar. However, such a bog environment does not exist on the site.

Podzol soils are confined to steep portions of the site and generally have a high constraint to construction because of the steep terrain. However, where drainage is impeded, organic soils may occur, resulting in saturated areas containing a deep non-decomposed overburden. The LPG terminal largely avoids the steep podzols but affects some of the organic fibrisols.

Clearing, excavation, filling and blasting will result in the removal or covering of most of the nutritive soils as well as in the disruption of surface and groundwater flow. Removal, stockpiling or disposal of these soils should be in accordance with a soil management plan. This should include soil stockpiling for later landscaping and soil disposal plans if soil volumes exceed landscaping demands.

The fibrisol soils have a tendency to slurry if worked by machinery during the wet season. Drainage should be provided prior to removal. Prompt revegetation will help to stabilize disturbed soils, in order to minimize soil erosion and sedimentation in affected plant communities.

4.3 Aquatic Resources

4.3.1 Freshwater Biology

It is anticipated there will be no major impacts on freshwater systems associated with construction or operation of the LPG terminal. Degradation of aquatic habitat and resources in the vicinity of the site will be negligible, and in all probability, rectified by natural processes. Minor impacts should be detected by monitoring and the causes rectified.

a) Survey, Planning and Construction Phase

Minor hydrogeological impacts will be associated with the loss of surficial soils and vegetation and the diversion and containment of surface runoff. Suspended solids, turbidity and colour will change as rates of local surface runoff are changed with site preparations. Fine particles of organic soil material will comprise most of the suspended solids increase. The surface runoff should be managed using the Provincial and Federal guidelines (Chillibeck, 1993).

b) Operation and Maintenance

Water quality parameters most affected by the project include suspended and dissolved solids, colour and metal concentrations. The magnitude of these potential impacts is considered low because settling ponds will be used during operation for treatment of wash water.

c) <u>Abandonment and Reclamation</u>

Impacts on surface water quality following decommissioning of the complex should be negligible. The site must be cleaned up and reclaimed to a suitable vegetative cover, if appropriate.

d) <u>Other Discharges</u>

The LPG terminal, including the refrigeration plant, pumping stations, loading dock and LPG storage vessel, are designed for zero emission with the following exceptions.

- office and crew lunchroom - grey and blackwater discharge will be to the grain terminal which has a sewage plant capable of accepting sewage volumes anticipated for the land-based facility. Approximately 15 to 20 personnel are expected to use the toilet and shower facilities on-site
- LPG storage vessel - will maintain a permanent crew of 15 to 20 personnel and will have a sewage treatment plant on board. The treated sewage will then be discharged into Chatham Sound. The treated sewage will comply with sewage treatment levels as required under the Waste Management program of the Ministry of Environment, Lands and Parks.
- bilge water of LPG storage vessel - contaminated bilge water will be pumped into a 100 tonne container within the ship. This material will then be pumped ashore into tank trucks for disposal. Clean bilge water may be pumped to the ocean.
- washdown of LPG storage vessel - will only be allowed should this be routine cleanup. Should any contamination, such as oil wastes, be found on the vessel, these will be cleaned and contained separately.
- plant maintenance of refrigeration plant - will have drip pans under machinery where oily wastes could be generated. These will then be collected and contained in suitable containers for recycling and/or

treatment. Other washdown will occur and will flow into storm drain systems which have been designed to include suitable sediment retention and, where appropriate, oil waste separators before discharge to fresh or salt water environment.

4.3.2 Oceanography

a) Site Preparation

The relatively small scale of the facility will have little or no effect on the local physical oceanography. Incident wave and wind climates will not be altered by site preparation. Temperature and salinity distributions in the main channel will be unaffected, as the facility site lies in a protected embayment that is much shallower than the adjoining waters. An increase in suspended material in the waters will occur due to construction activity; however, the strong tidal currents in the main channel will disperse this material quickly.

b) Construction

Construction of the facility should have little or no effect on the local oceanographic processes such as winds, waves, currents and tides. The causeway will impact the current flow paths within the embayment areas. However, these impacts will not be significant. Essentially, the causeway will create 2 embayments, where one now exists, and both embayments will be well flushed at low tide.

Additional suspended material, both native and imported, can be expected in the water. Construction scheduling and monitoring of the material should mitigate its impacts, which are expected to be minor.

c) <u>Operation</u>

The small scale of the facility will have little or no effect on the local oceanographic processes such as winds, waves, currents and tides. The embayment at present empties and fills through a number of small channels, and measurement and observation of the surficial currents in the embayment indicates that the volume of water flowing through the embayment from one end to another is not significant. These measurements also indicate that the currents within the embayment are significantly smaller than those in the main channel.

Sedimentation patterns will be altered slightly. Transported sediments will now accrete adjacent to the causeway, instead of at the intersection of Ridley and South Kaien Islands. The transported volume of sediment is small, and the accretion will have a minimal effect on the local bathymetry.

4.3.3 Marine Biology

Intertidal and Subtidal Ecology

The intertidal and subtidal area in the region of and directly adjacent to the proposed causeway development is essentially a tidal mud flat protected by many large intertidal rock outcroppings and by Bishop Island. Surface current studies undertaken during August 2 and 3, 1993 indicate that currents in the shallows over this embayment were weak and some flow reversals were observed especially towards the end of ebb tide (Hay & Co, 1993). This study indicated that currents and tidal flushing would not be significantly reduced by the proposed causeway.

The mud flats support healthy but very patchy eelgrass growth with most productive patches at or near the low tide line. The macrobiota of the remainder of the mud flat is dominated by burrowing benthic invertebrates such as the ghost shrimp (*Callianassa* *californiensis*), cockles (*Clinocardium nuttalli*), and a number of polychaetes as well as crawling invertebrates such as starfish and some crabs.

Ecologically, the presence of eelgrass indicates a productive habitat. Typically, small algae and diatoms are associated with the leaves of the eelgrass and a number of invertebrates live on the leaves or among the rhizomes and roots (Harding & Butler, 1979). Many small fish including juvenile salmon are known to frequent eelgrass beds in general and may be seasonally present (Section 3.3.2) in the region of the proposed development. Similarly herring make use of eelgrass, and kelp beds as a spawning substrate but there is no significant evidence of this occurring within the immediate vicinity of the proposed development (Section 3.3.2).

The rock outcroppings are typically productive areas of seaweed growth (Section 3.3.3). The type and abundance of the seaweed is affected by the tidal level on which it is found (Section 3.3.3) as well as the exposure of the rock surfaces to currents and waves. The seaweed itself, as well as the relatively protected rock surfaces underneath the seaweed support and protect invertebrates which grow on them. Both the seaweed and the attached invertebrates will provide food and protection for fish, particularly intertidal fish such as sculpins, gunnels and rockfish. The flora and fauna associated with the intertidal and subtidal rock formations is typically more diverse on the rock faces of those rocks furthest out from shore and facing west. This is a function of the greater current strength and therefor water exchange in this area compared to the current strength east of this area over the shallow mud flats (Hay & Co, 1993). The greater currents on the western side of the intertidal islands supply oxygen, nutrients, and larval organisms resulting in greater diversity than on the rocks within the shallows to the east of this. It is not expected that this will be significantly affected by the proposed causeway and berthing structures (Hay & Co. 1993).

The construction of the proposed causeway and berthing structures will inevitably lead to the loss of approximately 2 ha of intertidal and subtidal habitat as discussed under the section on construction below. It will also provide approximately 1.18 ha of new rocky intertidal area by virtue of the rock making up the intertidal surfaces of the causeway itself. Short term deterioration in water quality may effect both primary and secondary production in the area. If water quality is not maintained at a reasonable level as discussed in the sections below, sensitive species will be adversely affected resulting in a decrease in species diversity and a shift toward hardier species.

a) Site Preparation

There are three aspects of the site preparation which may result in short term negative effects on the intertidal and subtidal flora and fauna. These are:

- clearing,
- ditching and drainage alterations, and
- excavation.

The activities listed above will all be carried out on a relatively small scale for the LPG terminal and would only affect the intertidal and subtidal ecology secondarily through minor alterations in surface water run off patterns and through temporary potential increases in suspended solids in the run off water due to vegetation removal and soils disturbances. There is no creek alteration associated with this initial LPG project and removed overburden will be used on land to create a berm around the storage facility site.

Temporarily increased suspended solids in run off water could cause a decrease in algae and eelgrass growth due to a reduction in light penetration through the water. Similarly increased suspended solids could adversely affect marine invertebrates in a number of ways, most obviously by overburdening or clogging of gill structures and filter feeding devices used by many sedentary benthic organisms (eg. mussels, clams, barnacles, etc.).

Local fish populations would likely avoid the area in the event of increased suspended solids in the water.

The potential negative effects on intertidal and subtidal habitat listed above will be avoided entirely or mitigated in the following ways:

- sedimentation ponds and filters for drainage ditches will be created and installed as required; and
- work will be carried out during winter months to avoid potential negative effects on juvenile fish populations.

b) Construction Phase

The factors affecting the intertidal and subtidal environments in the immediate vicinity of the proposed site during the construction phase are:

- construction of the onshore facility; and
- construction of the causeway and berthing structures.

The construction of the onshore facility will involve some blasting and levelling. Rock produced from this blasting will be used as fill for the causeway. Utilities and product pipeline will be installed. The negative effects of these onshore activities during the construction phase are similar to those described for the site preparation phase with a temporary increase in suspended solids being the primary concern. The mitigation procedures already mentioned under site preparation will be continued through the construction phase to prevent or minimize risks from potential suspended solids to the localized marine environment.

The causeway construction will produce some unavoidable negative impacts on the local intertidal and subtidal flora and fauna:

- Increased suspended solids due to the settling of the rock fill for the causeway and the subsequent squeezing out of the mud beneath it. The placement of fill for the causeway could potentially result in a much greater degree of disturbance to the intertidal and subtidal habitat than the footprint would indicate. However, construction methods employed will minimize the negative impact. Rock fill will be placed by end tipping from trucks. Final placement of rock will be done using a bulldozer, which will push the rock forward in lifts, thereby minimizing siltation and damage to the surrounding area. Low tide periods will be used as much as possible during placement of rock.

  The squeezing out of the existing mud from under the rock fill will inevitably cause some disturbance of the existing mud flat on either side of the causeway footprint. To partially offset this the calculated area of mud flat that will be covered by the footprint includes an extra margin of 10%.

  The burrowing invertebrates of the mud flat in this area adjacent to the causeway will be adversely affected by this mud shifting, but given that any displaced mud will be from the original mud flat this condition should be temporary.

  Monitoring of burrowing marine invertebrates will continue and suspended solids in the area of the causeway construction will be monitored so that remedial action can be taken as required.Baseline readings are being developed.

- Potential contamination from machine oil spills. This is an ever present problem in construction zones, however care and preventative safety measures (eg. to contain and clean up any spills before they seep into the drainage systems) will together minimize the risks. Should contamination occur it will result in a temporary deterioration of water quality in the local intertidal and subtidal area. This would, in turn, adversely affect the flora and fauna of the area.

- Potential adverse effects due to alterations in current patterns and flushing rates. A study by Hay & Co. in August 1993 (Appendix C) was initiated to address the question of how the causeway would affect the current pattern and overall flushing rate within the mud flat area. As already stated, measurements of surface currents within the embayment suggested a very protected environment. Further, this current study revealed that the existing 'embayment' or mud flat area emptied and filled through several channels suggesting that the volume of water flowing through the embayment from end to end was not significant. Finally, it is suggested that the causeway will create two embayments, where one now exists and each will be well flushed at low tide. This in turn would mean that the net overall effect of the causeway on the flora and fauna of the intertidal mud flat, due to changing water flow pattern should be insignificant. With respect to the extension of the causeway past the Bishop Island and the larger adjoining 'intertidal islands' to the exposed outcrops, the report by Hay & Co. indicated that the causeway would deflect the currents at that point causing a local alteration in the flow regime. However, the report also suggests that since the contours are very steep, they would not expect the deflection of flow to contribute significantly to the local current velocities.

- Potential negative effects may be felt by shorebird populations and mammals utilizing the local intertidal area. Shorebird and migratory bird populations, as well as any mammals such as seals or river otters that utilize the intertidal area in the immediate vicinity of the causeway and berthing area construction will likely be disturbed by the noise and disruption. It is likely that they would avoid the area for the duration of the construction.

- Loss of 1.29 ha of intertidal habitat and .71 ha of subtidal habitat would be directly affected as documented in Section 3.3.3. It has been calculated that an intertidal and subtidal area of approximately 2 ha will be filled in during construction of the causeway. This area includes: .49 ha rocky intertidal habitat, .82 ha mud flat of which .055 ha supports eelgrass growth, and 0.71 ha of subtidal habitat including .136 ha of subtidal mud and .58 ha of rocky subtidal habitat.

Some mitigation of the lost intertidal and subtidal habitat will be provided by the causeway itself. As is shown in Figure 4.3-1, the causeway will be constructed of varying grades of rock fill according to design specifications, but the surface of the sloped embankments of the causeway will be faced with large grade (1 m to 3 m) rock which will form a stable rocky intertidal habitat. Further to this, Table 4.3-1 shows a summary of the impacted habitat areas before and after adjustment for the slope of rock faces. The area of each habitat mitigated by the causeway itself is listed in column 3 and the net loss or net gain of habitat is shown in columns 4 and 5, respectively.

It can be seen from this table that there is no net loss of rocky intertidal habitat and that in fact the causeway will provide a net increase in the rocky intertidal of .58 hectare.

The other habitats cannot be mitigated by the causeway itself. Mitigation for these will be decided in consultation with the Department of Fisheries and Oceans. As shown in Table 4.3-1, these areas include:

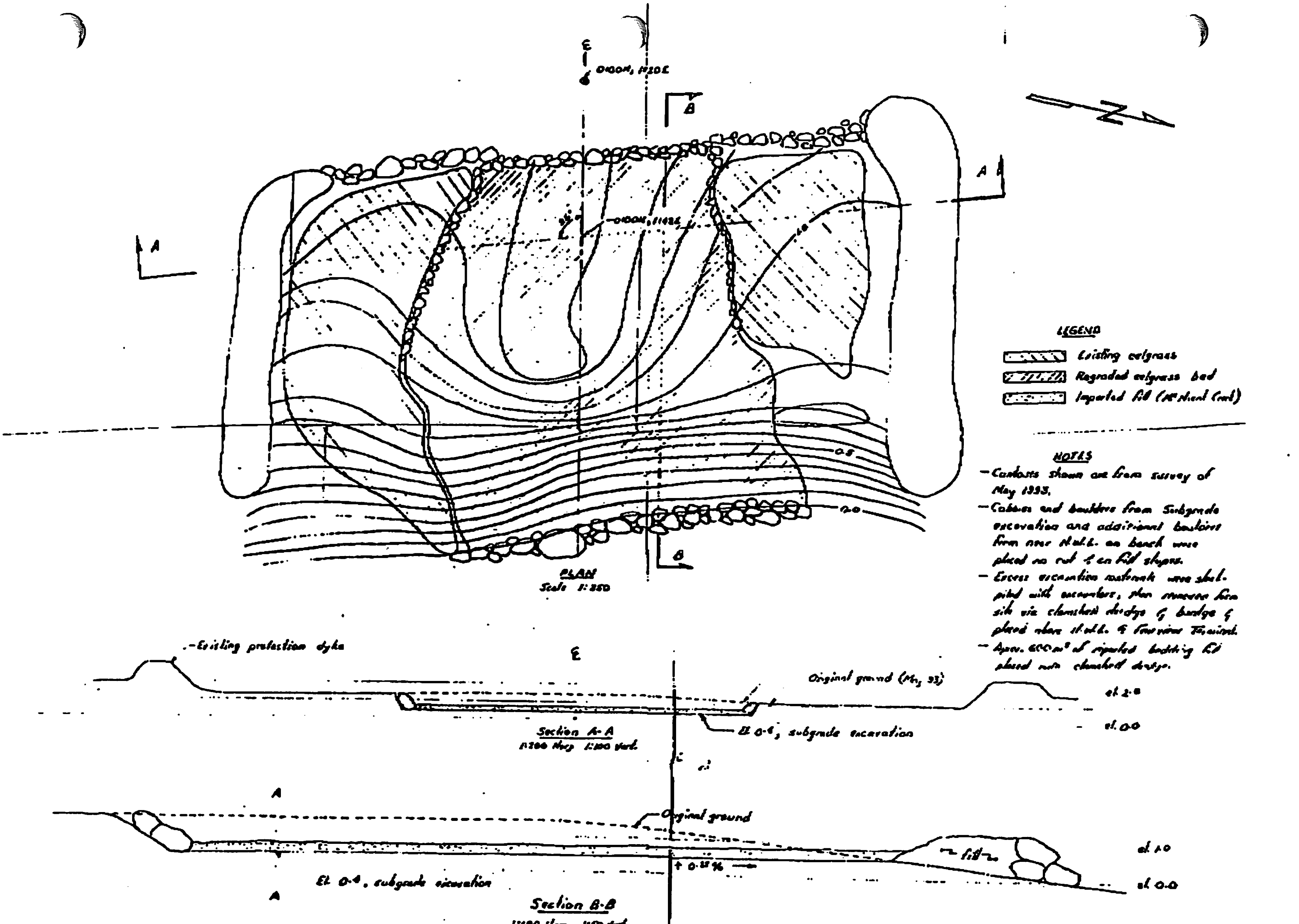


Figure 5.2-1

FAIRVIEW TERMINAL EXPANSION
EELGRASS HABITAT RECEPTOR SITE
REMEDIATION WORKS

- 0.82 ha of intertidal mud flat and 0.136 ha of subtidal mud flat;
- 0.055 ha of eelgrass; and
- 0.530 ha of rocky subtidal kelp habitat.

Options for compensation might include the following:

- The impacted area of eelgrass is 550 m^2 (.055 ha). This could be compensated for by transplanting eelgrass. The Port Corporation carried out an eelgrass transplant in conjunction with its Fairview Terminal expansion. While a number of problems were encountered with respect to this transplant (it was a learning experience), it is thought that most of these problems could be avoided with future eelgrass transplants. The original eelgrass transplant was successful within the terms of the contract with the Department of Fisheries and Oceans, however problems with elevation and substrate development were identified. In consultation with Fisheries and Coastal Engineers, a remediation program was undertaken by the Port in August of 1993. It is hoped that this will enhance eelgrass growth in the less successful areas of the transplant site and will provide additional useful data for future transplant projects.
- Mud flat could be created by building of a rock berm across part of a nearby bay creating a sheltered embayment area.
- Areas of mud flat could be compensated for by creation of additional areas of eelgrass.
- Rocky subtidal could be compensated for by the additional areas of rocky intertidal area provided by the causeway itself and/or by the creation of a subtidal reef adjacent to the existing reef.

c) Operation Phase

Potential ongoing adverse effects from the operation of the LPG Facility could be minimal if high safety standards as well as good engineering design, construction, and maintenance are implemented. However, potential sources of adverse impacts from the ongoing operation of the LPG facility and mitigation/compensation options are discussed in Chapter 5.

4.4 Terrestrial Resources

4.4.1 Vegetation

Vegetation Ecology

Five parameters relating to environmental value were used to estimate the ecological value of the four vegetation types in the study area. Each parameter was scored from zero to two (for less significant parameters) up to a score from zero to six (for more significant parameters) in each vegetation type. The sum of the scores was used as an index of ecological value (Table 4.4-1).

Biological diversity is vital in maintaining ecosystem sustainability and encouraging recovery from disturbances (Burton et al, 1992). Methods of quantifying biodiversity are varied, however the number of species is the most common and simple measure.

Most wildlife species respond more to the structure of plant vegetation than to the plant species making up the community (Thomas, 1979). In addition, the vegetative productivity of a site is a strong determinant of its capacity to support wildlife. Consequently, structural diversity, measured as the number of vegetative strata and frequency of gaps within the vegetation, and vegetative productivity have been included in the environmental sensitivity index.

Table 4.4-1

ECOLOGICAL VALUE OF VEGETATION

	VEGETATION TYPE			
	YOUNG DECIDUOUS FOREST	MATURE CONIFEROUS FOREST	SHRUB	MATURE DECIDUOUS FOREST
Species Richness[1]	1	3	0	1
Structural Diversity[2]	0	3	0	2
Vegetative Productivity[3]	1	2	0	2
Rare or Endangered Species[4]	5	5	3	4
Regional Uniqueness[5]	2	0	2	2
ECOLOGICAL VALUE[6]	9	13	5	11

1 Species Richness Criteria

Number of species		Index Value
	<6 species	0
	6-12 species	1
	13-18 species	2
	>18 species	3

2 Structural Diversity Criteria

	Index Value
few strata, few gaps	0
several strata, few gaps	1
many strata, several gaps	2
many strata, many gaps	3

3 Vegetative Productivity Criteria

net primary productivity	<10	0
(tonnes/hectare/year)	10-14	1
	14-18	2

4 Rare/Endangered Plant Species Criteria

	Index Value
no potential or observed rare species	0
potential R4 site (Straley, 1985)	1
R4 species observed	2
potential R3 site	3
R3 species observed	4
potential R1 or R2 site	5
R1 or R2 species observed	6

5 Regional Uniqueness of Vegetation Type Criteria

similar veg type >1ha and <1km away	0
similar veg type <1ha and <1km away	1
similar veg type >1ha and <10km away	2
similar veg type <1ha and <10km away	3
similar veg type any size >10km away	4

6 Ecological Value: <6 = Very Low; 6 to 9 = Low; 10 to 12 = Mod; >12 = High

Many animal species can be quite dependent on uncommon plant species, especially during critical periods of stress. Such keystone species may set the carrying capacity for dozens of invertebrate species (Terborgh, 1986). Hence, the actual or probable presence of rare or endangered plant species has also been included in the formulation of the sensitivity index.

Finally, the recognition of the importance of minimum viable habitat size for the preservation of many vertebrate species (Soulé, 1988) has encouraged natural resource managers to consider the proximity and abundance of rare habitat types. The proximity and abundance of the observed vegetation types within the region has, therefore, been incorporated into the sensitivity index.

The highly homogenous young deciduous forests of the study area can be reproduced easily; only their relative infrequency in the area raises their value from very low to low. The mature coniferous forests are 'highly valuable' as a consequence of their high structural and biological diversity. They are, however, nearly ubiquitous in the region, occupying almost the entire forested area of the islands and mainland within a 10 km radius of the site. Contrarily, shrub vegetation which is very unproductive and homogenous, is rare in the region, although it is produced at almost every disturbance site which is not artificially regenerated by planting. It, therefore, warrants a very low ecological value rating. The mature deciduous forest warrants a 'moderate' ecological value by virtue of its relative infrequency and productivity.

Ecological Reserves

The only ecological reserve in the vicinity of the proposed LPG plant site is the Nature Trust property on Smith Island. Its distance from the proposed LPG site should result in the absence of any deleterious effects on the bog by the construction or operation of the LPG plant.

Rare or Endangered Plants

None of the rare or endangered plant species identified by the Conservation Data Centre which occur in the Prince Rupert forest district were observed on the study site during the field visit. This is not unexpected, as 12 of 15 of the species identified occupy wetland habitats which are not found in the site.

Timber Values

Of the 10.3 ha of vegetation within the LPG study area, only 7.1 ha is forested. Of this area, only the mature conifer forest (4.9 ha) has saleable trees. Sitka spruce - the most sought after commercial tree species in the region - comprises only (5%) of the trees in the mature conifer area. Because of the high precipitation and humidity throughout the year, forest fires are uncommon; as a consequence, much of the forest is overmature, uneven-aged and decadent. The lack of a nearby sawmill for processing the small volume of alder on the site would give the alder commercial value only as firewood.

a) Site Preparation

With the exception of the 0.6 ha stand of mature coniferous forest east of the CNR bunkhouse, most of the 10.3 ha of terrestrial vegetation in the project area will require clearing in preparation for the construction of the LPG terminal. The tank storage areas and access road will account for the majority of the vegetation losses. Table 4.4.2 identifies habitat lost to the LPG terminal. Mature coniferous forest comprises 2.6 ha, shrub 0.9 ha, and young deciduous forest 0.7 ha of the site. Although the mature coniferous forest has a high ecological value, it is nearly ubiquitous in the region and has low commercial timber value. The shrub and young deciduous forest have little ecological value and no commercial value.

Table 4.4-2

VEGETATION AND WILDLIFE HABITAT LOSS DUE TO TERMINAL DEVELOPMENT

HABITAT	HABITAT LOST TO TERMINAL (ha)
Marine	1.8
Non Vegetated	1.5
Mature Coniferous Forest	2.6
Shrub	0.9
Young Deciduous Forest	0.7
TOTAL	7.5

Subsequent site preparation activities (road construction, ditching, excavation, filling, blasting and drainage alteration) will significantly impact the potential for revegetation of the site following abandonment. In general, the impact on forestry will be greater than the impacts on minor vegetation, due to the greater rooting depth requirements of the former.

b) Construction

Construction and paving over most of the site will preclude the regrowth of native vegetation.

The probability of a forest fire occurring as a result of site preparation and construction is low due to the region's heavy precipitation. Liaison with the local fire department should be maintained during construction and operation of the proposed facilities.

c) Operation

Regular operational activities are not anticipated to have any significant impact on the vegetation of the study area. Only spills occurring outside of the spill containment area should have any effect on the vegetation. However, due to the paucity of native vegetation which would remain on the site following construction, the magnitude of the impact would be relatively small.

4.4.2 Wildlife

A matrix focusing on the greatest potential impacts and most sensitive wildlife species groups is shown in Table 4.4-3. The following sections describe potential impacts as a result of the three phases of the proposed project.

Table 4.4-3

WILDLIFE IMPACT MATRIX

PHASE	ACTIVITY	SPECIES GROUP					
		AQUATIC WILDLIFE	LARGE MAMMALS	WATERFOWL & SHOREBIRDS	OTHER WILDLIFE	OTHER BIRDS	SUMS
Site Prep	Clearing	1	8	3	9	7	28
	Excavation	1	8	3	7	3	22
	Blasting/Drilling	2	6	8	6	6	24
Cons	Facility	1	2	6	2	2	13
	Causeway	8	2	7	4	4	25
Oper	Spills/Accidents	3	2	3	3	5	16
TOTAL		15	28	30	31	27	

Wildlife Ecology

Factors which influence the sensitivity of wildlife to the port development were based in part on the habitat principle. Vegetation makes up an important component of wildlife habitat. Should vegetation be disturbed, it in turn disturbs the animals which rely on the habitat for their existence. Therefore, the sensitivity rating of wildlife habitats was closely linked to the sensitivity of its vegetation habitat. Other factors included occurrence, number of species, species diversity, and vegetation productivity, as outlined in Table 4.4-4 below. In addition, critical habitat requirements during the life stage of important vertebrates were attached to wildlife habitat types. The following habitat values were identified:

Young Deciduous Forest Habitat	Moderate Value
Mature Coniferous Forest Habitat	High Value
Shrub Habitat	Low Value
Mature Deciduous Forest Habitat	High Value

Because of the wide geographic range required by large mammals such as deer, as well as birds, isolated segments of habitat may be of little value. In this regard, special notes have been added to the wildlife descriptions.

The winter range of ungulates includes the salt marshes which are located within the foreshore areas of the region. Although no salt marsh is affected by the LPG terminal, the intertidal eelgrass mudflat is used by ungulates and waterfowl. The railway and road right-of-way interfere with large mammal access to this habitat somewhat. The development of the study area will result in the loss of 2 ha of intertidal habitat, including approximately .05 ha of eelgrass. This should have a low impact on ungulates, as there is an abundance of marsh and eelgrass habitat in nearby areas (Table 4.4-2 in vegetation section).

Table 4.4-4

WILDLIFE HABITAT ECOLOGICAL VALUE[1]

	HABITAT TYPE			
	YOUNG DECIDUOUS FOREST	MATURE CONIFEROUS FOREST	SHRUB	MATURE DECIDUOUS FOREST
Plant Diversity (0-3)	1	3	0	1
Vegetation Height (0-3)	2	3	1	3
Canopy Volume (0-2)	1	2	0	1
Canopy Closure (0-2)	1	2	0	2
Structural Diversity (0-3)	0	3	0	2
Herbage Production (0-2)	1	1	2	2
Browse Production (0-2)	1	2	1	2
Animal Diversity (0-4)	2	4	3	2
Woody Debris (0-2)	1	2	0	2
ECOLOGICAL VALUE[2]	10	22	7	17

1 Based on Brown et al (1985)

2 Ecological Value: 0 to 7 = Low; 8 to 15 = Moderate; 16+ = High

Reference to Table 4.4-3 shows that the shrub habitat is of low relative importance to birds and mammals. This is due to the generally monotypic, dense nature of the shrub areas and low structural diversity. This results in a low overall wildlife diversity, although browse and herbage for ungulates and other herbivores is available.

The young deciduous forest has a moderate value as wildlife habitat. This habitat is found throughout the region within disturbed sites and generally succedes to a mature deciduous forest within 50 to 70 years and, subsequently, into a coniferous forest. It has a moderate value due to the low plant diversity, canopy closure and stocking which results in generally poor wildlife diversity.

The young deciduous forest will succede to the mature deciduous found within the site. This habitat was found to have a high value to wildlife due to the large amount of woody debris and relatively high amounts of herbage and browse production.

The mature coniferous habitat is of high value to wildlife and is the most important upland wildlife habitat within the site. However, this is a ubiquitous habitat found throughout the Prince Rupert region. This habitat was found to have a relatively high value to wildlife due to the high plant diversity and productivity as well as the high vertical and horizontal structural diversity, and resultant wildlife species diversity and abundance. This habitat is especially important to cavity nesters as many of the trees are older and decadent snags. This habitat is also very important for roosting and nesting to raptors such as bald eagles and cover for deer as winter range.

a) <u>Site Preparation</u>

Table 4.4-3 shows that the greatest potential impacts is a result of clearing, mainly to small and large mammals and furbearers. This is due to the complete loss of habitat within the site. The largest impact is on those species such as small mammals unable to move to adjacent habitats. Larger mammals such as deer, while able to move to

Photo 4.4-1
Eagle roosting in mature confierous
forest

adjacent areas, do use this area as winter range. These impacts are of a permanent nature, which results in a 5.7 ha loss of wildlife habitat (Table 4.4-2 in vegetation section).

Excavation, blasting and drilling during site preparation all have a potentially high impact to wildlife resources within and adjacent to the study site. Although these activities have a short temporal impact, their spatial impact may be great, especially in the case of blasting. These impacts are magnified when conducted during the waterfowl and shorebird migratory period when resources of migratory wildlife are taxed. The species groups with the greatest potential impacts from excavation, blasting and drilling are large mammals and waterfowl.

b) Construction

The activities with the greatest potential impact during the construction phase would be the actual facility and causeway construction. Those species groups with the highest potential impact include waterfowl and, potentially, aquatic wildlife such as seals, sea lions and other marine mammals. As waterfowl and shorebirds are generally migratory within the study area, the extent of impacts are contingent on timing of construction activities.

Impacts to terrestrial/aquatic wildlife would primarily result from noise and the presence of machinery in aquatic areas during filling rather than habitat loss or degradation. Species groups of highest potential impact are waterfowl, shorebirds and other birds such as raptors (ie. bald eagle) and great blue heron. This is contingent on timing of the filling activities, with the greatest impact occurring during the breeding/nesting and migration periods.

c) Operation

Some potential impacts to wildlife resources as a result of operation of the LPG Terminal are shown on Table 4.4-3. This matrix only considers the LPG Terminal and ancillary facilities, not shipping and/or offshore movement of the LPG. A spill of liquid propane disperses quickly into the atmosphere. The species groups effected by spills or accidents (ie. fire) are those which come into direct contact with the gas during an accidental spill. These would be species adjacent to the LPG Terminal transfer points within the causeway or tank storage areas within the main facility.

In summary, the site preparation and construction of causeway has the greatest potential for impacts to wildlife resources of the site due to habitat loss. The operation phase has the potential for minor impacts due to potential spills and accidents. The wildlife species of greatest sensitivity to impact within or adjacent to the study area are small mammals in the upland and waterfowl and shorebirds during construction in the marine areas.

4.5 Cultural Resources

4.5.1 Land Use

The City of Prince Rupert and the surrounding region has a well developed municipal infrastructure and expansion potential. It is anticipated that the existing growth capacity is sufficient to accommodate both the expected increase in short term population during the construction phase and the projected long term growth as a result of the development of the bulk liquids terminal at South Kaien Island.

As well, due to the industrial presence already established by the pulp mill and the adjacent grain and coal terminal, development of the South Kaien Island site should not result in significant adverse social or land use impacts.

Photo 4.5-1
Culvert of unnamed creek east of site

Photo 4.5-2
Abandonned installation of the Department
of National Defense

4.5.2 Heritage Resources

Due to the disturbance of the existing archaeological site by the CNR mainline, further filling will not impact this site.

5.0 MITIGATION AND COMPENSATION OPTIONS OF LPG TERMINAL

The environmental impact assessment, described in Chapter 4, presents a number of mitigation options on a discipline-by-discipline basis. The objective of this chapter is to summarize the mitigation plans and discuss options for compensation for loss of fisheries and wildlife habitats.

5.1 Summary of Mitigation Options

5.1.1 Air Emissions

The site preparation and construction emissions include those of dust and construction equipment exhaust. Dust control is particularly important for friable schistose rock which requires frequently wetting during the dry season. Exhaust emissions by construction and vehicular equipment is regulated by Federal and Provincial agencies and should include the provision for monitoring and repair of combustion engines with excessive levels of air emissions.

5.1.2 Noise Emissions

Noise emissions associated with construction equipment and operational equipment (such as refrigeration plant and storage and loading vessels) should comply with relevant international, Federal and Provincial noise standards. Consideration should be given to a noise berm or greenbelt between the refrigeration plant and the CNR dormitories.

5.1.3 Soil Management

The site preparation and construction of the LPG terminal requires considerable excavation, blasting and soil movement on site. The mineral and rock-derived soils can generally be disposed of as part of the filling operation, while organic soils can either be used for landscaping as topsoil or disposal in suitable land disposal sites. For the LPG phase of the development, there is sufficient areas between the tank farm, road, rail and refrigeration plant to allow for landscaping and recycling of organic soils as appropriate.

5.1.4 Water Management

Surface water drainage and treatment have to be an integral part of the surface water management during site preparation and construction. A properly designed construction drainage system with suitable retention and treatment facilities has to be developed. The same system can be designed to later become part of the operation storm drainage system of the LPG terminal. This allows the installation of retention systems which can be turned into wetlands, ponds and ditches such as the ones to Porpoise Harbour at the "duck pond" between the CNR mainline and CNR marshalling yard of the grain terminal. All storm water management should comply with Land Development Guidelines for the Protection of Aquatic Habitat oft the Ministry of Environment, Lands and Parks and the Department Fisheries and Oceans (Chillibeck, 1993).

Spill containment areas generally require draining by manual valves and will have to be monitored prior to discharge to the storm drainage system. Waste lubricating oils and metal conditioning chemicals will be collected for recycling from the refrigeration plant and the trans-shipment facility dockside. The disposal of waste oils and fuel contaminants must comply with Provincial disposal standards and regulations.

Impacts due to accidental spill of chemicals on-site will be minimized by effective containment structures and operational contingency plans. Chemical spill containment and cleanup methods will have to be described in a detailed contingency plan for use by plant staff and pertinent Provincial and municipal agencies.

The Marine Environment

During the construction of the causeway, the marine environmental requires the placement of fill to be, as much as possible, outside of the wetted portion of the intertidal. This can be done in lifts above the low water mark at low tide such that fines associated with the broken-up rock will enter the water column after placement when the tide flods and can rapidly settle in situ. The schedule for filling below low water in the subtidal construction should avoid periods of juvenile salmon rearing during February and March. If this is not possible, the subtidal waters should be isolated through nets or buble curtains if juveniles have been identified through a test fishing.

Spills of oily and fuel wastes should be contained through proper spill containment devices such as oil booms, as part of the Prince Rupert Port Corporation's oil spill contingency program.

Water emissions include those from the following.

- The LPG storage vessel is equipped with a sewage plant which will discharge tertiary-treated sewage to Chatham Sound. The discharge will comply with Ministry of Environment, Lands and Parks, Waste Management, standards.
- Land-based LPG plant sewage discharge will be to the existing sewage plant of the grain terminal which has ample capacity.
- Bilge water will be treated and contaminated bilge water stored in the LPG storage vessel in a 100 tonne container and pumped to tanker truck for disposal.

5.1.5 Vegetation Management Plan

The upland vegetation for the LPG terminal will be cleared, which may result in direct loss of vegetation and minor amounts of windthrow involving trees along the margins of the undisturbed forest. Many of the shrub areas on the old fill of the grain terminal construction, can be landscaped between the tank farm, road, rail and refrigeration plant. This, in conjunction with the berms and soil stockpile margins, can create an attractively landscaped buffer between those facilities. In addition, the drainage to the pond and, ultimately, into Porpoise Harbour can revegetate into a wetland pond if designed using Land Development Guidelines for the Protection of Aquatic Habitat (Chillibeck, 1993).

The strategic selection of several veteran conifer trees adjacent to the tank farm could significantly reduce the visual impact of the facility. Tree selection would involve careful estimation of low hazard locations as well as the windfirmness and visual screening of candidate trees within each area.

Intertidal Vegetation

The intertidal rocky reef, boulder beach and eelgrass mudflat have habitats which will be lost due to the filling of the causeway and require compensation as part of the policy of the Department of Fisheries and Oceans policy of "no net loss of fisheries habitat". The compensation ratios for the Fairview Terminals for eelgrass were at 1.5:1, while compensation for mudflat was not required. A 1:1 ratio was applied to the Fucus and rock reef habitats. A discussion of the compensation success of the eelgrass receptor site is included in Appendix D. This may help set compensation ratios for the LPG terminal to mitigate habitat loss of the intertidal and subtidal.

Photo 5.2-1
Fairview Terminals eelgrass receptor site

Photo 5.2-2
Closeup of Fairview Terminals eelgrass
receptor site

5.1.6 Wildlife Management

The loss of upland wildlife habitat can be mitigated through vegetation management, which creates ecotones at the edge of the plant. In addition, landscaped buffers between the refrigeration plant, tankage, road and rail facilities would create some habitat which could make up for loss of bird habitat. The raptor roost areas along the shoreline should consider maintenance of some large veteran trees, if possible.

Marine Environment

Mitigation of the marine area should include the establishment of shoreline buffers to separate the high water mark from the tank farm and provide protection from land. The provision of this shelter strip is particularly important during low tide when some waterfowl feed in the intertidal.

Fish and Invertebrates

Besides direct loss of habitat of both intertidal and subtidal areas, fish and invertebrates are affected by the presence and noise caused by the activities of vessel movement and land based vehicles on the causeway. In general, fish exhibit avoidance behaviour when confronted with unusual noise and events. However, sufficient escapement on each side of the causeway so as to avoid entrapment in created tidal pools has to be provided. The adjacent low areas should be shaped such that major tide flats can naturally empty and drain into the adjacent ocean. This is particularly important where water can drain through the core of the causeway and riprap, leaving fish and other invertebrates entrapped.

Movement of fish, in particular juvenile salmonids, within the newly created embayments on each side of the causeway is not expected to be a problem, especially once the causeway has revegetated with macrophytes. Attention should be given to where the causeway ends and the piled pier connects to the moored LPG storage vessel. Sufficient room should be left to allow fish movement.

5.2 Compensation Options

Options for compensation of intertidal and subtidal habitat are possible both on-site and off-site. An existing compensation site for Fairview Terminals, directly south of Philips Point, has established and created the knowledge to conduct eelgrass compensation. On-site compensation sites are located each side of the causeway through the creation of embayments at the mudflat elevation and the creation of rocky reefs which will shore up the mudflats.

Compensation off-site could include:

- extension of the existing Fairview Terminals receptor site to establish compensation for present and future LPG and bulk liquids terminal habitat loss;
- compensation may be possible at the south of Digby Island where large, shallow boulder shelves could be cleaned up and filled with sand and mud for the creation of a receptor site; and
- creation of smaller receptor sites south of Casey Point, expanding the existing eelgrass pockets.

Status of Fairview Terminal Eelgrass Transplant

Appendix D contains reports by Dr Paul Harrison and Duncan Hay, PEng discussing the future remediation for improvement of the eelgrass receptor site. As of the fall of 1992, of the 3,200 m^2 of planted eelgrass, only 1,600 m^2 have survived. Reasons for this die-back have been identified as being physical reasons. These have been remedied in the summer of 1993 and the site is expected to recolonize to the 3,200 m^2 by 1994-1995 (Figure 5.2-1).

Photo 5.2-3
Potential compensation site south of Casey Point

Photo 5.2-4
Potential compensation site at South Digby Island

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Appendix A

INTERTIDAL HABITATS PHOTOGRAPHIC SURVEY

SECTION 1
THE ROCKY INTERTIDAL ZONE

a) The Kelp Zone:
(approximate locations of photographs are given on Figure 3.3-18)

Photo i
Kelp ledge at low tide level on the seaward side of the outer reef. This is the area showing the most prolific kelp growth.

Photo ii
Close up of kelp in Photo i showing *Laminaria groenlandica* as well as *Alaria marginata*. This is the location of one of the quantitative kelp counts in Figure 3.3-15.

Photo iii
Ledge shown in Photo i, showing extent and density of kelp ledge at A. Laminaria and Nereocystis predominate and mixed red and brown filamentous can also be seen.

Photo iv
Close up of Laminaria and one large Nereocystis on ledge.

Photo v
Kelp below tideline at
Point B on Figure 3.3-18.

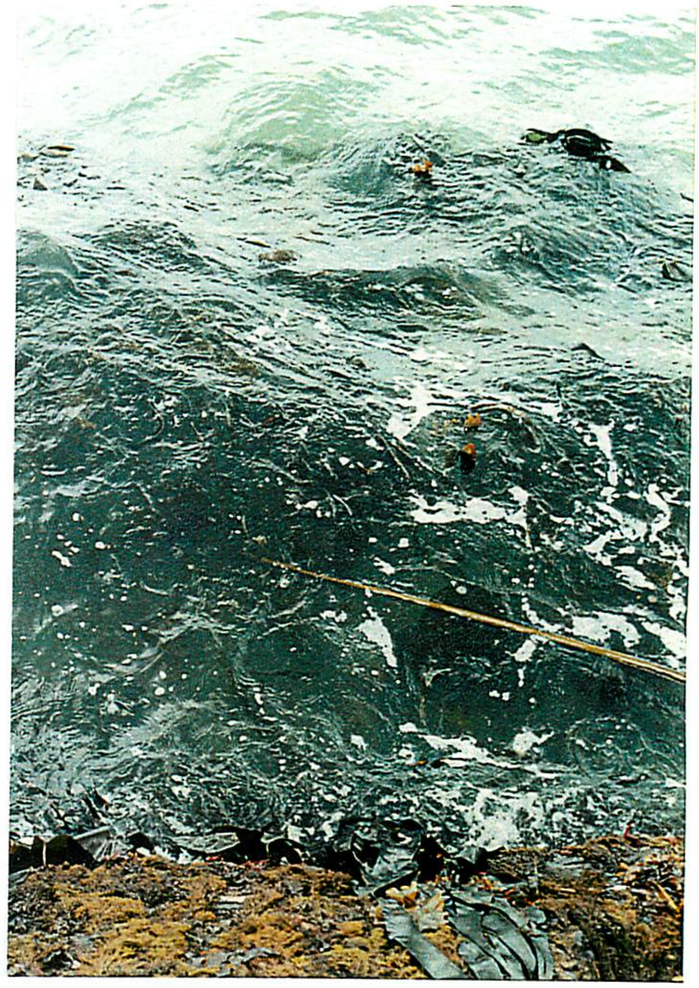


Photo vi
Kelp and *Palmaria palmata* on rocks leading down to tideline. Kelp extends below tideline.

Photo vii
Small amount of *Laminaria groelandica* and *Laminaria saccharina* below tide line at or near Point C on Figure 3.3-18.

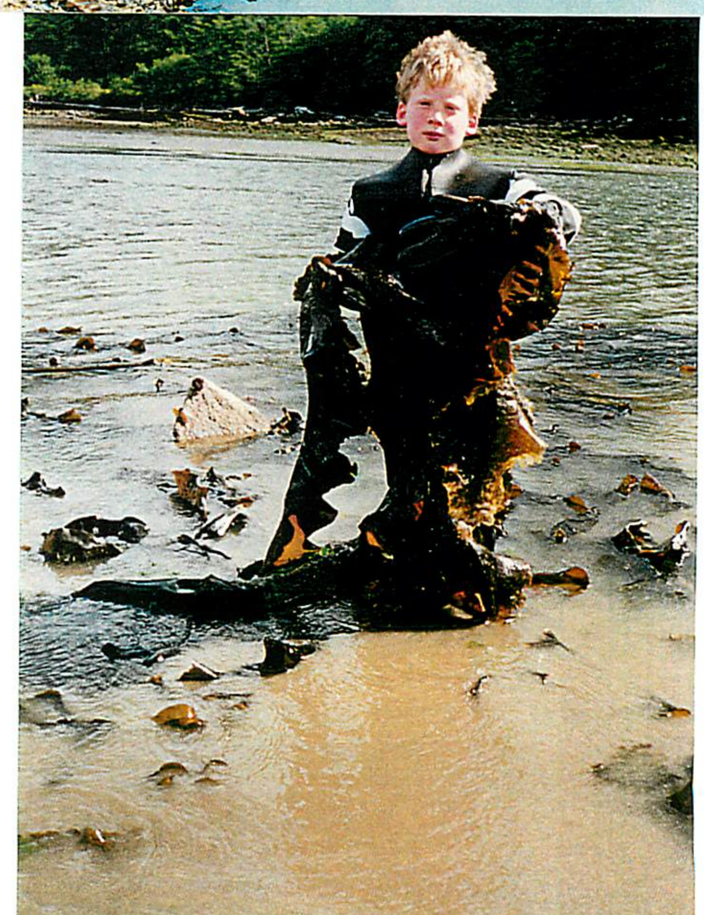


Photo vii
Close up of *Laminaria saccharina* blade from Photo v above.

Photo ix
Kelp on mixed small rock and mud at tideline at Point D, South Kaien Island shoreline. The width of this band varies between 1 and 3 m in this area.

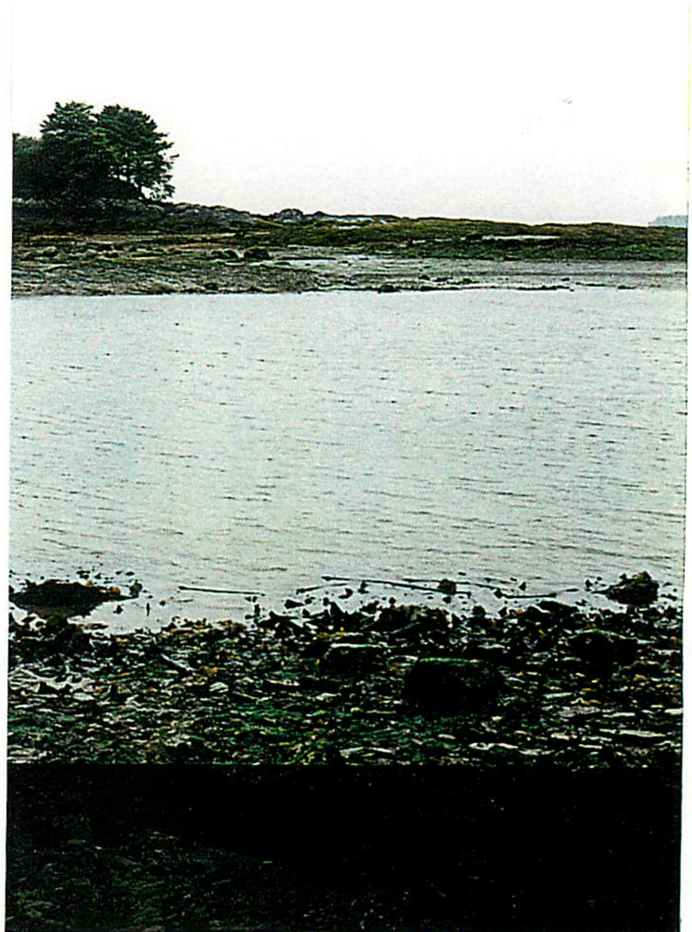


Photo x
Narrow band of *Laminaria goenlandica* and *Laminaria saccharina* at limited points near Point E, Figure 3.3-18.

SECTION 1
THE ROCKY INTERTIDAL ZONE

b) The Ulva/Barnacle/Polysiphonia Zone
(approximate locations of photographs are given in Figure 3.3-17)

Photo i
On right, Ulva on the rocks rising from the mud of this relatively protected channel.

Photo ii
Close up of Ulva, Fucus and Halosaccion in region shown in Photo i above.

Photo iii
Ulva and barnacles on rock face near Point B on Figure 3.3-19.

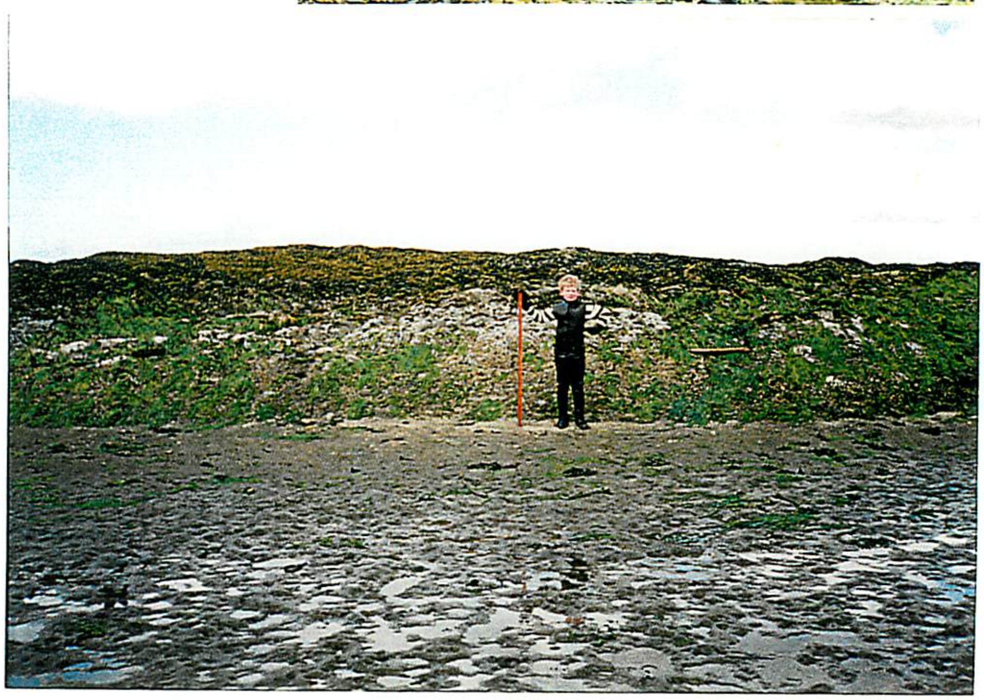


Photo iv
Ulva on rocks rising from mud flat near Point C in Figure 3.3-19. Ulva band estimated to vary between 1 and 1.5 m in height in this region.

Photo v
Closeup of Ulva on rocks at Point C on Figure 3.3-19.

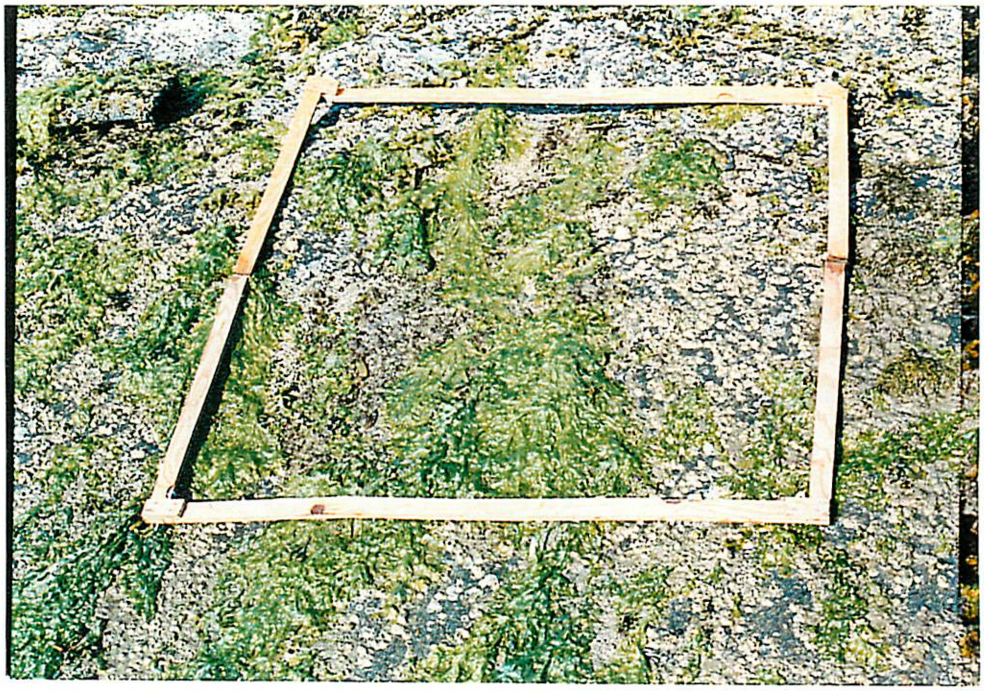


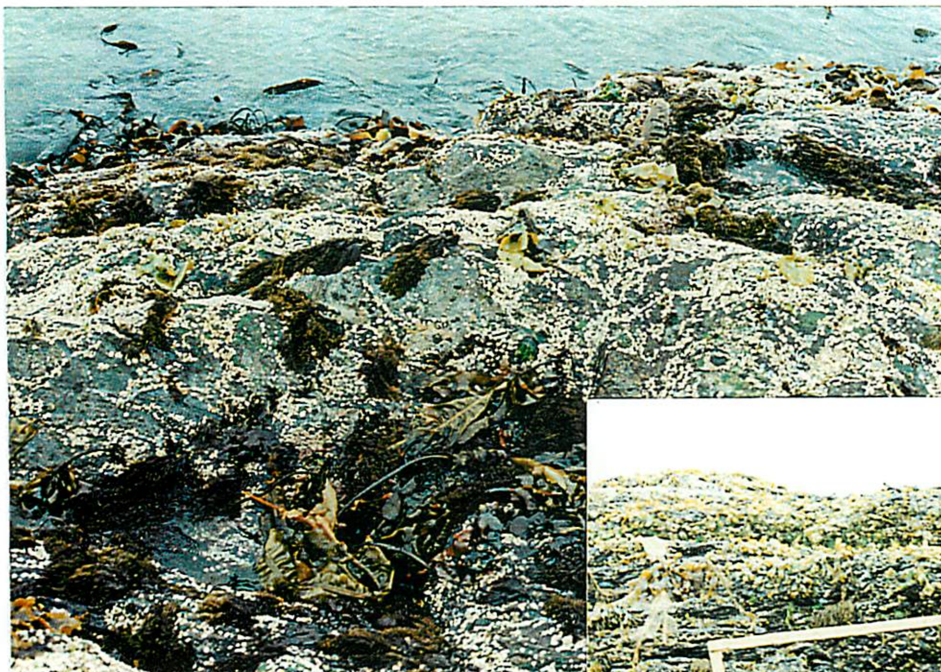
Photo vi
Ulva zone along the South Kaien Island shoreline (Point D of Figure 3.3-19). In this area the Ulva is growing on mixed small rocks and a few larger boulders. Sedimentation appears to be fairly heavy in this area making growth and attachment of seaweeds more difficult than in other areas.

Photo vii
Ulva growing on loose rocks along the South Kaien Island shoreline (Point D on Figure 3.3-19). A number of small red algae (Rhodophyta) can also be seen here.

SECTION 1
THE ROCKY INTERTIDAL ZONE

c) <u>The Alaria/Halosaccion Zone</u>
(approximate locations of photographs are given on Figure 3.3-19)

Photo i
Alaria, Polysiphonia and barnacles at Point E of Figure 3.3-19. This represents an overlap region between the previous zone (Ulva/Barnacles/Polysiphonia) and this zone.



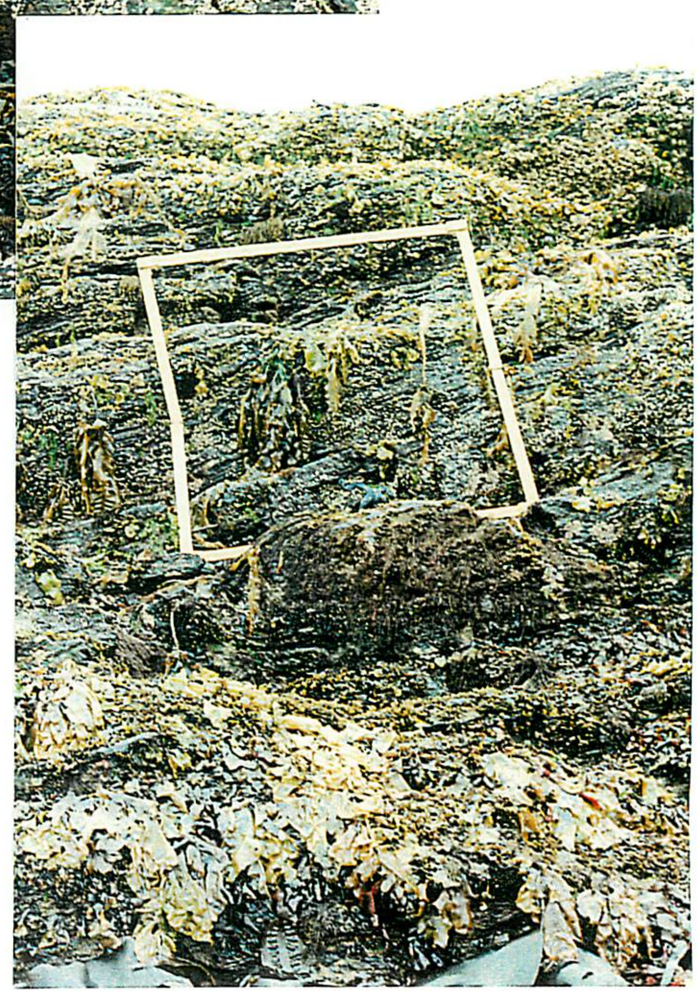


Photo ii
Alaria/Halosaccion zone on rock face at Point E on Figure 3.3-19.

Photo iii
Close up of Alaria on the rock face at Point E on Figure 3.3-19.

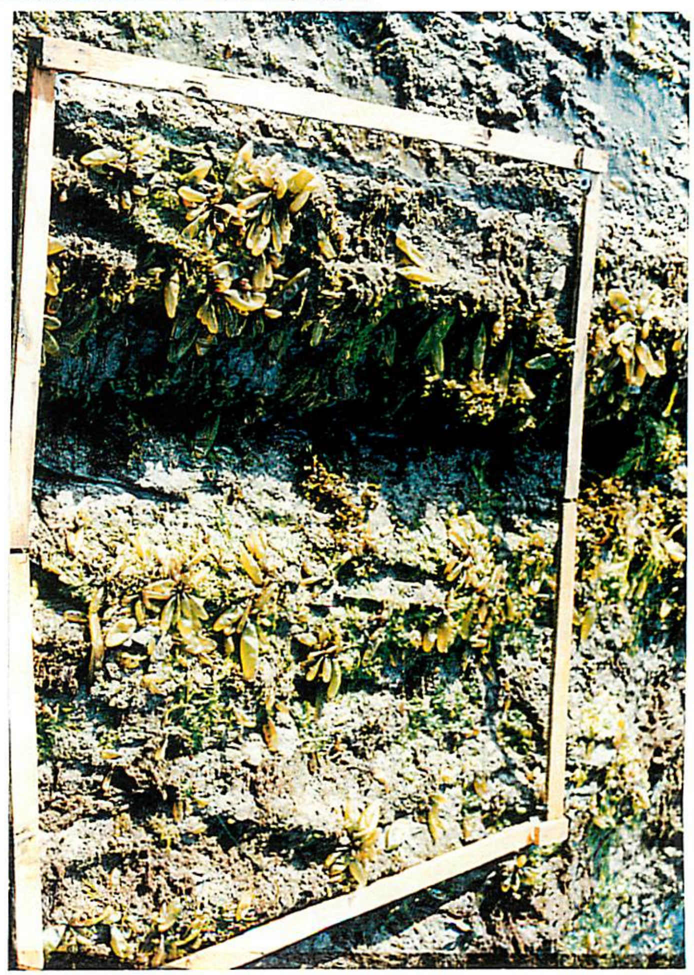


Photo iv
Close up of Halosaccion on the rock face at Point E on Figure 3.3-19. Halosaccion in the rock crevices utilizes all available growing space.

SECTION 1
THE ROCKY INTERTIDAL ZONE

d) <u>Fucus Zone</u>
(approximate locations of photographs are given on Figure 3.3-20)

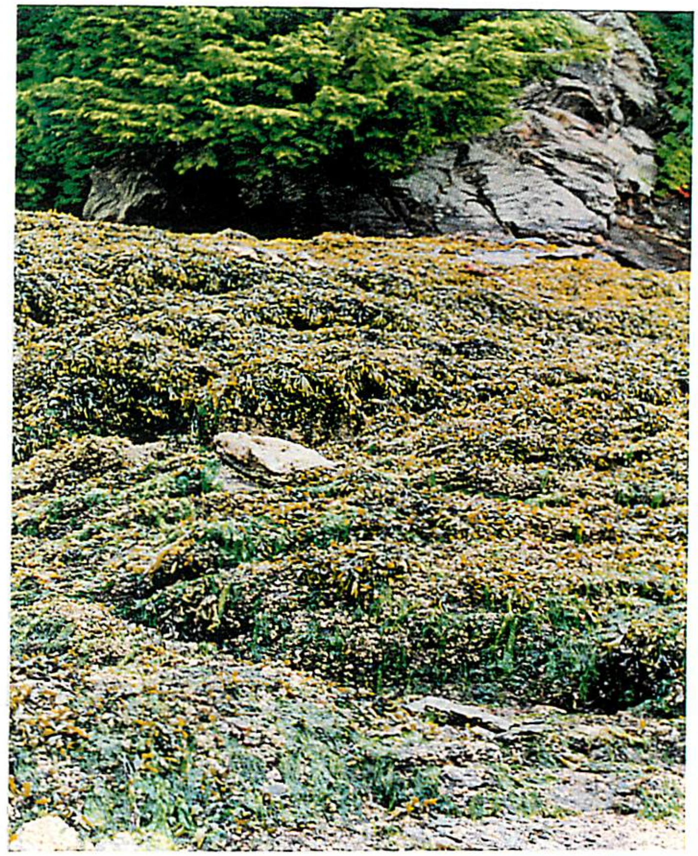


Photo i
From the South Kaien Island shoreline looking towards the splash zone. The steep embankment almost eliminates the limpet/barnacle zone and the algae/lichen zone.

Photo ii
From the South Kaien Island shoreline looking out along the line of the causeway over the Fucus zone (at Point A on Figure 3.3-20).

Photo iii
Looking back along the length of the causeway from Point B on Figure 3.3-20. The Fucus zone of Point B is shown in the foreground.

Photo iv
Close up of Fucus on rocks at Point B on Figure 3.3-20.

Photo v
Dense Fucus coverage on rock at Point C on Figure 3.3-20.

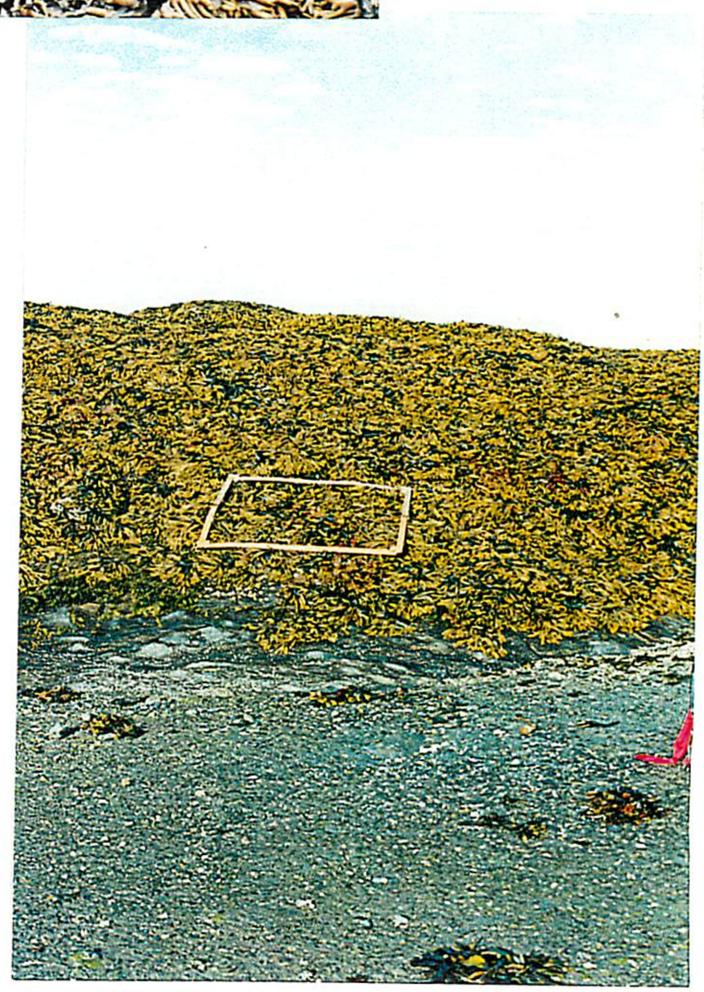


Photo vi
Dense Fucus on rock formations at Point C. This illustrates the fact Fucus requires a stable substrate for attachment since the Fucus ends when the rock formations end.

Photo vii
Close ups of Fucus at Point C

Photo vii
Fucus on boulders at Point D on Figure 3.3-20.

Photo ix
Fucus Zone: from Point E on Figure 3.3-20 looking out along the top of the rocks to Point F.

Photo x
Dense Fucus at Point F on Figure 3.3-20. The photo is taken looking out towards the red can buoy.

Photo xi
Close up of Fucus at Point F on Figure 3.3-20.

Photo xii
Fucus lifted aside to reveal barnacle coverage underneath

SECTION 2
MUD FLAT

a) <u>Eelgrass Patches</u>

Photo i
Photo showing eelgrass patches at "B" on Figure 3.3-16. Counts for these patches are also given under B of Table 3.3-14. These are the most extensive eelgrass patches within the proposed causeway foot-print area.

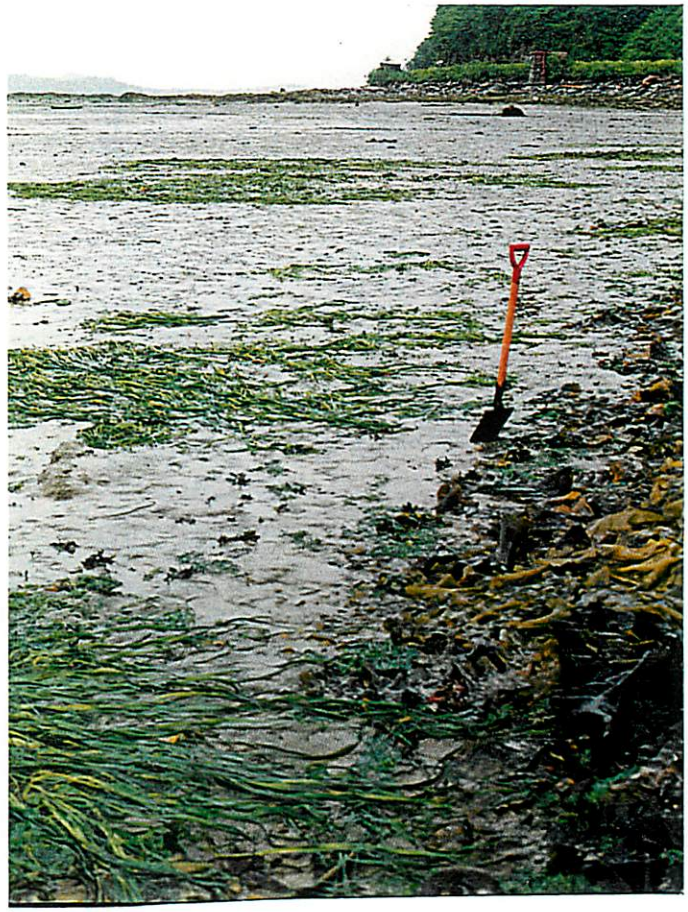
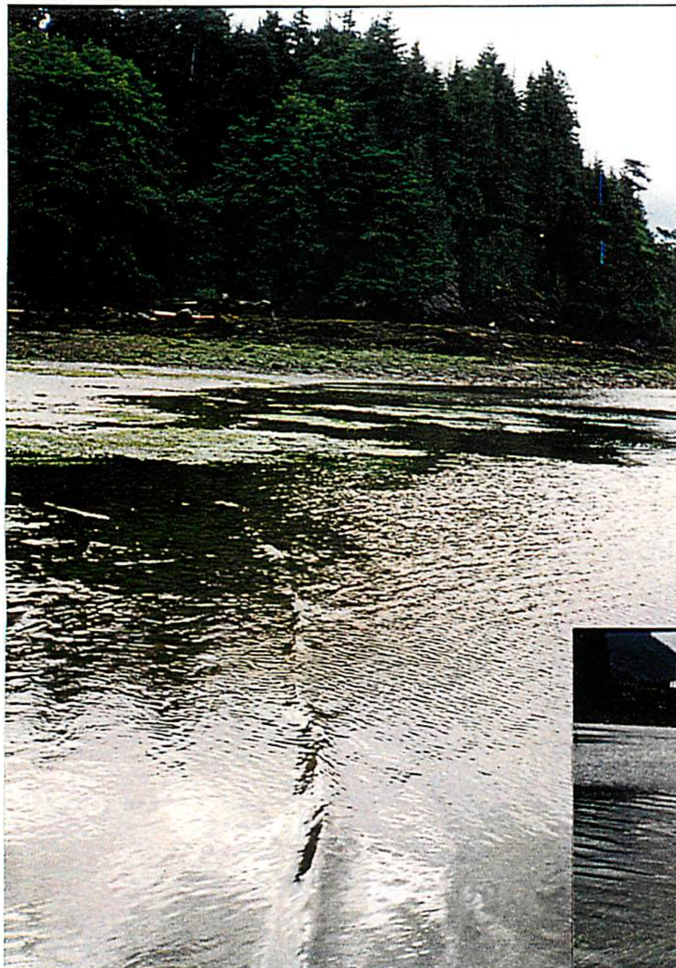


Photo ii and iii
Closeups of eelgrass
at tide line in
patches at "B" as
described for Photo
i above.

Photo iv
View of eelgrass at
"B" taken from mudflat.



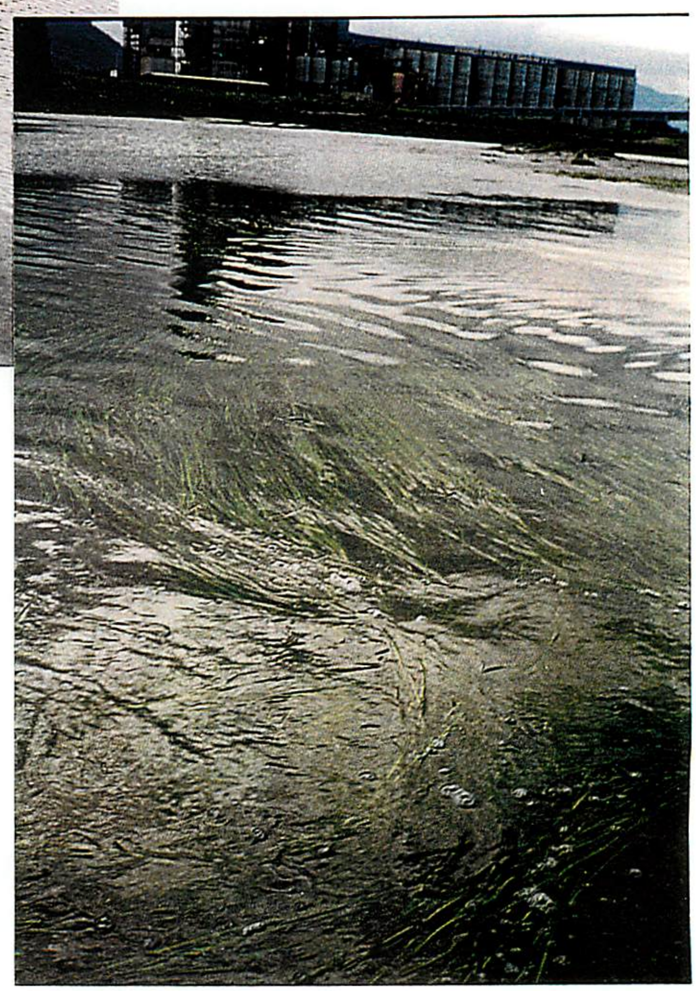
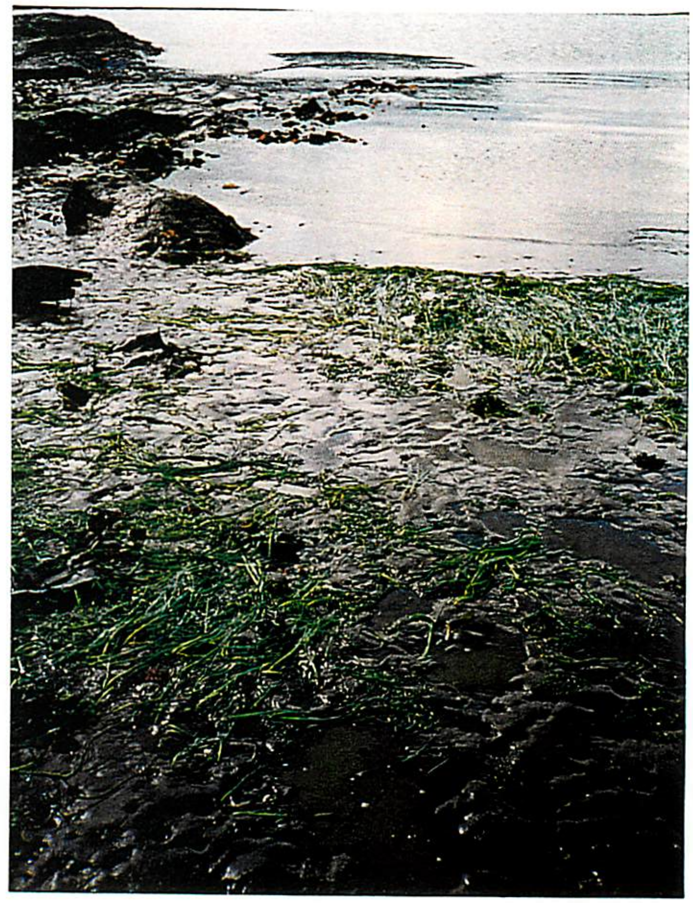


Photo v
Eelgrass at high tide
line and below at "B"
on Figure 3.3-16.
Taken at low tide on a
1.2 m tide.

Photo vi
Patches of eelgrass at Point A in Figure 3.3-16. Quantitative counts for these patches are also given under A in Table 3.3-14.

Photo vii
Patches of eelgrass at Point C on Figure 3.3-16. Quantitative counts for these patches are also given under "C" in Table 3.3-14.



SECTION 2
MUD FLAT

b) Mud Flat

Photo i
Overview of mud flat showing extensive area outside of footprint as well as the footprint area. Generally includes Area D indicated on Figure 3.3-16.

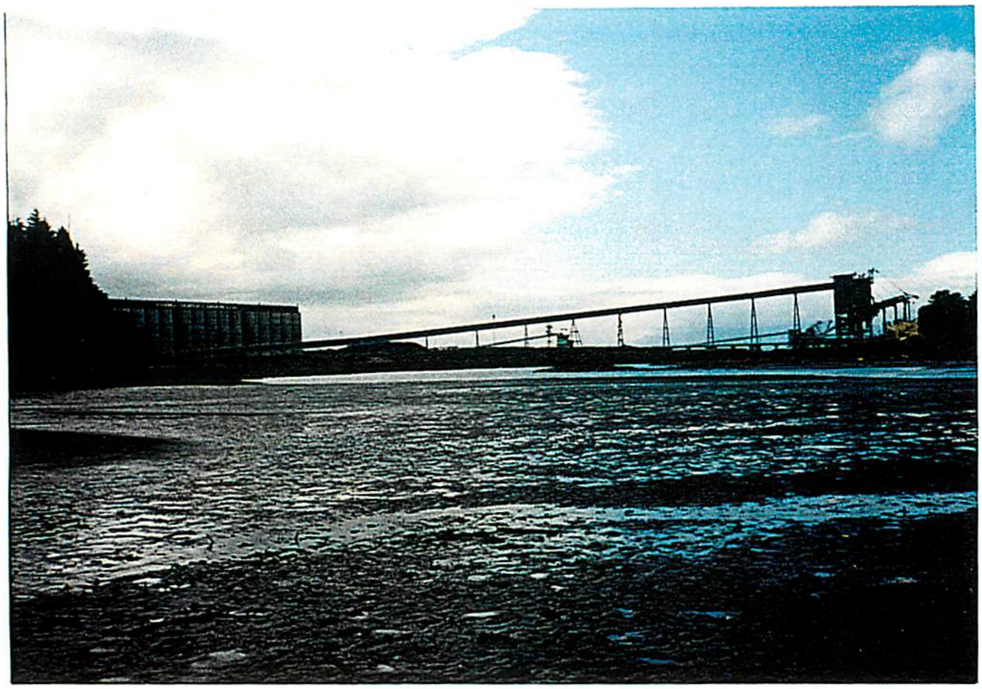


Photo ii
A very productive area in Area D and one of the locations for the quantitative counts.

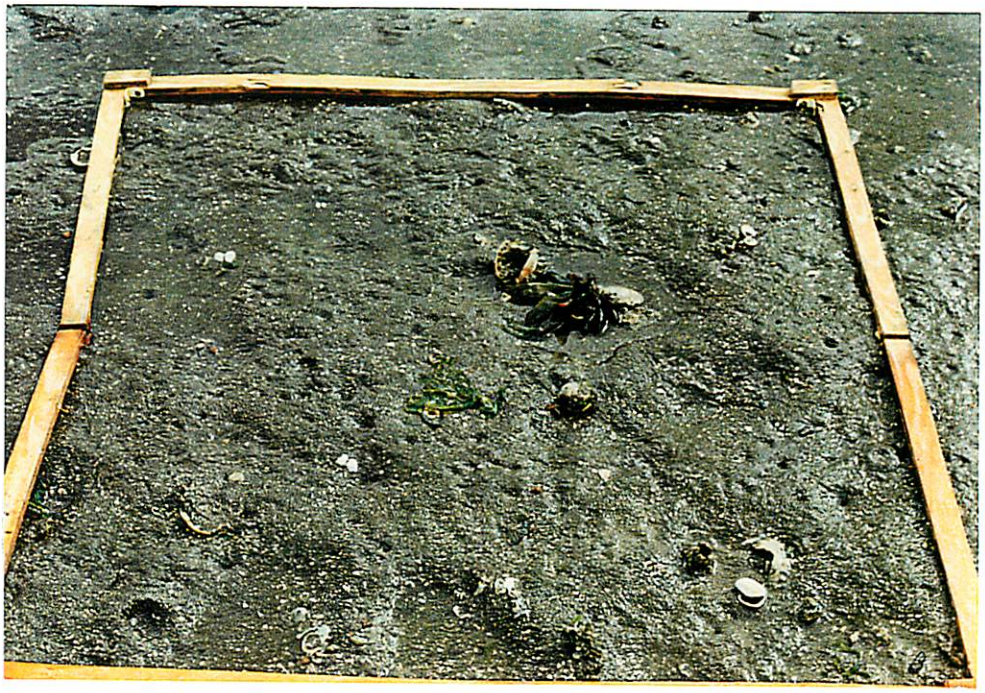


Photo iii
Another example of mud flat in Area D but a less productive quadrant than the one shown in Photo i above.

Photo iv
A gravelly bar located close to Bishop Island at higher elevation than the main mud flat. It was included under mud flat for purposes of determining total area of mud flat but was not included in the quantitative productivity counts.

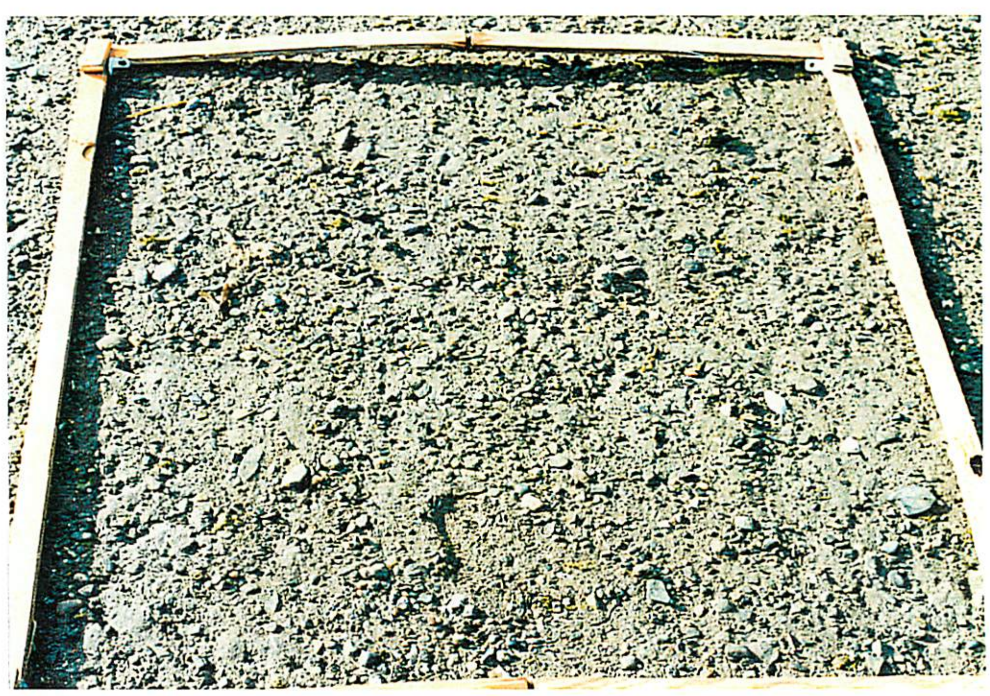


Photo v
Overview of mudflat at Point E on Figure 3.3-16.

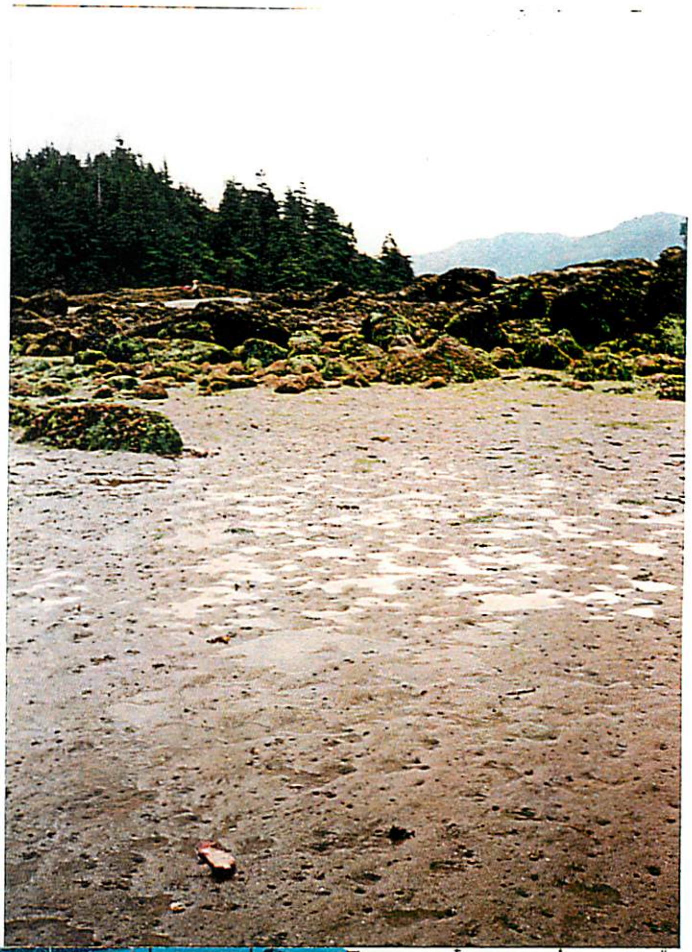
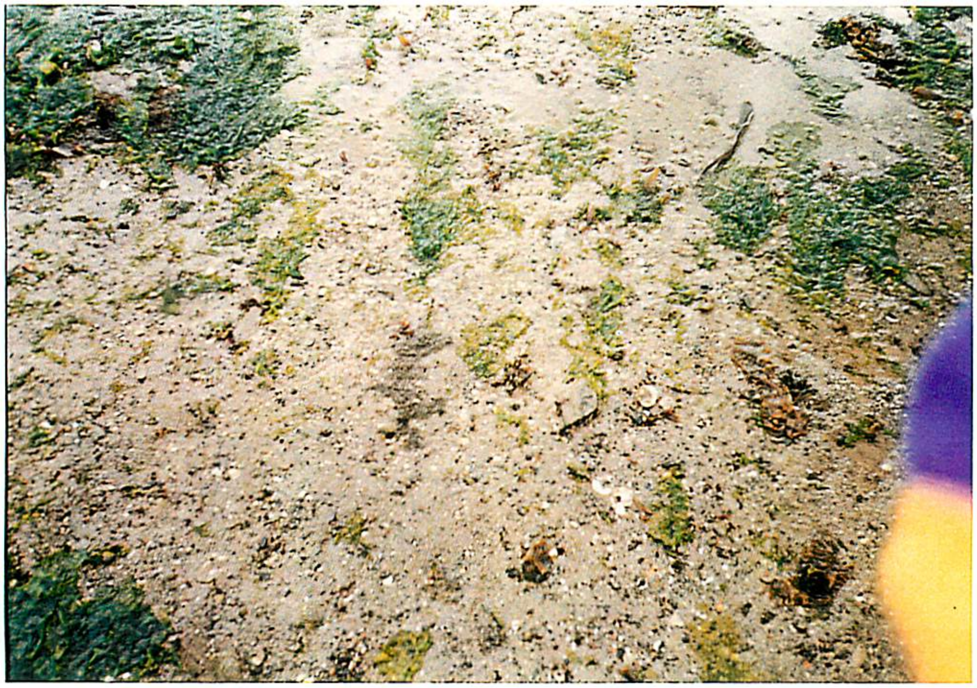
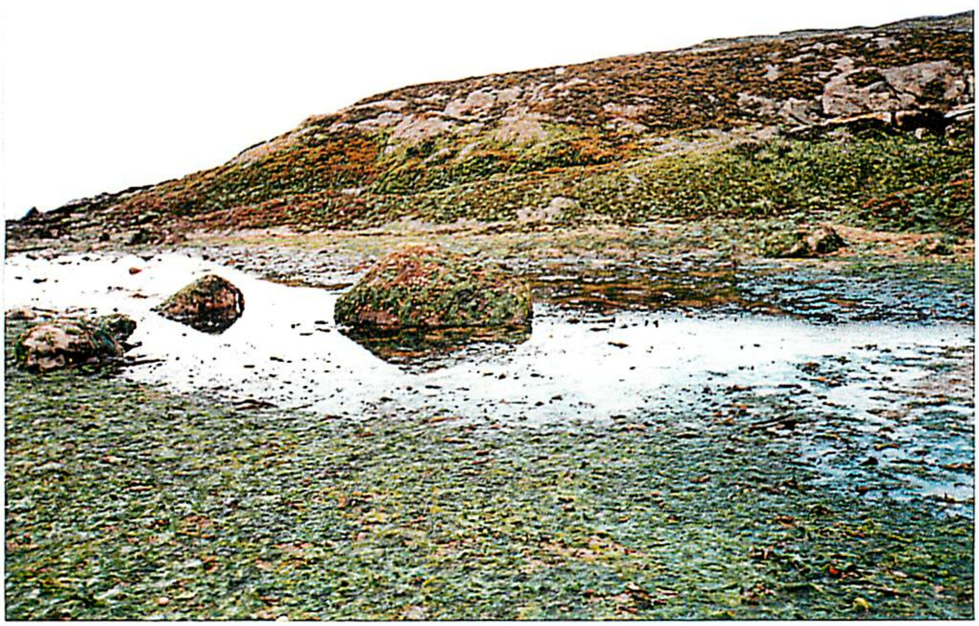


Photo vi
Overview of the mudflat at Point F on Figure 3.3-16. This appears to be an area of reduced circulation with a tendency for debris to accumulate.

Photo vii and viii
Closeups of mud flat with debris and loose Ulva at Area F on Figure 3.3-16.





Appendix B

HISTORICAL AND ARCHAEOLOGICAL ASSESSMENT

prepared by

DAVID ARCHER, HERITAGE CONSULTANT

A DETAILED HERITAGE IMPACT ASSESSMENT OF TWO PROPOSED DEVELOPMENT PROJECTS AT THE SOUTH END OF KAIEN ISLAND: AN LPG TRANSFER FACILITY AND AN MTBE MANUFACTURING PLANT AND SHIPPING TERMINAL

Prepared by

David J.W. Archer
Heritage Consultant

589 5th Avenue East
Prince Rupert, B.C. V8J 3Y3
624-6894

for

Prince Rupert Port Corporation
110 3rd Avenue West
Prince Rupert, B.C. V8J 1K8

September 17, 1993

MANAGEMENT SUMMARY

Two major development projects have been proposed for the south end of Kaien Island. One is a new transfer facility designed to handle liquid petroleum gas (LPG); the other is a new production plant for manufacturing and shipping methyl tertiary butyl ether (MTBE). Both projects will have an extensive impact on the local landscape, and in view of this, a heritage impact assessment of the proposed developments was requested. The assessment process involved two components: (1) a search of library and archival sources relating to the history and prehistory of the area and (2) an in-field heritage site survey. Four days were allocated to research on the ethnography, archaeology and history of the region, with the aim of determining the heritage potential of the study area. This was followed by two days of in-field site survey.

As a result of these investigations two heritage sites were identified within the boundaries of the study area. GbTn-18 is a small shell midden located at the southern tip of Kaien Island. It falls within the area to be developed for the LPG facility. However, GbTn-18 was completely destroyed in the early 1980s when the Ridley Island Access Road was constructed. There are no other potential heritage conflicts with the proposed LPG facility. The other heritage site, GbTn-T1 (1993) is located within the area of the proposed MTBE plant. This is a new site that was discovered during the in-field survey. The site was identified on the basis of a single stone artifact, known as a cobble chopper. The artifact was not in its original position, but the general context of the find suggests that it

may date to the early postglacial period (8,000 to 12,000 years ago). If this proves to be the case, it would be a very significant discovery, since the archaeological record for the Prince Rupert area currently reaches back only 5,000 years. It is strongly recommended that the initial phase of the plant construction be monitored by a qualified archaeologist in order to locate the site from which the cobble chopper came. If the site can be found and if it is still partly intact, an archaeological salvage excavation should be conducted before the development of that area proceeds.

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INTRODUCTORY STATEMENT

This report has been prepared at the request of the Prince Rupert Port Corporation. It represents a detailed heritage impact assessment of two proposed development projects slated for the south end of Kaien Island. One is a new transfer facility designed to handle liquid petroleum gas (LPG); the other is a new production plant for manufacturing and shipping methyl tertiary butyl ether (MTBE). The purpose of my investigation is to assess the impact of these projects on the heritage resources of the area and, if necessary, to make recommendations for impact mitigation or for continued monitoring of the area as construction proceeds.

The assessment process involved two components: (1) a search of library and archival sources relating to the history and prehistory of the area and (2) an in-field heritage site survey. Four days were allocated to research on the ethnography, archaeology and history of the region, with the aim of determining the heritage potential of the study area. This was followed by two days of in-field site survey, the goal of which was to locate and evaluate any heritage resources that might be present. The results of the background research and field survey are presented in the current report. It begins with a brief description of the two proposed development projects and their potential impact on local heritage resources. Data on the natural environment of the area are then summarized, with an emphasis on those characteristics that may have influenced human occupation from earliest times to the recent past. Attention then turns to the ethnography, history and archaeology of the area. This section ends with a listing of known heritage sites within the study area, based on heritage surveys conducted over the last several decades. The current field investigations are then described and the findings presented in detail. The conclusion to the report contains a summary and discussion of the results, together with recommendations for further action.

PROPOSED DEVELOPMENT PROJECTS

The Prince Rupert Port Corporation is currently engaged in two major development projects at the south end of Kaien Island. The first of these is a new liquid petroleum gas (LPG) transfer facility to be located between the CNR mainline and the existing grain terminal facility at the north end of Ridley Island. The project will involve the construction of a rail receiving yard and a refrigeration plant and pumping station on the east side of the Ridley Island Access Road, as well as storage tanks for the product on the west side of the road. A new berthing facility will also be required, and this will involve the construction of a rock-fill causeway extending from the south end of Kaien Island across Bishop's Island to the deeper waters just beyond. Construction is scheduled to begin in January 1994 and the facility is expected to in operation by March 1994. The project will involve extensive alteration to the area between the CNR mainline and the northern tip of Ridley Island and any heritage sites that might be located within the impact zone would likely be destroyed.

The second development project slated for this area is a new manufacturing and shipping facility for methyl tertiary butyl ether (MTBE). MTBE is a fuel additive that reduces hydrocarbon emissions in automobile exhaust. The plant will be operated by Ecofuel, an international petrochemical firm based in Milan, Italy. The proposed site for the new facility is at the southwest corner of Kaien Island, north of the CNR mainline and west of the Ridley Island Access Road. The development will entail construction of a manufacturing plant, as well as receiving, storing and shipping facilities. An assessment is currently underway to determine the technical and financial viability of the project, as well as its environmental acceptability. Depending on the results of this assessment, construction could begin as early as 1994, with the plant potentially opening in 1996. During the initial phase of construction an extensive amount of land alteration will occur. The plant site will be leveled, and the fill from this operation will be used to create the adjacent berthing facility. The nature of the development is such that any heritage sites located in the area of the plant would be completely destroyed.

THE STUDY AREA

The area to be impacted by these two development projects includes the southwest corner of Kaien Island and the northernmost tip of Ridley Island (Figure 1). This, then, constitutes the study area for the current investigations. The following pages serve to place this tiny area within the broader context of Prince Rupert Harbour and the surrounding terrain.

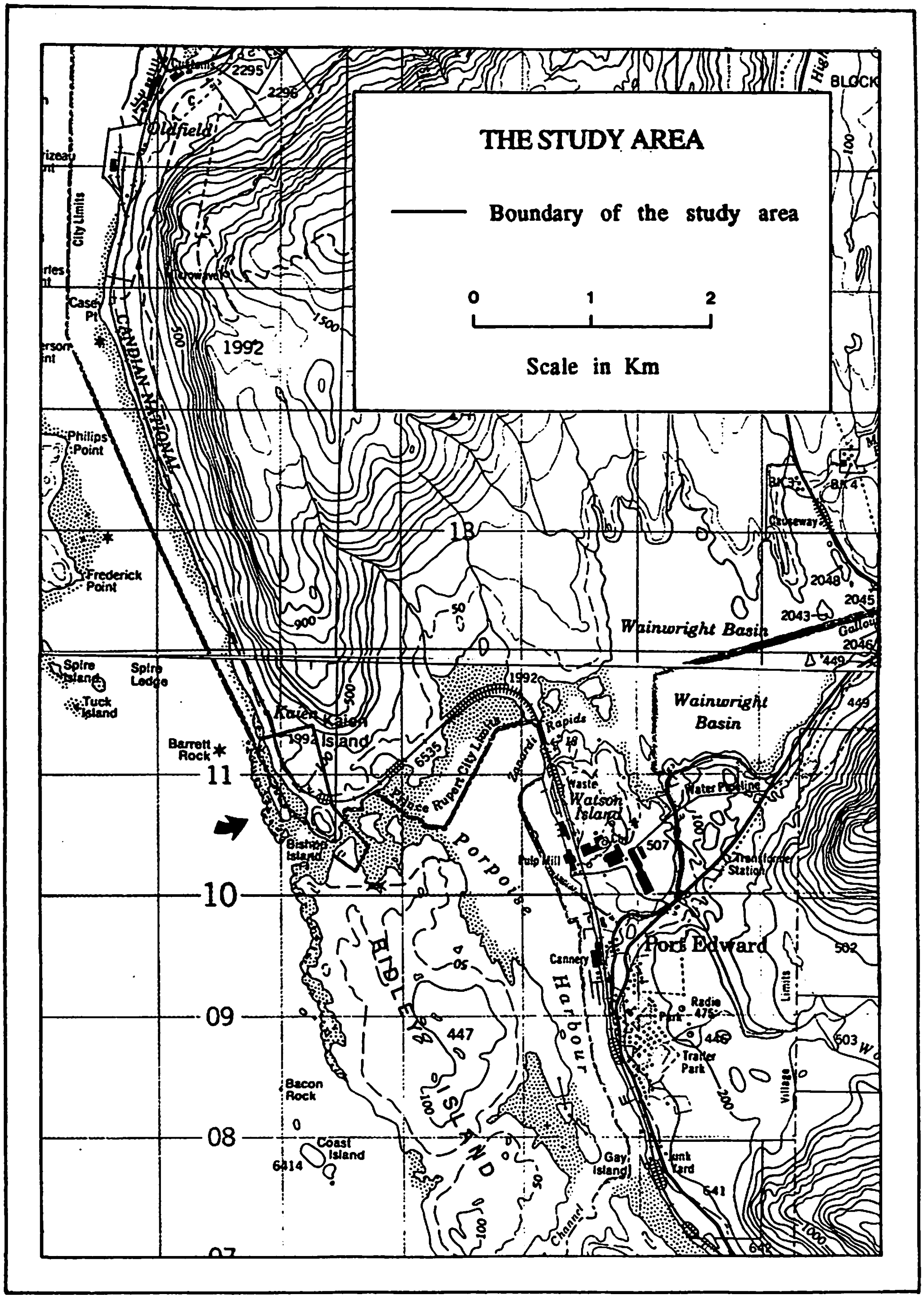

Figure 1. The Study Area.

Physiography

The study area lies at the junction of two major physiographic subdivisions: the Hecate Depression and the Coast Mountain Area. The Hecate Depression, part of the Coastal Trough, is a structurally depressed area lying between the Queen Charlotte Islands and the mainland coast. Although much of it is submerged beneath the waters of Hecate Strait, the eastern edge of the depression rises above sea level to form a low, flat coastal plain, known as Hecate Lowland (Holland 1964:28, 32). Many of the large offshore islands, including Dundas, Melville, Stephens, Digby, Ridley and Lelu fall within this zone. By contrast, the mainland portion is small and basically limited to the western half of Tsimspsean Peninsula. In general, elevations within Hecate Lowland are less than 100 m, though hills and ridges up to 750 m in elevation do occur. Drainage patterns tend to be poorly developed and large expanses of muskeg are a typical feature of the area.

Towards the east, the lowland terrain gradually increases in relief, eventually merging with the Kitimat Ranges of the Coast Mountain Area. Most of Kaien Island falls within this area. The high point on the island is the summit of Mount Hays with an elevation of about 670 m. Elsewhere on the north coast the mountains rise to elevations of 1200-1500 m, while further inland, there are peaks as high as 2100 m. The lower mountain tops, like Mount Hays, are typically rounded and dome-like in outline, while those above the 1800 m level are generally rough matterhorns. Small alpine glaciers are present within the Kitimat Ranges but are not widespread. Along the coast, deep fiord inlets are a common feature. The lower course of the Skeena River was once a fiord, but over time the depths have gradually filled with river-laid deposits (Dolmage 1923:11). Drainage patterns vary within Coast Mountain area. The principal drainage system of the region is the Skeena River, with an overall length of 580 km. The Skeena has a number of important tributaries along its length including the Exchamsiks, the Exstew, the Gitnadoiks and the Ecstall. Coastal areas, on the other hand, are largely independent of the Skeena system. The mountains and valleys along the shore are drained by many small streams and rivers that flow directly into the sea. Most of these are only a few kilometres long.

Climate

The climate of the Prince Rupert area is influenced by two important features: a warm offshore current and the steep mountain ranges that run along the coastline. The offshore current, known as the North Pacific Drift, moves northward along the coast of British Columbia and acts as a heating agent for the offshore air masses. At the same time, the Coast Mountains serve to restrict the movement of air masses between the coast and interior. As a result, the coast is dominated thoughout the year by mild maritime systems, whereas the interior is controlled by continental air masses, having a much wider annual range in temperature. The coast mountains also have a profound effect on precipitation levels. Driven by the prevailing westerly winds, moisture-laden air from the Pacific is forced to ascend the rugged western slopes of the mountains causing heavy condensation. By contrast, the air that continues into the interior is relatively dry (Kendrew and Kerr 1955). These two effects combine to create marked differences in climate between the coast and adjacent interior.

Climatic records are available for two stations in the region: Prince Rupert, located on the coast, and Terrace, located about 120 km inland. Selected data from the two stations are presented in Table 1. Note that the winters are unusually mild on the coast. At Prince Rupert the mean daily temperature for January, the coldest month of the year is still above the freezing point. Inland, at Terrace, winters are more severe. Mean daily temperatures are below feezing in December, January and February, and most of the precipitation during these months comes in the form of snow. On the coast, rain and cloudy skies are the typical winter conditions. Snowfalls tend to be light, and generally the snow remains on the ground for only a few days at a stretch. Storms are common on the coast during the winter months and are usually accompanied by heavy rains and strong southeasterly winds. Summer is the dry season throughout the area. In Prince Rupert rainfall drops to about 12 cm per month from May through August; Terrace receives less

Table 1. Selected Temperature and Precipitation Records for Prince Rupert and Terrace.

Weather Station	Mean Daily Temp. Jan.	Mean Daily Temp. July	Mean Annual Rainfall	Mean Annual Snowfall
Prince Rupert	1.8° C	13.6° C	230.1 cm	113.0 cm
Terrace	-5.0° C	16.5° C	91.7 cm	181.6 cm

than half this amount. Mean daily temperatures at Terrace are consistently a few degrees higher at Terrace than at Prince Rupert. Both Terrace and Prince Rupert are, of course, low altitude weather stations. With increasing elevation above sea level, temperatures decline, precipitation levels tend to increase and a much higher proportion of the precipitation falls as snow.

Flora and Fauna

Three biotic zones are represented in the north coast region: the Coast Littoral Zone, the Coast Forest Zone and the Alpine Zone (Cowan and Guiguet 1965:17-28; Lyons 1965:7-13). Each of these is characterized by a distinctive association of plant and animal life. Our current study area lies at the junction between the Coast Littoral Zone and the Coast Forest Zone and partakes of both.

The Coast Littoral Zone includes the intertidal areas as well as the shallow offshore waters covering the continental shelf. The plant life in this zone consists mainly of various species of seaweed. Eelgrass (Zostera marina) and bladder wrack (Fucus furcatus) are common along the shoreline, while bull kelp (Nereocystis luetkeana) is abundant in waters 2-15 m deep (Carl 1966:17-21; McConnaughey and McConnaughey 1985:85-96).

The animal life within the Littoral Zone is immensely varied. Mammals found in the offshore waters include the hairseal (Phoca vitulina), northern sea-lion (Eumetopias jubata), harbour porpoise (Phocaena vomerina), Dall porpoise (Phocaenoides dalli), Pacific striped dolphin (Lagenorhynchus obliquidens), and killer whale (Grampus rectipinna) (Cowan and Guiguet 1965). Many species of waterfowl winter on the coast, near the mouth of the Skeena and northward along the coastline as far as Port Simpson. Some of the more common winter visitors include the pintail (Anas scuta), greater scaup (Aythya marila), lesser scaup (Aythya affinis), common goldeneye (Bucephela clangula), Barrow's goldeneye (Bucephela islandica), bufflehead (Bucephela albeola), oldsquaw (Clangula hyemalis), common scoter (Oidemia nigra), white-winged scoter (Melanitta deglandi), surf scoter (Melanitta perspicillata), double-crested cormorant (Phalacrocorax auritus), pelagic cormorant (Phalacrocorax pelagious), horned grebe (Podiceps auritus), western grebe (Aechmorphous occidentalis), and arctic loon (Gavia arctica). The common loon (Gavia immer), mallard (Anas platyrhynchos), great blue heron (Ardea herodias), glaucus-winged gull (Larus glaucescens) and several other species of water birds are present throughout the year (Robbins, Bruun and Zim 1966).

The offshore waters also support large populations of fish. Of these the most important are the five species of Pacific salmon: coho (Oncorhynchus kisutch), sockeye (O. nerka), chinook (O. tshawytscha), chum (O. keta) and pink (O. gorbuscha). All five species have major runs in the Skeena River system; chum and pink salmon also spawn in some of the smaller rivers and streams of the region. The timing of the run varies from one species to another, but taken together they span the period from late spring to late fall. Eulachon (Thaleichthys pacificus), another important anadromous species, spawn in the lower reaches of the Nass and Skeena Rivers in late March and April. Non-anadromous species available in the offshore waters include dogfish (Squalus suckleyi), herring (Clupea pallasii), ratfish (Hydrolagus colliei), halibut (Hippoglossus stenolepis), Pacific cod (Godus macrocephalus), starry flounder (Platichthys stellatus), greenlings (Hexagrammus spp.), lingcod (Ophiodon elongatus) and various species of rockfish (Sebastodes spp.) (Hart 1973).

The intertidal zone is a particularly rich habitat for animal life. Several species of bivalves are abundant locally, including butter clam (Saxidomus giganteus), native little-neck clam (Protothaca staminea), basket cockle (Clinocardium nuttalli), horse clam (Schizotherus capax), bay mussel (Mytilus edulis) and California mussel (Mytilus californianus). Other common intertidal spefies include acorn barnacle (Balanus cariosus), rough keyhole limpet (Diodora aspera), wrinkled purple (Thais lamellosa) and leather chiton (Katharina tunica). Northern abalone (Haliotis kamtshatkana), geen sea urchin (Strongylocentrotus drobachiensis) and giant sea cucumber (Stichopus californicus) occur at or below the lowest tide level (Carl 1966; Griffith 1967; Quayle 1973).

The Coast Forest Biotic Zone extends over the lower mountain slopes from sea level to the timber line. Typical of this zone is a dense coniferous rainforest dominated by western hemlock (Tsuga heterophylla), Sitka spruce (Picea sitchensis) and western red cedar (Thuja plicata). In the upper levels these give way to mountain hemlock (Tsuga mertensiana), silver fir (Abies amabilis) and Alaska yellow cedar (Chamaecyparis nootkatensis). Various deciduous species including red alder (Alnus rubra), Sitka alder (Alnus sinuata) and northern black cottonwood (Populus trichocarpa) commonly grow in forest clearings and along the margins of streams and lakes. In the mature forest undergrowth is sparse. Shade tolerant plants such as salal (Gaultheria shallon), bunchberry (Cornus canadensis), wild lily of the valley (Maianthemum dilatatum) and several species of ferns and mosses are common. Open exposed areas often support a rank growth of salmonberry (Rubus spectabilis), Thimbleberry (Rubus parviflorus) and wild rose (Rosa nutkana).

Wildlife populations in the Coast Forest are limited by the low food potential of its climax vegetation. Among the mammals found in this zone are Sitka deer (Odocoileus hemionus sitkensis), wolf (Canis lupus fuscus), red squirrel (Tamisciurus hudsonicus picatus), mink (Mustela vision energumenos), short-tailed weasel (Mustela erminea richardsoni), marten (Martes americana caurina), fisher (Martes pennanti columbiana), American beaver (Castor canadensis belugae), muskrat (Ondatra zibethica spatulata), Canadian river otter (Lutra canadensis pacificus) and porcupine (Erethizon dorsatum). In summer and fall, when the salmon are spawning, American black bear (Ursus areicanus kermodei) may also be plentiful at lower elevations. Other large game animals, such as grizzly bear (Ursus arctos horribilis) and mountain goat (Oreamnos americanus americanus) are rare in the Coast Forest Zone (Cowan and Guiguet 1965).

The Alpine Zone includes those parts of the region that are above the timber line. The lower limit ranges in elevation from 1400 m on the coast to 1700 m further inland. Climax vegetation consists of white moss heather (Cassiope mertensiana), and red and yellow heathers (Phyllodoce empetriformis and P. glandiflora). Scattered clumps of dwarf willow (Salix nivalis), trailing azalea (Loiseleuria procumbens) and dwarf juniper (Juniperus communis saxatilis) are also common. Numerous species of alpine flowers grow in the moister areas. The Alpine Zone supports large numbers of mountain goats and hoary marmots (Marmota caligata raceyi) (Cowan and Guiguet 1965; Lyons 1965:11, 12).

Post-Glacial Changes in the Environment

The last major glacial advance, known as the Fraser Glaciation, began about 25,000 years ago and reached its climax about 14,500 years ago (Clague 1985:256). At that time a continental ice sheet covered the Prince Rupert area. From primary centres in the Kitimat Ranges ice tongues moved westward along valleys such as the Nass and Skeena and out to the coast, coalescing and overriding all of the offshore islands (McConnell 1914:62). By about 14,000 years ago the climate had warmed to the extent that the ice was beginning to recede. Radiocarbon dates show that Hecate Lowland was ice-free by about 12,700 years ago, and the lower Skeena Valley by about 10,200 years ago (Clague 1985:260).

During periods of deglaciation the relative positions of the land and sea are subject to major fluctuations. The basic processes at work are: isostatic rebound of the land surface as the load of ice is reduced and the eustatic rise in the level of the oceans produced by the release of water from the melting ice fields. On a local scale, tectonic movements of the earth's crust, not directly related to deglaciation, may also be important (Clague 1975:17).

At the beginning of the glacial retreat the land was depressed under the weight of ice, and sea levels were high. According to Clague (1985:264), shorelines in the Kitsumkalum-Kitimat trough were about 200 m higher than at present in the period between 10,500 and 11,000 years ago. At this time the lower Skeena Valley as far east as Terrace was an arm of the sea. In the Prince Rupert area the ice cover was thinner, and the land was not so depressed. Evidence is limited, but the suggestion is that sea levels in this area were never more than 135 m above their present position (Clague 1985:262; Heusser 1960:193).

As deglaciation proceeded, the land rebounded producing a drop in relative sea levels. The emergence was very rapid at first, and most of the movement was probably accomplished within 500 years of deglaciation. Data from the Terrace-Kitimat area indicate that shorelines were down to about 120 m above present level by 10,100 years ago and to about 35 m above present level by about 9,300 years ago (Clague 1985:264). At the mouth of the Skeena River, sea levels had fallen to about 2 m above their present level by about 8,500 years ago (Clague et al 1982:604). It is possible that the emergent trend culminated in sea levels slightly lower than those of today. Archaeological evidence from the Prince Rupert area indicates that present shorelines have been inhabited by native Indians for the last 5,000 years, which suggests that sea levels have been stable for at least that long, if not longer.

Palynological research in the different regions of British Columbia show that climatic conditions have fluctuated since the end of the Pleistocene (Banner and Pojar 1983; Heusser 1960; Mathewes and Heusser 1981). Mathewes and Heusser (1981) have proposed a sequence for the southwestern part of the province, covering almost the entire postglacial period. They suggest that the interval between

10,000 and 7,500 B.P. was characterized by conditions that were warmer and drier than at present. This was followed by a cooler and moister interval between 7,000 and 6,000 B.P. Since then, conditions have been much as they are today. Further research is needed to determine whether the same patterns apply to the north coast (cf Banner and Pojar 1983).

To date, the most extensive pollen studies on the north coast are those of Heusser (1960). His samples came from five locations: (1) the north end of Kaien Island; (2) Rainbow Lake, 18 km east of Prince Rupert; (3) Summit, 4 km east of the Rainbow Lake site; (4) Pitt Island, 120 km south of Prince Rupert; and (5) Susan Island, 235 km south of Prince Rupert (Heusser 1960:225). Heusser's data suggest that early postglacial forests were dominated by a pioneer association of lodgepole pine, alder, willow and various ferns. By 8,000 B.P. there were forests of Sitka spruce, mountain hemlock, alder and ferns. After 6,000 B.P. western hemlock became more prominent in association with mountain hemlock, Sitka spruce, lodgepole pine, heaths and sphagnum (Heusser 1960:179). In a recent study, Banner and Pojar (1983:946) argue that cooler, moister conditions between 7,000 and 6,000 B.P. may have led to a succession from productive forest to muskeg over much of the north coast.

Information on postglacial animal populations within the study area is limited to the faunal remains recovered from archaeological sites. The evidence indicates that all of the modern species have been present for at least 5,000 years, though population sizes may have varied during this period (Fladmark 1975:193-94). Faunal data for any time before 5,000 B.P. are lacking. Based on the record of environmental changes, Fladmark (1975:195-216) has inferred that land mammals as well as salmon and other anadromous fish may not have reached their present levels of productivity until after 5,000 B.P. Preferred habitats, seasonal migrations and other behavioural attributes have probably remained the same throughout the postglacial period.

Implications for Heritage Site Distribution

In summary, it may be said that the north coast region is notable for its ecological diversity. The types of environments that occur in the general vicinity of the study area include offshore waters, shorelines, rivers and streams, lowland forests and steep, rugged mountains. Moreover, each of these major environmental types is characterized by internal variability. Faunal and floral resources tend to vary from one zone to another and from place to place within each zone. Many of the resources also exhibit a pattern of seasonal fluctuation in abundance or availability. These attributes impose a fundamental structure on the type of adaptation that could be achieved by prehistoric societies that were dependent on hunting, fishing and gathering. As yet, information on past environments in the region is sketchy. Many of the basic attributes of the modern environment would certainly apply to the entire postglacial period, though important changes in the resource base may have occurred through time, particularly during the first few thousand years after deglaciation. It was during this period that the most dramatic alterations took place in the local landscape. Between 12,000 and

5,000 years ago sea levels dropped steadily, and in all probability, this would have kept salmon and other anadromous fish populations to sub-climax levels. As a result, early human adaptations in the area may have been substantially different from those of more recent times. There are also serious implications for archaeological site discovery. Shorelines that were active in early postglacial times may now be up to 135 m above the present sea level. The remains of any shoreline settlements from that time are therefore likely to be some considerable distance from the modern shoreline. They may occur in densely forested areas beneath substantial accumulations of humus and other recent deposits. The discovery of these earliest sites poses a real challenge for archaeologists, and to date, no acceptable survey methodology has been developed to meet the challenge.

ETHNOGRAPHY

The following overview of Coast Tsimshian ethnography is meant to provide the basis for an assessment and interpretation of prehistoric archaeological resources in the Prince Rupert area. The linguistic affiliations of the Coast Tsimshian are indicated, and their traditional territories are outlined. Following this is a description of the culture with an emphasis on their subsistence, demography and sociology. The final section summarizes the available information on Coast Tsimshian settlement patterns organized by site type. Concluding comments point out the implications of the ethnographic record for predicting prehistoric site location.

The Coast Tsimshian and their Territories

The Tsimshian-speaking Indians of the northern mainland coast of British Columbia consist of four major ethno-linguistic groups: the Coast Tsimshian, the Southern Tsimshian, the Gitksan and the Nishga. The Prince Rupert area falls entirely within the territory of the Coast Tsimshian Indians (Duff 1964:14-15). Linguists generally classify Tsimshian as a member of a language stock known as Macro-Penutian. Its nearest relatives are found well to the south in Washington, Oregon and California. The people living to the west, north and east of the Tsimshian spoke languages of the Na-Dene stock (Haida, Tlingit and Northern Athapaskan), while those to the south spoke languages of the Wakashan stock (Heiltsuk and Haisla) (Duff 1964:14).

The territory of the Coast Tsimshian Indians includes the outer mainland coast and offshore islands north as far as the mouth of the Nass River and south as far as the northern end of Pitt Island. Along the Skeena River the Coast Tsimshian lived as far inland as Kitselas Canyon (Garfield 1939:173). Within this area two tribal groupings are recognized: Canyon Tsimshian and Lower Skeena Tsimshian.

THE CANYON TSIMSHIAN

Two Coast Tsimshian tribes, the Kitselas and the Kitsumkalum, held territories on the lower Skeena but had no direct access to salt water resources. The Kitselas, or People of the Canyon, lived along the banks of the Skeena River at Kitselas Canyon. Emmons (1912:468-69) describes four villages in the canyon and fishing stations extending upriver as far as Lorne Creek and downriver to

Little Canyon, near Terrace. The Kitsumkalum, or People of the Ridges, occupied the valleys of the Kalum and Zimacord Rivers, both of which lie just below Terrace.

THE LOWER SKEENA TSIMSHIAN

Ten Coast Tsimshian tribes had summer villages along the lower Skeena River and winter villages in the vicinity of Prince Rupert. Collectively, their territories included the Skeena River drainage up to the canyon, Tsimpsean Peninsula and the offshore islands, Work Channel, selected locations along Portland Inlet and certain areas at the mouth of the Nass River between Red Bluff and Fishery Bay. Each tribe had its own territory within which household groups owned particular sites.

There is not sufficient information to attempt a recpnstruction of tribal territories on the coast. However, the following is a list of territories along the Skeena, insofar as they can be determined.

Tribe	Skeena River Territory
Gitwilgyots	Khyex River drainage.
Gitsees	Kasiks River drainage.
Ginkangeek	Exchamsiks River drainage.
Gitandau	Exstew River drainage and possibly some areas on the opposite bank of the Skeena.
Gilutsau	Lakelse River drainage.
Ginadoiks	Ginadoiks River drainage.
Gitzaklalth	Ecstall River drainage and possibly some of the Dundas Island Group.

Gispakloats	Possibly the Shames River drainage or an area on the opposite bank of the Skeena.
Gitlan	The Zymoetz River drainage and possibly an area on the opposite bank of the Skeena.
Gitwilkseba	Part of the Lakelse River drainage by arrangement with the Gilutsau.

Demography

The size of the Coast Tsimshian population at the time of European contact is uncertain. Duff (1964:38-39) claims that there are no accurate census estimates for anywhere in British Columbia earlier than 1835. By that time at least one smallpox epidemic had occurred among the Coast Tsimshian. The most widely accepted population estimates for 1780 are those put forward by Mooney, although Duff considers them conservative. In Kroeber's (1939:135) tabulation of Mooney's figures, the Coast Tsimshian number 3,500. Taking into account the effects of disease, the actual precontact population may have been two or three times the figure given by Mooney. In a recent study, Boyd (1990:136) estimates that the population at contact was around 6,000 to 8,000.

Social Organization

The main social unit among the Coast Tsimshian was the matrilineal household. Although basically autonomous, households were united politically into tribes. Each tribe had usufruct rights to house sites, campsites, and hunting, fishing and berrying grounds within the tribal territories. The head of the household acquired his rank through inherited and acquired wealth. Household heads were ranked within each tribe as well as among the tribes. An individual's social position was determined by the prestige of the household head and the closenèss of his relationship to the household head (Boas 1889:830-31; Drucker 1950:220-21; Duff 1964:16).

Garfield (1931:47) describes a three-class society for the Tsimshian: chiefs and their immediate descendants, commoners and slaves. She notes that some mobility existed (both up and down) for chiefs and commoners, depending on their ability to acquire and maintain wealth and prestige. Slaves were captives or children of captives and were owned absolutely by the household. According to Garfield (1945:628), slave labour was important because it enabled the accumulation of a larger surplus which in turn stimulated greater specialization, development of art etc.

The Coast Tsimshian kinship system was based on four exogamous matrilineal clans or phratries which had rights to certain privileges, such as names and crests. In most villages there were several households belonging to each clan. Eligible marriage partners were determined by clan affiliation as well as by the status of the individuals concerned. In general, people married within their own class. Polygyny was common among chiefs and other high-ranking members of the society (Boas 1889:828; Drucker 1950:215, 220, 222; Garfield 1931:54, 1939:234).

Tsimshian burial customs are described by Boas (1889:837). Corpses were placed in boxes along with the dead person's dancing ornaments and weapons. All bodies except those of shamans were cremated. Shamans were buried in caves or in the forest. Memorial poles were erected some time after death.

Subsistence Patterns

Salmon was the staple and single most important food of the Coast Tsimshian, as it was for most Northwest Coast groups. Each tribe spent a considerable portion of the year at villages or camps located near the salmon fishing areas, catching the fish as they ascended the rivers to spawn. Salmon were abundantly available for those who were industrious, and large quantities were preserved for consumption later in the year (Drucker 1965:118-19).

Eulachon were another major element in the diet. These small oily fish spawn near the mouths of large rivers over a period of several weeks in the early spring. In order to maximize the resource it was important to be on hand at the fishing sites when the eulachon arrived. Seasonal timing and access to fishing locations were crucial. To procure and preserve a surplus of the eulachon was for the Coast Tsimshian a major source of wealth (Drucker 1965:116-17).

Other fauna were less important than salmon and eulachon. However, halibut, cod and herring were regularly caught and preserved by drying. Sea mammal hunting was directed at seals, as well as sea lions, porpoises and sea otters. Whales were not hunted, but stranded animals were used when available. Deer were the most important of the land mammals. Hunters also took black bear, grizzly bear, mountain goat, marmot, beaver, porcupine, grouse and various waterfowl. Shellfish and other invertebrate faunal resources included clams, mussels, abalone, sea urchins, barnacles, and squid.

Plant foods consisted of berries (huckleberries, salmonberries, thimbleberries, currants, raspberries, strawberries, and salal berries, seaweed, the young shoots and roots of several species, and the inner bark of the hèmlock tree (Boas 1916 44; Drucker 1950:171-76; Niblack 1890:276).

Settlement Patterns

Resource procurement involved the Coast Tsimshian in a regular cycle of activities. In February the tribes migrated to the mouth of the Nass to catch the eulachon during their March-April spawning period. The preserved fish and oil were packed in boxes and taken by canoe to the winter villages, most of which were located on the mainland coast or immediately adjacent islands near the mouth of the Skeena River. After a brief stay at these villages and short excursions to fish for halibut and hunt sea mammals, the Coast Tsimshian proceeded to their summer camps on the lower courses of the salmon spawning rivers, mostly along the lower Skeena. Fishing and processing salmon were the primary activities of the summer and fall, with berry picking also being important during the latter part of the summer season. Hunting forays for land and sea mammals preceded a several month sojourn at the winter villages. During the winter, shellfish and other locally available foods were collected, but the focus was on ceremonies and feasting. The stored supplies lasted until early spring, when the prospect of the eulachon mobilized people for the next annual cycle (Boas 1916:399; Drucker 1965:117-19). Sites used by the Coast Tsimshian during their annual round included winter villages, eulachon fishing camps, summer villages, stopover camps, hunting and fishing camps, burial sites and defensive sites.

WINTER VILLAGES

The typical Coast Tsimshian winter village consisted of a row of closely spaced plank houses facing the water. With the exception of the canyon groups, who lived year-round on the banks of the Skeena River, the Coast Tsimshian spent the winter on salt water. The villages were clustered along the shores of Venn Passage near the modern town of Prince Rupert. The typical village site was relatively level and well-drained with direct access to a beach suitable for hauling up canoes. The houses were aligned with the contours of the shoreline, just above the high water mark. Some villages had two or more rows of houses, one behind the other. Carved memorial poles stood in front of the houses (Garfield 1966:9-10; Niblack 1890:309; Vastokas 1966:18). There is little information on village size. According to Garfield (1966:10), most villages had fewer than 100 inhabitants, while the largest probably had no more than about 500. However, these figures fail to take into account the heavy loss of population due to the introduction of smallpox and other European diseases. Recent estimates would suggest that an average village may have had as many as 300-500 inhabitants.

EULACHON FISHING CAMPS

The principal eulachon fihing grounds were at the confluence of the Nass and Ishkheeniskh Rivers. Here, rows of houses extended along both banks of the river. Each tribe had its own territory and many lineages had permanent houses. Others made temporary shelters from cedar bark and planks (Barbeau 1940:21; Garfield 1939:277).

SUMMER VILLAGES

The summer villages were located on rivers where salmon could be trapped in abundance en route to their spawning grounds. The number of houses at a particular location or village was related to the size of the run on that river. The dwellings served also for drying and smoking salmon. They were plank houses, like those in the winter village, but were provided with permanent drying racks (Drucker 1950:251; Niblack 1890:298).

HUNTING AND FISHING SITES

Hunting, and fishing for species other than salmon and eulachon, were individual or small group activities. When the resources were not located near a village, temporary base camps were established. Often these were in exposed settings, the main criterion for site location being proximity to the resource. Shelters at the camps were made of wide strips of cedar bark that were brought rolled up in bundles. These were arranged over a framework of poles that were left up from one visit to the next (Drucker 1950:180, 251; Niblack 1890:298-99).

STOPOVER CAMPS

Some of the seasonal migrations involved a journey of more than one day, and people used traditional sites for overnight camping. Each of the Lower Skeena tribes had stopover sites along the routes to the Nass River eulachon fishery and to the salmon fishing grounds along the Skeena. Drucker (1950:251) notes that for brief stays expediency determined the form of shelter. As examples he cites camping under a rock ledge or large tree. Niblack (1890:205) describes a temporary shelter made with two forked saplings and a cross pole, covered with wide strips of bark. The bark strips were brought to the site already prepared for this purpose.

Burial Sites

Cemetery areas were located on the outskirts of the villages. They contained elevated mortuary structures consisting of one or more carved poles supporting a decorated box wich contained the remains of the cremated corpse. Shamans were not cremated, nor were they buried in the village cemetery. The corpse was deposited in a flexed position in a small grave house made of planks. The grave house was in an isolated location, in the forest, on a headland or in a cave (Boas 1889:837; Emmons 1912:470; Niblack 1890:356, 358).

Defensive Sites

Occasional references to fortified sites are found in the ethnographic literature, but no detailed descriptions are available. Site selection in general was probably influenced by considerations of defense. In all likelihood, preference was given to small islands or points of land that commanded a wide view of any approaching enemies (Garfield 1966:10; Niblack 1890:303).

<u>Implications for Heritage Site Distribution</u>

The one factor that is common to almost all Coast Tsimshian habitation sites was proximity to navigable water. Villages and camps were established on the sea shore or river bank where canoes could be loaded and unloaded with the least effort. With few exceptions, resource exploitation sites were also located on navigable water. Most of the winter villages were located in the Prince Rupert Harbour area, with the main centre of settlement being along the shores of Venn Passage. Eulachon fishing camps were all at the mouth of the Nass river, where the maximum number of fish could be taken during the brief spawning cycle. Salmon fishing villages were located wherever migrating salmon could easily be trapped--at stream mouths, in constricted passages, canyons, etc. Overnight camps were located along water routes between the various seasonal settlements. Other camps were located near particular resources, often in outlying areas away from the main centres of settlement. Burial sites were at the outskirts of villages and in isolated locations, including caves.

HISTORY

The following pages offer background information for the identification and assessment of historical sites in the Prince Rupert area. A brief overview of the early historical period is presented, with some discussion of the impact of European contact on the native culture of the area. The section concludes with a sketch of the recent history of the area.

The 18th and 19th Centuries

European contact was comparatively early on the northern B.C. coast. Spanish explorers reached the Queen Charlotte Islands in 1774, and within a decade the rush for sea otter pelts had begun. By the 1790s Europeans had ventured into Coast Tsimshian territory and were trading with the inhabitants. The early traders operated from their ships, taking the furs directly to markets in China. In return they brought to the Northwest Coast iron, copper, brass, muskets, cloth, rum and trinkets. The British, Americans and Russians were the main competitors for the north coast trade. In 1825 the Treaty of St. Petersburg was signed, establishing the southern limit of Russian trading at the present U.S.-Canada border. The British then consolidated their position by establishing a series of permanent land-based trading posts including Fort Simpson at the mouth of the Nass River in 1931 (relocated in 1834 to the present site of Port Simpson on Chatham Sound) and Fort McLoughlin at Bella Bella in 1833. By this time the fur trade was in decline, though it persisted for several more decades.

The maritime fur traders imported to the area a variety of trade goods, changed the focus of the local economy, and profoundly affected the Native population through the introduction of European diseases. They did not attempt to annex territories or inflict their way of life on the Natives. With the establishment of land-based trading posts the alterations to the aboriginal culture were more dramatic. Relocation to the vicinity of the forts resulted in large concentrations of people from diverse tribes which required adjustments in social institutions and inter-group relations.

Moreover, missionaries soon appeared on the scene imposing their notions of civilized life--sedentism and puritanism.

During the latter half of the 19th century commercial interest in the north coast shifted to the fishing industry. The first cannery was established in 1876 at Inverness near the mouth of the Skeena River, and others soon followed. The industry exploited the Skeena and Nass salmon runs, which defined the locations of the canneries and the seasonality of their operation. Native Indians were hired for fishing and processing, and additional workers, mainly Japanese, Chinese and Finnish, were brought in as needed. The communites that sprang up around the canneries were occupied year-round with an influx of people during the salmon-fishing season (April-October). Each ethnic group tended to cluster in its own section of town. In addition to salmon, commercial fishing was directed towards deep sea fish, particularly halibut.

The gold rush of the 1870s had a direct impact on the area. Traffic to and from placer mines in the northern interior and Queen Charlotte Islands passed right through Coast Tsimshian territory. Port Essington at the mouth of the Skeena River boomed as a supply stop for miners on their way to the Omineca. Transportation at this time was mostly by water. Steamers made regular stops at the major settlements, while the more remote locations were reached by Native canoe. Until the 1890s the Coast Tsimshian regularly carried supplies to the Hudson Bay Company post at Hazelton on the upper Skeena River. In 1894 the first sternwheeler ascended the Skeena and for the next two decades sternwheelers monopolized both passenger and cargo transport.

The 20th Century

In 1905 the site of Prince Rupert was chosen as the western terminus of the Grand Trunk Pacific Railway. Construction of the railroad along the right bank of the Skeena was completed in 1914. Rail transport contributed to the growth or communities along the line, and port facilities in Prince Rupert linked the continental railway with shipping on the Pacific. The town of Prince Rupert grew rapidly to become the economic centre of the north coast region, while other early settlements that were not on the railway (eg. Port Essington) went into a period of decline.

Logging operations were begun in order to supply lumber for local construction, and saw mills were established at many of the early settlements. During the late 19th century there was also a demand for cordwood fuel for the steamboats. Commercial logging began in the Kitsumkalum area about 1910, and by 1920 the mills were mechanized. The town of Terrace boomed in response to the demand for lumber during the two world wars and even more so after the establishment of pulp mills in the 1950s.

Farming in the Coast Tsimshian area has been for local subsistence purposes only. Garden plots were part of the trading post establishments, missionary settlements etc. Indians on the north coast were growing potatoes by the early 19th century both for their own consumption and for trade. Homesteading began along the Skeena in the early 1900s and was centred on the Kitsumkalum Valley (Asante 1972; Duff 1964; Howay 1929; Knight 1978).

THE HERITAGE RESOURCE BASE

The process of identifying and recording heritage sites in the Prince Rupert began soon after the turn of the century and has continued with increasing intensity to the present day. There are now 176 recorded heritage sites in the local area, most of which relate to the Native Indian occupation. The following pages present a brief history of these investigations, together with a listing of the known heritage sites by type. The section ends with a discussion of the limitations of the current survey record.

History of Investigation

The first archaeological investigations in the Prince Rupert area were conducted by Harlan I. Smith, one of the pioneers of Canadian archaeology. Smith began his north coast research in 1907 with a survey of selected locations between Bella Coola and Skagway. In Tsimshian territory he identified a number of shell middens between Prince Rupert and Metlakatla, and others near Port Simpson and Kincolith (Smith 1909). Smith returned to Prince Rupert from time to time over the next 20 years gradually adding more sites to the regional inventory (Smith nd).

After a brief hiatus, archaeological research was taken up again under the direction of Philip Drucker. In the fall of 1938 Drucker conducted an extensive survey of the northern and central Northwest Coast, locating and testing shell midden sites. His first priority was to define the historic and protohistoric cultural horizons, with the idea that these would serve as standards against which the prehistoric cultures of the area could be compared. Prince Rupert Harbour was a major focus of these investigations. Drucker recorded 25 archaeological sites in the area and made test excavations at two of them (Drucker 1943:24). In neither of these sites did he find convincing evidence of culture change. Minor differences in artifacts were noted from level to level, but he felt that these could just as easily be explained by sampling error. He concluded that the earliest cultures identified through his investigations were similar to those of the historic period. The age of these early cultures remained uncertain.

One of Drucker's secondary aims was to stimulate academic interest in north coast archaeology, but in this he was notably unsuccessful (Drucker 1943:23). Between 1938 and 1966 hardly any archaeological work was done in the Coast Tsimshian area. The only investigations to occur during this period were initiated by James Baldwin, a high-school student from Prince Rupert. Under the direction of Charles Borden, an archaeologist at the University of British Columbia, Baldwin visited sites found earlier by Drucker and added several new sites to the inventory. He and Borden also conducted salvage excavations at a large prehistoric village site located on Kaien Island, near the Co-op Cannery (Calvert 1968).

In 1966 George MacDonald of the National Museum of Canada began the first major programme of archaeological research in the Tsimshian area. Almost every year from 1966 to 1983 National Museum crews were in the field conducting archaeological surveys and excavations over an area extending from the lower Nass River in the north to Milbank Sound in the south, and from the Queen

Charlotte Islands in the west to the Babine River system in the east. George MacDonald directed the project throughout, but a host of other researchers have participated at different times.

One of the principal contributions of this massive project was the demonstration of significant time depth in the Tsimshian area. There is now abundant evidence to show that the northern mainland coast has been occupied for at least 5000 years (MacDonald and Inglis 1981:44). Even older sites are possible in this area, though as yet none has been found. The excavations conducted by MacDonald provided the data for a detailed overview of the major developments in the prehistory of the Prince Rupert area from 3000 B.C. to the time of European contact.

In MacDonald's view the last 5,000 of north coast prehistory may be divided into three periods. The earliest of these is Period III, which lasted from 3000 to 1500 B.C. Among the artifacts considered typical of this period are: heavy chipped stone points, either leaf-shaped or with square bases; cortex spall tools; pebble tools; edge-ground cobbles; hammerstones; bone awls and points; bone wedges or chisels; canine tooth pendants; beaver incisor tools; bird bone tubes and beads; and adze blades and points made of California mussel shell. Bilaterally barbed bone harpoons, either with a line hole or bilateral line guards are characteristic of this early period. Decorative patterns of lines and dots were sometimes applied to harpoons and other utilitarian objects. The midden deposits of Period III tend to be shallow and restricted in area, and bay mussel shell is invariably an important constituent. Houses were small but there is some evidence to suggest that they were already arranged in a row along the beach as they were in later times (MacDonald 1969:250-51; MacDonald and Inglis 1976:74; MacDonald and Inglis 1981:42, 45).

Period II, which lasted from about 1500 B.C.-A.D. 500, is characterized by a continuation of the basic tool kit with some notable additions. Ground slate points and 'pencils', rarely found in Period III deposits, are now abundant. Unilaterally barbed bone harpoons with multiple-notched unilateral line guards appear for the first time, as do nephrite celts, pecked and ground stone tools, sea mammal bone rods, socketed points, red ochre pigment balls, shaman's mirrors and labrets. Decorated objects are more common than in Period III, and zoomorphic designs occur as well as elaborate geometric motifs. The appearance of exotic materials such as obsidian, copper, amber and dentalia suggest that a pattern of regional trade was already developing at this time. A substantial increase in population is suggested by the presence of larger houses and a more rapid accumulation of shell midden deposits. Grave goods associated with some of the burials from Period II indicate social ranking within the community (MacDonald 1969:250-51; MacDonald and Inglis 1976:77; MacDonald and Inglis 1981:45-52).

The beginning of Period I (A.D. 500-1830) marks the emergence of a fully developed Northwest Coast culture. Changes in the artifact inventory include a general decline in the importance of chipped stone tools. Only cortex spalls, pebble tools and end scrapers continued to be made. Ground slate points are rare. Pecked and ground stone tools, on the other hand, show an increase and several new forms made their appearance, including spliting adzes, grooved mauls, bark shredders, clubs and bowls, many of them decorated with zoomorphic designs. Other artifact categories which reach their peak frequency in Period I include small jade adze blades, bird bone drinking tubes, and artifacts made of California mussel shell. European trade goods were introduced into the area in the late 1700s and some of these appear in the upper levels of the middens, but the prehistoric pattern remains essentially unaltered until the 1830s (MacDonald 1969:252-53; MacDonald and Inglis 1976:77-78; MacDonald and Inglis 1981:52).

Another important contribution made by MacDonald and his associates was the increase in our knowledge of Coast Tsimshian sites and their distribution. In 1966, when MacDonald first began to work in the area, there were fewer than 40 recorded archaeological sites in the Prince Rupert area. Over the next 18 years the tally increased substantially with major surveys occurring in 1966, 1974, 1982 and 1983 (MacDonald 1969; Inglis 1974; Archer 1983, 1984). No major excavations have been conducted in the Prince Rupert area in the last decade, but the process of locating and recording sites has continued under the direction of the present writer. Fieldwork in the Prince Rupert area has been pursued on a regular basis since 1988, and during that time many new sites have been recorded (Archer 1989, 1990, 1991). Significant improvements have also been made in the methods employed in coastal site surveying since the beginning of the 1980s, and the results of these investigations are now more dependable than ever before (Archer 1985).

The Current Heritage Site Inventory

There are now 176 recorded heritage sites within the Prince Rupert area (Table 2). Five of these are historical in age, pertaining to the recent Euro-Canadian presence in the region. All the rest relate in some way to the Native Indian occupation of the area. In the accompanying tabulation, the historical sites are lumped together in one category, simply because they are few in number. They include two isolated refuse areas near the mouth of the Skeena (GbTm-4 and GbTn-23), an abandoned logging camp on the west side of Digby Island (GbTo-45), an early historic cemetery near the village of Metlakatla (GbTo-62) and the courthouse building in downtown Prince Rupert (GbTn-33). The sample of Native Indian sites consists of four major categories: (1) shell midden sites, (2) isolated find sites, (3) rock art sites and (4) burial sites. These are subdivided into eight formal classes. The shell middens represent habitation sites, and, based on size and other characterisics, two types are recognized: village sites and camp sites. The isolated find sites represent some form of human activity that occurred away from the habitation sites. Again, two types are recognized: isolated artifacts and isolated canoe runs. The third category are rock art panels. The images on these panels are two basic types: carvings (or petroglyphs) and paintings (or pictographs). At one site both techniques are in evidence, and for convenience, this site was placed in a third class. The last category consists of burial sites. Only one site of this type has been found in the Prince Rupert area, and this is a burial cave, located on the remote west side of Digby Island.

Table 2. Current Inventory of Heritage Sites in the Prince Rupert Area

Site Class	Number	Percent
Historical Sites		
Isolated refuse areas	2	1.1
Abandoned logging camp	1	0.6
Cemetery	1	0.6
Courthouse building	1	0.6
Shell Midden Sites		
Village sites	59	33.5
Camp sites	85	48.3
Isolated Find Sites		
Artifacts	6	3.4
Canoe runs	1	0.6
Rock Art Sites		
Pictographs	2	1.1
Petroglyphs	16	9.1
Petroglyphs & Pictographs	1	0.6
Burial Sites		
Cave burials	1	0.6
Total	176	100.1

The current inventory is an impressive record, but it does have limitations. The shoreline zone throughout the Prince Rupert area has has been intensively surveyed, and in all probability, the vast majority of aboriginal sites within this zone have now been identified. The proportion of these sites that have been recorded may be as high as 90-95 percent. The lands away from the shoreline have not been examined in any meaningful way. To date, no attempt has been made to survey former shorelines that are now well above modern sea level. Nor has there been any attempt to search for the remains of hunting camps or other site types that might have been located in the upland areas away from the water. These represent significant weaknesses in the current site inventory. One other weakness should also be mentioned. Historical sites of all kinds are certainly underrepresented in the current inventory. As yet, no systematic survey for historical sites has been conducted in the Prince Rupert area. Those that are reported were observed incidentally while conducting surveys with other research objectives. In general, archaeologists tend to focus on the remains of Native Indian cultures, while historians have tended to focus on written documents to the exclusion of material remains. The result is that historical sites have been widely ignored.

In the present listing of heritage sites, there is one that falls within the boundaries of the study area. GbTn-18 was a small shell midden site located at the southernmost tip of Kaien Island, directly opposite the northern tip of Ridley Island. It is estimated that the midden measured 6 x 3 m, which suggests that it was a minor camp site. The ruins of a cabin were observed on top of the midden. The site was first recorded in 1974 by Richard Inglis. Sometime between 1979 and 1983 the site was completely destroyed due to the construction of the Ridley Island Access Road. The status of the site was checked and confirmed in 1983 by the present writer. For reference purposes, a heritage site form for GbTn-18 is included in the appendix to this report. To date, no other heritage sites have been discovered in the study area.

CURRENT INVESTIGATIONS

An in-field survey of the study area was conducted on September 11 and 12, 1993. The two-person field crew consisted of David Archer (M.A. anthropology, U.Vic) and Malcolm Rewcastle (B.A. anthropology, U.Vic.), both of whom have extensive experience in local archaeological survey. The methods employed are described below, followed by a brief statement of the results.

Methodology

Two different methodologies were employed in carrying out the assessment of the study area. There is a considerable body of evidence to indicate that most heritage sites are likely to occur on or near the present shoreline. Heritage sites may also be present in areas from the shoreline, but the probability of encountering sites in these areas is extremely low. Because of the higher potential for sites, the entire shoreline was subjected to an intensive examination. The procedures adopted were identical to those used by the writer on a number of other survey projects in the Prince Rupert area (see Archer 1983, 1984, 1989, 1990, 1991). The two members of the survey team walked in parallel about 10 m apart, each making a careful check of the terrain on either side of his transect. Two sets of transects were completed: one covering the edge of the forest and the other covering the intertidal zone. On the forest transects Oakfield soil samplers were used on a judgemental basis to check for the presence of sub-surface cultural deposits. Natural exposures, such as tree throws or erosion features were also examined whenever they were observed. The types of evidence that we were looking for in the forested areas included historic or prehistoric cultural debris, historical structures, cultural depressions, path features and culturally modified trees. In the intertidal areas we searched for rock art sites, canoe runs, stone fish traps and once again historic or prehistoric cultural debris.

The areas away from the modern shoreline were examined using a less intensive methodology. This involved a series of shovel tests to determine the nature of the sub-surface deposits and to check for the presence of artifacts or other cultural material. The test units measured approximately 30 x 30 cm, corresponding to the width of a standard shovel blade. Most units were taken down about 50 cm. To continue digging below this was impossible, given the size of the exposure. In all, about 15 shovel tests were completed over the study area.

Results

The intensive survey of the shoreline zone produced no new sites. The terrain was found to be generally steep and rocky, and often there was an abrupt rock face rising directly off the beach (Figures 2 and 3). Areas such as this tend to have a low potential for heritage sites, and the absence of any new occurrences was therefore not unexpected. A review of the existing site inventory for the

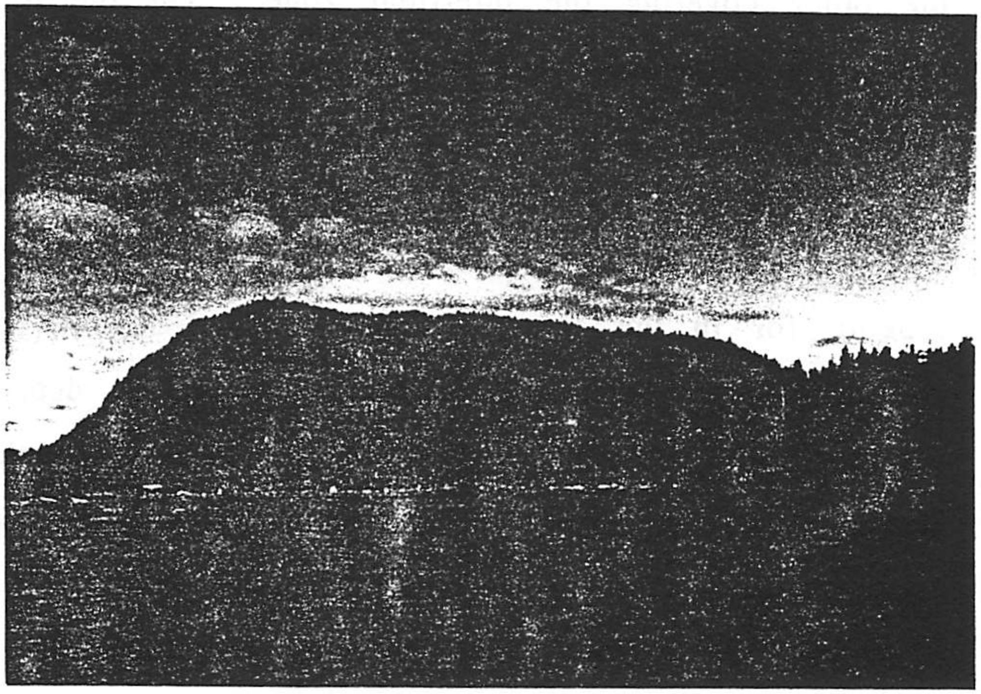

Figure 2. The North End of the Study Area.

Figure 3. The South End of the Study Area.

Prince Rupert area indicated that one site had been recorded at the extreme southern tip of Kaien Island (Figure 4). The site (GbTn-18) was described as a small shell midden, measuring about 6 x 3 m. It probably represented the remains of a minor prehistoric camp site. According to the site record, the midden was completely destroyed during construction of the Ridley Island Access Road. No trace of it remained when the area was rechecked in 1983, and this conclusion is supported by the current investigations. For reference purposes, a site form for GbTn-18 is included in the appendix to this report.

After completing the shoreline survey we turned our attention to the non-shoreline portion of the study area. We decided to make our way up to the higher ground using one of the Second World War roadways, and lying in the surface of this road a single stone artifact was found. The location of this find (GbTn-T1 1993) is indicated on the accompanying map (Figure 4). The artifact is classified as a cobble tool--a simple cutting or chopping implement made by striking a series of flakes from one end of a beach cobble (Figure 5). Tools of this kind are not restricted to any particular time range. In the Prince Rupert area they occur throughout the 5000 year sequence, and elsewhere in British Columbia they reach back even further in time, to the very beginning of human occupation in the province (Borden 1965). The age of the cobble tool found in the study area remains uncertain, but it is possible that it dates to the early postglacial period (9,000 to 12,000 years ago). It was found in a sandy beach deposit at an elevation of about 5.35 m above modern sea level, and it is clear from the water-worn condition of the specimen that the beach was active at the time the artifact was

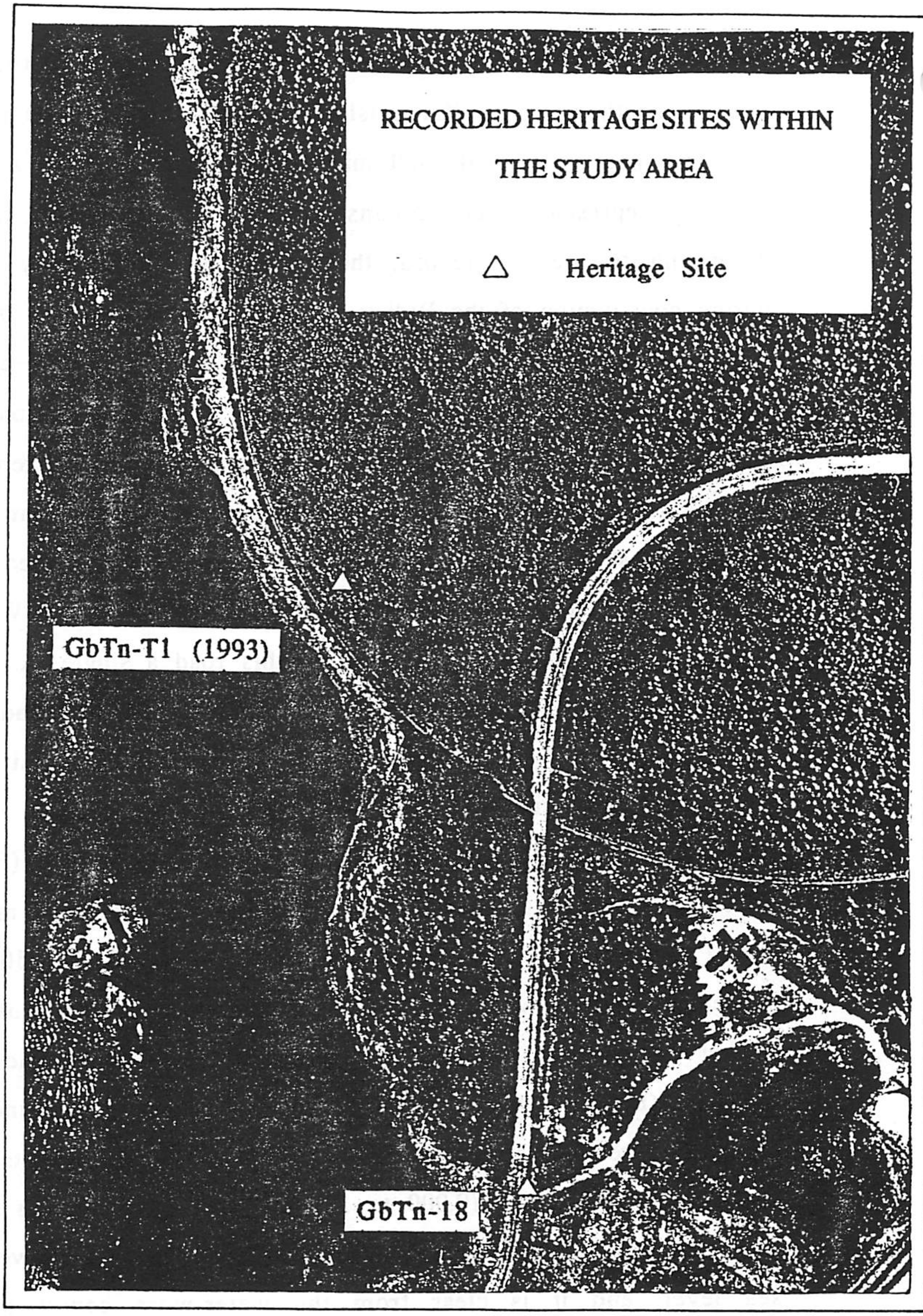

Figure 4. Recorded Heritage Sites within the Study Area.

Figure 5. The Cobble Chopper at GbTn-T1 (1993).

deposited. This suggests that the time of deposition pre-dates the establishment of modern sea levels around 5,000-8,000 years ago. If so, it would be the oldest artifact yet found in the Prince Rupert area. The discovery is, however, highly problematic. Since the artifact was found on a Second World War roadway, it had almost certainly been moved from its original context. The original location was probably close by, but there is nothing to indicate precisely where it might have been. Several shovel tests were made in the general area, and nothing further was found, but this is not considered conclusive. It is, of course, possible that the original site was completely destroyed when the road was pushed through during the wartime period. However, the potential significance of the find is such that further investigation of the area is warranted. If it were possible to locate the original site and conduct a systematic archaeological excavation, the information gained might well fill an important gap in our understanding of north coast prehistory. For reference purposes a heritage site form for GbTn-T1 (1993) is included in the appendix to this report.

The rest of the shovel testing programme, focusing on the upper part of the study area, yielded negative results in each and every case. No further evidence of prehistoric human occupation was found. In part, this may be due to the extensive alterations to the area that occurred during the Second World War. Here, at the entrance to the harbour, there was a major army establishment, known as Barrett's Fort, which included three large gun positions, look-out posts, trenches, guard rooms, store rooms, barrack buildings and a large recreation hall (Bowman 1987:11-13, 39). The concrete foundations of many of these buildings are visible throughout the study area. These recent remains are of little scientific importance, but they are of interest to many of the residents of Prince Rupert. During the war years large numbers of soldiers were stationed in Prince Rupert, and Barrett's Fort was one of the main defensive installations in the area.

CONCLUSIONS AND RECOMMENDATIONS

In the area to be developed for the proposed LPG facility there was one previously recorded heritage site: GbTn-18, but nothing of this site remains. It was utterly destroyed in the early 1980s when the Ridley Island Access Road was constructed. No new heritage sites were found during the current survey, and it may therefore be concluded that the proposed LPG facility will have no significant impact on the heritage resources of the Prince Rupert area. In view of this, no further action is indicated.

In the area to be developed for the proposed MTBE facility there were no previously recorded heritage sites. However, one new site was discovered during the course of the current investigations (GbTn-T1 1993). This is identified as an isolated find site. It consists of a single stone artifact, a cobble chopper, found in a disturbed context on the west side of the study area. It is clear from the terrain that the artifact was moved from its original location when a dirt road was built through the area during the second world war, but how far it was moved is uncertain. In spite of this, the site may be of considerable scientific importance. It is possible that the artifact dates to the early postglacial period (8,000 to 12,000 years ago), when sea levels in the Prince Rupert area were higher than they are today. So far, the archaeological record in this area goes back only 5,000 years--we know absolutely nothing about the earlier peoples who occupied the area. In view of the potential importance of this site, further action is indicated. If the MTBE facility is approved for construction, I strongly recommend a programme of site monitoring during the initial ground preparation phase. The goal of this operation would be to identify, if possible, the original site from which the cobble tool came. If the site can be identified and if there are still intact cultural deposits at this site, in other words, if the site holds the remains of an ancient camp, then an archaeological salvage excavation should be conducted before the development of that area proceeds. The scale of the excavation would depend on the nature of the remains.

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ADDENDUM TO
A DETAILED HERITAGE IMPACT ASSESSMENT OF TWO PROPOSED DEVELOPMENT PROJECTS AT THE SOUTH END OF KAIEN ISLAND: AN LPG TRANSFER FACILITY AND AN MTBE MANUFACTURING PLANT AND SHIPPING TERMINAL

Prepared by

David J.W. Archer
Heritage Consultant

589 5th Avenue East
Prince Rupert, B.C. V8J 3Y3
624-6894

for

Prince Rupert Port Corporation
110 3rd Avenue West
Prince Rupert, B.C. V8J 1K8

October 15, 1993

RESULTS OF A FOLLOW-UP SURVEY

During the initial heritage site survey of the proposed MTBE site at the south end of Kaien Island a single stone artifact was found within the area to be developed. The artifact, a cobble chopper, was discovered along a dirt road that had been part of the Second World War defensive installation. It was clear from the context that the artifact was not in its original position. It had been transported from some other location together with the fill used to form the road bed. In my report I recommended that an attempt be made to locate more precisely where the artifact had come from. If the fill for the road bed had come from within the area to be developed, and if the site was still intact or partly intact, then an archaeological salvage excavation would have been indicated.

In order to clarify the situation, the Port of Prince Rupert asked for another survey of the area to pin down, if possible, the source of the road bed fill. The follow-up survey was conducted on October 7, 1993 by Larry Valentin of Levelton and Associates, Page Smith of the Prince Rupert Port Corporation and myself. It involved an extensive examination of soils across the entire area to be developed for the MTBE plant. Existing soil exposures were thoroughly checked and a number of new shovel tests were made. Nowhere on the development site did we find a soil deposit similar to that of the road bed fill. It can only be concluded that the fill was brought to the site from some distance away. Road-building material may have been transported by rail from somewhere up the Skeena Valley or by barge from somewhere along the coast. In either case, the artifact found within the road bed fill must be non-local. This eliminates the need for any further action with regard to heritage sites within the area of the proposed MTBE plant. No regular monitoring or salvage excavations should be necessary.

APPENDIX A

Site Forms for Recorded Heritage Sites located within the Study Area

ADDITIONAL INFORMATION

PLEASE CONSULT ACCOMPANYING GUIDE BEFORE COMPLETING

1. Site No. G b T n — 18

BRITISH COLUMBIA ARCHAEOLOGICAL SITE INVENTORY FORM

RECEIVED JUL 9 ... HERITAGE CONSERVATION BRANCH

2. Previous designation(s) N/A
3. Site name(s) Unknown
4. Legal Unknown
5. (a) Location Southwestern tip of Kaien Island at a point where it joins (at low tide) the northern tip of Ridley Island. The site is situated on an elevated terrace 3 m above the high tide line, on the southern tip of Kaien Island.

   (b) Access Take a boat from Prince Rupert Harbour and travel south to the southern extremity of Kaien Island. Moor the boat in a protected cove between Ridley and Kaien Island. The site is located on an elevated terrace about 3 m above high tide. Alternately, access may be gained by walking the CNR tracks from either Port Edward or the Fairview Port facility to the southern end of Kaien Island.
6. Administrative jurisdiction (a) Regional Dist. Skeena - Queen Charlotte

   (b) Forest/Grazing Dist. Prince Rupert (c) Highways Dist. 5 — 51, Prince Rupert

   (d) Park Dist. 5 — 1, Lakelse (e) Resource Management Reg. Skeena
7. Lat. 54° 14′ 15″ N. 8. Long. 130° 19′ 46″ W.
9. UTM 9U VL/E 134 N 105 10. Air photo BC 5084 - 006
11. Map (a) 103 J/ 01 (b) N/A
12. Drainage (a) minor N/A (b) major 24, Nass
13. Elevation (a) about 3 m ASL (b) N/A
14. Cultural affiliation (a) Tsimshian, Tsimshian (b)
15. Site type General Activity, shell midden/Historic, cabin, midden
16. Dimensions (a) exact 30 m N - S × 15 m E - W (b) estimated 40 m N-S x 25 m E-W

   (c) original same

17. Condition (a) present 0 % intact (b) future completely destroyed by Ridley Island development

18. Priority

19. Detailed information (a) Vegetation on site Western Hemlock, Sitka spruce, devil's club, moss, ferns, stinging nettle

(b) Major vegetation Coastal Western Hemlock

(c) Cultural matrix shell midden/cabin structure atop littermat (1979)

(d) Depth of cultural matrix maximum depth estimated at 3 m (1979)

(e) Non-cultural matrix sand gravel till

(f) Water source Unknown

20. Known finds and present location Shell midden has been exposed by historic excavation (root cellar) and measures 6 m N-S x 3 m E-W and may be 3 m deep (see remarks). The historic cabin measures 4 m N-S x 5 m E-W. The midden associated with this structure is approximately 2 m in diameter (1979).

21. Photo record Skeena Impact 1970, Konica R#5: 18,19,21. Praktica R#2: 11, 12, 13

22. Published and unpublished references (a) none

(b) R. Inglis, 1974. Archaeological Impact Study: Bulk Loading Facility (cont'd under remarks)

23. Site age and/or date (a) Unknown ☐ absolute ☐ relative

(b) Source N/A

24. Owner/Tenant Provincial Crown Land

25. (a) Informant N/A

(b) Observer Inglis, Ferguson, Acheson Date SEP 17, 19 74

(c) Recorder Inglis, Ferguson, Acheson Date SEP 17, 19 74

(d) Revisitor J. Williams, M. Wright Date JUL 04, 19 79

D. Archer Date AUG 23, 19 83

GbTn 11

26. Remarks

22 b) cont... Williams and Wright 1979 Skeena Impact Assessment. Archer, D. 1983-32 Prince Rupert Harbour Archaeological Project.

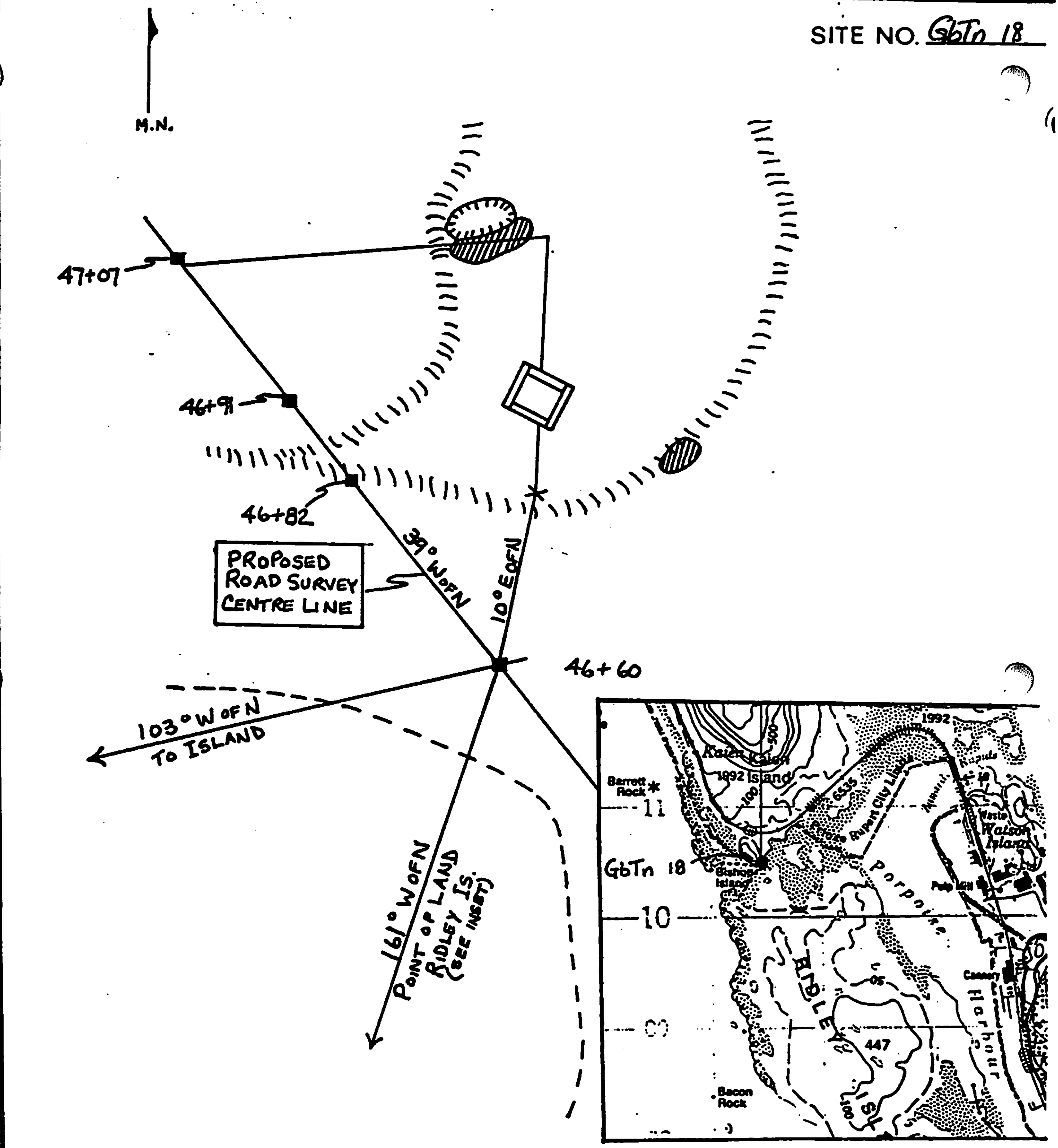
26. Our estimate of site size doesn't correspond with the estimates provided by Inglis, Ferguson, Acheson (1974). While it is possible that the entire terrace area was utilized the surface indications of cultural remains are restricted to the large shell midden deposit and the cabin/midden features.

The depth of the shell midden may not in fact approach 3 m as it is possible that the deposit is situated atop a natural knoll, in which case the true midden depth would be much less than 3 m.

The cabin structure and associated midden are not likely to be in excess of 70 years old as wire nails and bottles in the structure and midden indicate an early 1900's or later date for this dwelling (1979).

The site was completely destroyed by construction of the road leading to the Ridley Island Port Complex (1983).

SITE NO. GbTn 18



EXTENT OF SITE	—·—·—·—·—
BUILDING	■
FOUNDATION	□
ROAD	═══ =====
TRAIL	--------
RAILWAY	┼┼┼┼┼┼
FENCE	-X-X-X-X-X-
RIVER/CREEK	
STEEP RISE	

ADDITIONAL LEGEND

- ■ Survey marker - HWY's
- Historic cabin
- Depression
- X Steel pipe - vertical
- - - - High tide line
- Midden area

1:50,000 MAP NO. 103 J/1
LATITUDE 54° 14' 15" N
LONGITUDE 130° 19 46" W
UTM GRID REF. 9UVL 134105
TRUE □ MAGNETIC ■
DECLINATION USED
DATE July 7, 1979
SCALE: 1 CM. = 5 M.
0 5 10 15 20 25

BRITISH COLUMBIA

ARCHAEOLOGICAL SITE INVENTORY FORM

Site No. GbTn -

Map 103 / J / 1

Identification

1. Borden No. GbTn-   **2. Temporary No.** GbTn - T1

3. Site Name Unknown

Location

4. Location The site is on the SW corner of Kaien Island, due north of Bishop's Island. It is near the southernmost WW2 gun emplacement at the south end of Kaien Island. A concrete bunker lies on th N side of the tracks, across from the gun emplacement and the artifact was found 30m east of the bunker.

5. Access From Prince Rupert take Hwy 16 and turn off on Ridley Islar road. Continue to Ridley Island and park in lot opposite grain terminal. Walk back to CNR overpass and follow tracks in NW directi for 750m. At first gun emplacement take trail to bunker on N side c tracks. Artifact found 30m east of bunker on dirt road leading to WW2 facilities on top of hill.

6. Latitude 54 ° 14 ' 26 " N   **7. Longitude** 130 ° 19 ' 53 " W

8. UTM 09U / VL E 133 N 109   **9. Air Photo** B.C. 77101:152

10. Map 103 / J / 1   **11. Other Map** N/A

Land Status

12. Legal Description Coast Land District Range 5

13. Protection Status

14. Owner Prince Rupert Port Authority
110 3rd Avenue West, Prince Rupert, B.C. V8J 1K8

15. Municipality Prince Rupert

16. Regional District Skeena - Queen Charlotte

17. Ethnolinguistic Area Tsimshian, Tsimshian

Site No. GbTn - ______

Site Description

18. Site Type Cultural material, surface, isolated, cobble tool

19. Site Dimensions: L 2.0 m W 2.0 m

20. Cultural Strata The associated soil consisted of medium brown sandy silt with some gravel. Note, however, that the artifact was probably not in its original context.

21. Depth of Cultural Strata: Max N/A Min N/A Med N/A

22. Non-Cultural Strata

23. Archaeological Culture Unknown

24. Dates Unknown

25. Features None

26. Present Condition 1993: Very disturbed, Second World War harbour defence installation.

27. Future Condition ~~1993: Petrochemical plant.~~ 1994, Prince Rupert Port ~~Authority, 110 3rd Avenue West, Prince~~ Rupert B.C. V8J 1K8

Site No. GbTn - ______

Environment

28. Vegetation Zone Coastal Western Hemlock

29. Site Vegetation Trees: red alder, western red cedar; Shrubs: salmonberry, red berry elder, red huckleberry; Herbs: grass, moss, cow parsnip, youth-on-age, lady fern, wild lily of the valley, sword fern.

30. Drainage 24. Nass River

31. Landforms An area of glacial till deposits at the south end of Kaien Island, probably reworked to some degree by wave action.

32. Elevation (a) 5.35 m ASL (b) N/A

Investigations and Collections

33. Collector Archer, David 1993 **Permit** ______

______ **Permit** ______

34. Excavator N/A **Permit** ______

______ **Permit** ______

35. Significant Artifacts Cobble chopper, possibly dating to the early post glacial period: 8 000 - 12 000 years ago.

36. Collections Archer, David, 1993, unsystematic surface collection, on cobble chopper, repository: Museum of Northern B.C.

37. Photo Record Archer, David, 93/09/12, Museum of Northern B.C. 1: 13

38. Published References None

39. Unpublished References None

40. Informant N/A

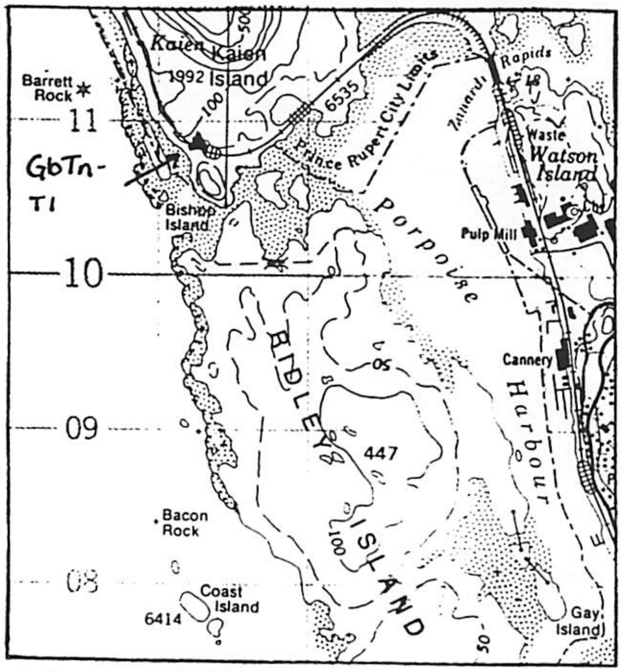
41. Recorder Archer, David and Rewcastle, Malcolm **Date:** 93 / 09 / 12

______ **Date:** ___ / ___ / ___

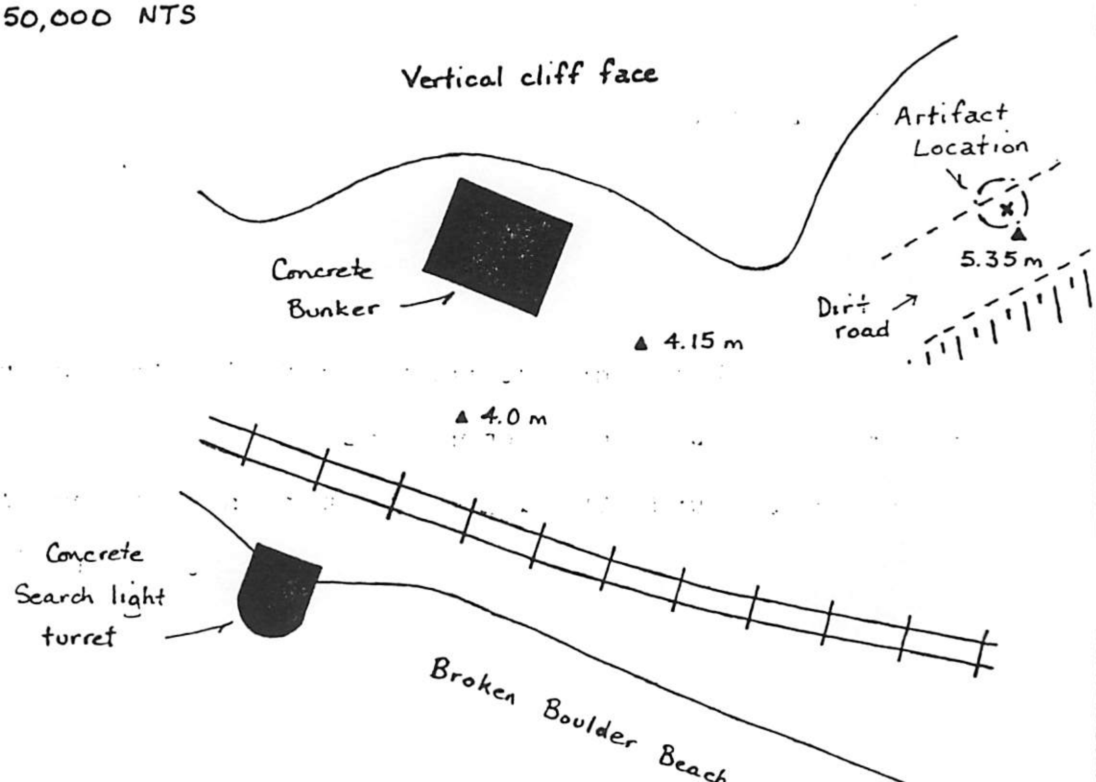
42. Remarks The artifact was found on a dirt road, built during the Second World War. The road ran from the harbour defence position on top of the adjacent hill,down to the facilities on the shoreline. These consisted of a searchlight and associated generator. It seems likely that the artifact originated somewhere further up the hill and was moved to its eventual position during the building of the road. However, exactly how much displacement occured is uncertain. The nature of the soil in which the artifact was found suggests a beach deposit, and the artifact itself is heavily water worn, indicating that the beach was active when the artifact was lost or discarded. Based on the available evidence, it is possible that the artifact dates to a time of higher sea levels 8 000 to 12 000 years ago.

Site No. GbTn -

TEMP. NO. GbTn - T1 (1993)



1:50,000 NTS



EXTENT OF SITE —·—·—·—

BUILDING ■

FOUNDATION □

ROAD ═══ = = = =

TRAIL — — — — — — —

RAILWAY ┼┼┼┼┼

FENCE —x—x—x—x—x—x—

RIVER/CREEK

STEEP RISE

ADDITIONAL LEGEND

× Artifact location

1:50,000 MAP NO. 103/J/1

LATITUDE 54° 14′ 26″ N

LONGITUDE 130° 19′ 53″ W

UTM GRID REF. 09UVL133109

TRUE □ MAGNETIC □x

DECLINATION USED 26 48

DATE Sept. 12, 1993

SCALE: 1 CM. = 5 M.

0 5 10 15 20 25

Appendix C

FLUSHING OF THE EMBAYMENT,
DROGUE STUDY
and
SEDIMENTATION PROCESSES AT THE PROPOSED DEVELOPMENT SITE
memoranda prepared by
HAY & COMPANY CONSULTANTS INC

MEMORANDUM

COPY

HAY & COMPANY
CONSULTANTS INC.
One West 7th Avenue
Vancouver, B.C.
Canada V5Y 1L5
(604) 875-6391
FAX: 875-8363

FILE: PRPC.003

TO	:	David Shearer, P.Eng.
FROM	:	Peter Morgan, P.Eng.
DATE	:	November 4, 1993
SUBJECT	:	Flushing of the Embayment

This memo details our analysis of the estimated impacts on the flushing of the tidal flat area due to the construction of the causeway for the LPG terminal. At present these flats are connected to the open waters of Chatham Sound through several small passages that run between the numerous rock outcroppings. Aerial photographs of the region at low tide show that there are two narrow and shallow channels - one entering from the north and one from the south of Bishops Island - which are slightly deeper than the surrounding flats. There is a slightly elevated area in the middle of the flats which prevents these two channels from connecting at lowest tide. This elevated region was probably created by the inward transport of sediment from surface wave action and possibly from currents. At present the location of the elevated area represents an accretion point in the transport of sediment from two opposite directions.

In order to investigate the flushing mechanism near the proposed terminal site, a bounded study region has been prescribed (Fig. 1). There are six open sections along the boundary of this region which connect the interior with Chatham Sound. The surface area of the region, the cross-sectional areas of the six sections, and the tidal prism volume at various tidal elevations are listed together in Table 1. In addition, the ratios of surface area to cross-sectional area have been calculated in order to estimate the current speeds through the openings by using a simple mass conservation approximation. These data are listed in Table 2. The integrated continuity equation is given by:

$$u(t) = \frac{Asrf}{Ax} \cdot \frac{dH(t)}{dt},$$

where $u(t)$ is the horizontal velocity at time t, and A_{srf} and A_x are the surface area and cross-sectional areas, respectively. $H(t)$ is the time dependent surface elevation (with respect to chart datum) which may be approximated by a sinusoid with amplitude H_o and period T; that is, $H(t)=H_o(1-cos(\varpi t))$, where $\varpi = 2\pi /T$ is the angular frequency. Substituting for $H(t)$ gives

$$u(t) = \frac{Asrf}{Ax} \overline{w}\, Ho \sin(\overline{w}t)$$

Although the final configuration of the proposed causeway has not yet been determined, it is known that it would extend from the shore across the tidal flats to Bishops Island and over a series of rock outcroppings to deep water. The effect of the causeway will be to divide the flats into two regions. Region A (R_A), to the south of the causeway, would have approximately 30% of the surface area, and 38% of the volume at high tide; while Region B (R_B) to the north would have the remaining 70% of the surface area, and 62% of the volume at high tide. We denote the total study area ($R_A + R_B$) by R_{A+B}. Cross-section 1 provides the lone connection between Chatham Sound and R_A, while cross-sections 2 through 6 connect R_B to Chatham Sound. The last three columns of Table 1 provide the values for the ratios for each of the three regions at 1 m increments in the tidal elevation.

If we consider a hypothetical, large amplitude (7 m), semi-diurnal tide such that $H_o = 3.5\ m$ and $T=12.42\ h$, then $\varpi H_o = 0.05\ cm/s$. From Table 1 we can calculate the current magnitude that we would expect to find in the cross-sections which connect to each of the three regions. Table 2 lists the calculated magnitudes at one hour intervals through a half tidal cycle (flood or ebb). For each of the regions R_A, R_B, and R_{A+B}, the maxima are approximately 2, 18, and 5 cm/s, respectively. The currents in all three regions are weak relative to speeds that have been measured in mid-channel (Hay & Company, 1993). In general, the effect of the causeway would be to decrease the current speed into or out of R_A by a factor of about 2, while increasing the current into or out of R_B by roughly a factor of 2. An exception occurs near low water in R_A, when currents would be significantly greater due to the decreased cross-sectional area through which the water could enter.

Observations made over two days in August, 1993 in conjunction with a surface drogue study (Hay & Company, 1993) confirm that current speeds near the proposed terminal site are weak at all phases of the tide. The drogue paths also support this conclusion since a large flood or ebb current entering onto or leaving from the flats would have altered the course of the most landward drogue.

Water leaving the flats on an ebb tide tends to remain near the surface if the receiving waters are highly stratified. This situation exists in summer months when enhanced surface heating and elevated Skeena River discharge contribute to the formation of a pycnocline. Heating of the water over the flats is particularly effective because of the shallow depths there. During summer, therefore, we would anticipate that the water leaving the flats on an ebb tide would tend to pool near the surface in Chatham Sound, and would experience little vertical mixing.

A model for calculating the flushing (e-folding) time for small embayments is discussed by Sanford et al. (1992). For the purpose of applying this model to the proposed terminal site we assume a much simpler geometry for each of the three regions than is actually the case. For each of R_A, R_B, or R_{A+B} we assume all waters to be confined to an embayment of equivalent volume and surface area, and connected to the receiving waters of Chatham Sound via a single channel with cross-sectional area and depth equivalent to the combined set of sections listed in Table 1 for the corresponding region. The flushing time is given in Sanford et al. by

$$T_f = \frac{VT}{(1-b)P}$$

where V,T,P and b are, respectively, the embayment volume at mean sea level, the tidal period, the tidal prism volume, and the return factor for waters that have left the embayment on an ebb tide $(0 \leq b \leq 1)$. This last quantity is the most difficult to estimate and much of the Sanford paper is devoted to calculating a reasonable value for b. An appropriate velocity scale for the water which exits a region on an ebb tide is calculated using the integrated conservation of mass equation, and is given by

$$Vo = \frac{P\pi}{\bar{A}_x T}$$

where $\bar{A}_x$ is now the cross-sectional area at mean sea level of the channel connecting the region to the receiving waters. An appropriate velocity scale, U, for the shore-parallel tidal current can be obtained from earlier measurements using surface drogues (Hay & Company, 1993). A value of U = 70 cm/s is representative of maximum ebb tide currents in the vicinity of the terminal site, and has been used in these calculations. Sanford et al. also define the ratio $r=Vo/U$, and the equivalent channel width $Bo=\bar{A}_x/H$, where H is the depth at mean sea level in the connecting channel. Values for Vo, Bo and r are tabulated in Table 3. All calculations assumed a 7 m tidal range with a semi-diurnal period of 12.4 h. In Table 3 the region volumes, cross-sectional areas, and depths correspond to those at 4 m above chart datum, which is the approximate value for mean sea level. The tidal prism volume is based on the assumed tidal range of 7 m.

The expression for b depends on a length scale y_m, which corresponds to the offshore distance reached by the initial discharge after leaving the connecting channel on an ebb tide. For small values of r, such as occur in these cases, the appropriate expression is given by;

$$Ym = 0.5_r B_o$$

For the parameter values used in this study, calculated values for y_m are relatively small–10 m or less (Table 3). This means that the water exiting any of the three embayments is quickly captured by the nearby shore-parallel tidal flows. The width of the discharged plume in this case is given by (Table 3).

The final parameter value required to calculate the return rate b, is a diffusion length scale given by;

$$\sigma_t = \sqrt{0.5UhT}$$

where h is the depth of the receiving waters outside the embayments. Referring to the navigation chart for this region we selected a value of 50 m for h. Using the values for U and T of 70 cm/s and 12.4 h noted earlier, we calculate that σ_t = 884 m. In these cases, where y_m/b = 0.5, Sanford et al. solve for b as a function of σ_t alone. The graph of this function included in their paper was used to determine the values for the present set of parameters. Values for σ_t/B are relatively large for all three regions, and the corresponding values for b extracted from the graph are all significantly less than 0.1 (Table 3). This seems reasonable, since conditions near the development site are such that on an ebb tide a relatively small volume of water is slowly discharged from the flats into a rapidly moving current that flows out of Prince Rupert Harbour into Chatham Sound. We would not expect that a large fraction of the water leaving the flats would return on the subsequent flood tide, and the calculations support this reasoning.

Values for the residence, or flushing time T_f, were calculated and are listed in Table 3. The times range from 14 to 20 h, and represent between one and two semi-diurnal tidal cycles. Given the imprecise nature of the calculations, the variation among the three regions cannot be considered as significant.

Hay & Company concludes that the construction of a causeway over the tidal flats will not significantly alter the rate of flushing in a region which is, at present, well flushed by the energetic tidal currents in the region. The presence of the causeway will probably result in a slow redistribution of sediment in the two new embayments since the present state of equilibrium will be disrupted. This will cause minor modifications to the bottom slopes on either side of the causeway.

References

Hay & Company Consultants Inc. 1993. Internal Memorandum to Prince Rupert Port corporation. (Drogue Study at proposed LPG Expansion Site).

Sanford, Lawrence P., William Boicourt and Stephen Rivers, 1992. Model for Estimating Tidal Flushing of Small Embayments. Journal of Waterway, Port, Coastal and Ocean Engineering Vol. 118., No. 6, pps. 635-654.

(m)	Prims Vol. $(10^3 m^3)$	Surface Area $(10^3 m^3)$	Cross-Sectionl Area (m^2)									Ratios for each Region[1]		
			Section Number						Total for Region			A (30%)	B (70%)	A+B (100%)
			1	2	3	4	5	6	A	B	A+B			
8	2,297	287	2,610	288	1,068	475	1,265	970	2,610	4,066	6,676	33	49	43
7	1,932	276	2,368	221	878	335	1,025	818	2,368	3,277	5,645	35	59	49
6	1,574	262	2,125	153	688	195	785	665	2,125	2,486	4,611	37	74	57
5	1,229	246	1,893	111	533	105	545	528	1,893	1,822	3,715	39	95	66
4	915	229	1,660	68	378	15	305	390	1,660	1,156	2,816	41	139	81
3	628	209	1,438	41	278	0	205	273	1,438	797	2,235	44	184	94
2	364	182	1,215	13	178	0	105	155	1,215	451	1,666	45	282	109
1	178	178	1,010	0	106	0	53	78	1,010	237	1,247	53	526	143
0	0	0	805	0	33	0	0	0	805	33	838	0	0	0
-1	0	0	633	0	0	0	0	0	633	0	633	0	0	0
Maximum depth (m)			6	1	1	3	0	0	6	3	6			

Table 1: Parameters used in Calculations of Flushing Near Terminal Site

[1] Ratio = (% Surface Area) / (Total Cross-sectional Area)

Table 2: Estimated current speeds

H (m)	Time[2] (h)	Ratios for each Region			Current speed (cm/s)		
		A (30%)	B (70%)	A+B (100%)	A (30%)	B (70%)	A+B (100%)
7	6.20	35	59	49	0	0	0
6	4.67	37	74	57	1.3	2.6	2.0
5	3.97	39	95	66	1.7	4.2	2.9
4	3.38	41	139	81	2.0	6.8	4.0
3	2.82	44	184	94	2.1	9.0	4.6
2	2.23	45	282	109	2.0	12.6	4.9
1	1.53	53	526	143	1.8	18.1	4.9
0	0	0	0	0	0	0	0

2 Assuming a 3.5 mm amplitude, semi-diurnal, sinusoidal flooding tide

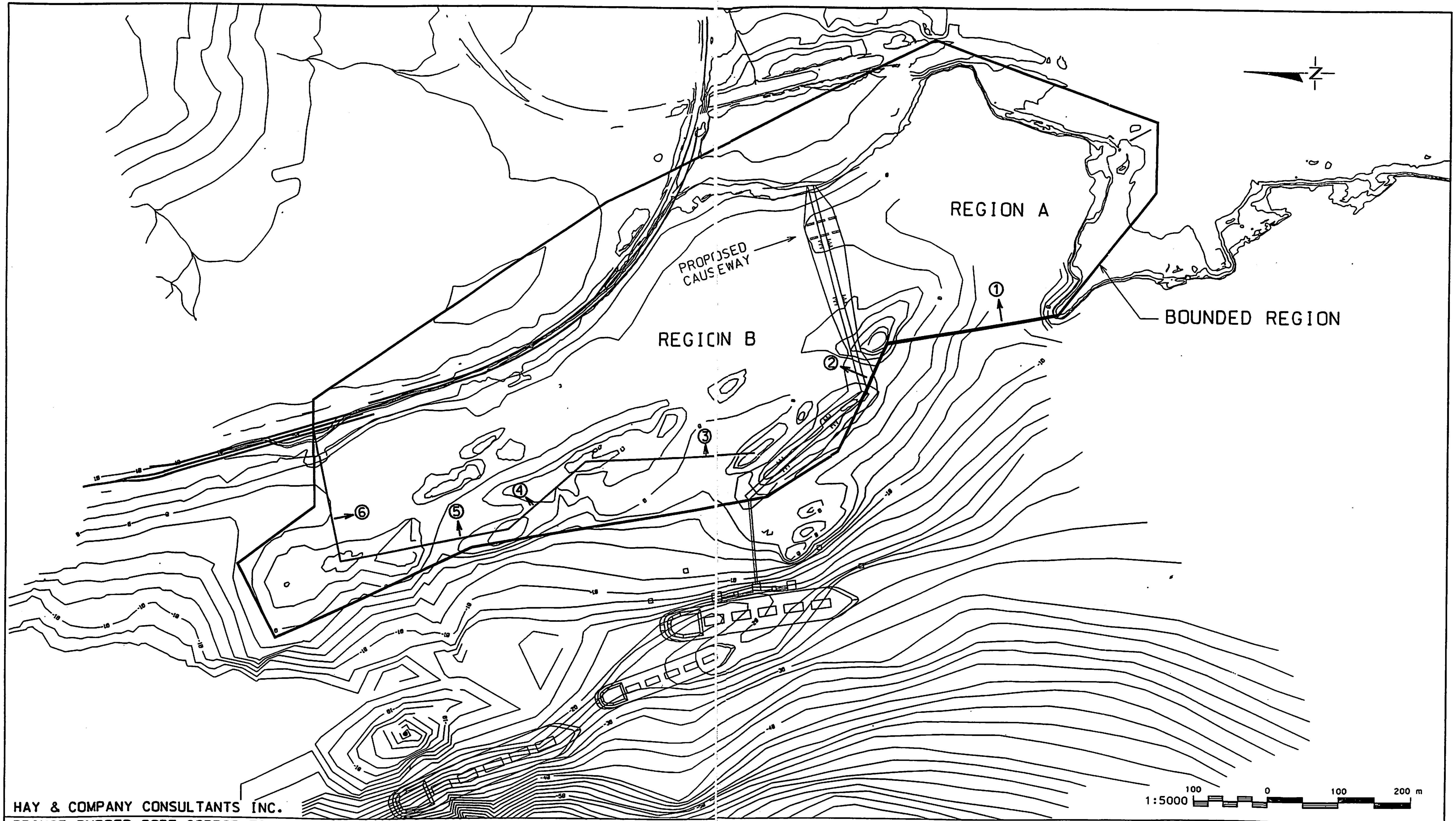
Table 3: Parameters for Each Region

Region	% Surface Area	Mean Values[1]				$V_0^{(1,2)}$ (cm/s)	B_0 (m)	$r^{(3)}$	B (m)	Y_m (m)	$\frac{\sigma_T}{B}$	b	T_f (h)
		Volume (10^3m^3)	Prism (10^3m^3)	X-Sec (m^2)	Depth (m)								
R_A	30	870	580	1,660	10	2.5	166	0.036	6	3	147	0.05	20
R_B	70	1,430	1,352	1,156	7	8.2	165	0.117	20	10	44	0.08	14
R_{A+B}	100	2,300	1,932	2,816	10	4.8	282	0.069	20	10	44	0.08	16

1 Based on mean sea level.

2 Based on a 12.4 h tidal period.

3 Assuming U = 70 cm/s.



HAY & COMPANY CONSULTANTS INC.

PRINCE RUPPER PORT CORPORATION

LPG TERMINAL EXPANSION

PROPOSED CAUSEWAY AND TERMINAL CONFIGURATION

FIG. 1

CAD FILE/ PRPC-003/F1&2-3D.DGN/RF = HYDROG.DGN / NOV.03.1993

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MEMORANDUM

HAY & COMPANY

CONSULTANTS INC.
One West 7th Avenue
Vancouver, B.C.
Canada V5Y 1L5
(604) 875-6391
FAX: 875-8363

FILE: PRPC.003

TO : David Shearer, P.Eng.

FROM : Peter W. Morgan, P.Eng.

DATE : November 5, 1993

SUBJECT : Drogue Study

We are pleased to provide this memo detailing the drogue deployment exercise carried out on August 2 and 3, 1993, and the data reduction and analysis undertaken.

INTRODUCTION

In February of 1993, the Prince Rupert Port Corporation retained Hay & Company to provide consultations in oceanography and coastal engineering as part of the environmental assessment of a proposed liquid petroleum gas (LPG) offloading terminal. As part of the assignment, Hay & Company were asked to analyze the tidal currents in the waters adjacent to the site, to estimate the magnitude and characteristics of those currents and to render an opinion on the impacts on those currents caused by the construction of the terminal, which was to consist of a causeway and a piled trestle structure.

The proposed development site is located at the intersection of Ridley and South Kaien Islands, on the east side of the approach channel to Prince Rupert Harbour (Figure 1). The foreshore at the site consists of tidal flats composed of sand, silt and mud deposits, with a number of exposed bedrock outcrops. All of the bedrock outcrops are underwater at high tide, except for Bishops Island.

The proposed development would consist of a causeway extending from the shoreline of Ridley Island to Bishops Island, and then continuing on to rock outcrops lying offshore of Bishops Island. From these outcrops would extend a piled trestle structure, to which the LPG tankers would moor (Figure 1).

BACKGROUND CURRENT DATA

A review of available information showed that there was a lack of site-specific current data. Estimates of maximum ebb currents of 2.5 knots (1.3 m/s) and maximum flood currents of 1.5 knots (0.77 m/s) are given on the CHS hydrographic charts for the area. Discussions with M. Woodward at the Institute of Ocean Sciences (IOS) in Sidney indicated that these estimates were probably based on driftpole measurements undertaken by the British Admiralty in the early 1900's and would be for "representative spring tide conditions". We have also had some discussions with Dario Stucchi at IOS; he has recently been measuring current data at a location within Prince Rupert Harbour; these data are still being reduced and analyzed and Mr.Stucchi will be forwarding copies of the analysis and results when he has finished the work.

DROGUE STUDY

To estimate current magnitudes and patterns throughout a representative spring tide cycle, Hay & Company, in conjunction with Port Corporation personnel, undertook a drogue study at the site on August 2 and 3, 1993. The objectives of the study were to:

- obtain estimates of peak surficial current speeds in the waters adjacent to the site at different intervals in a tidal cycle;
- determine the spatial variation in current speed and direction at different distances or offsets from the shoreline and identify the existence of any eddies or quiescent areas;
- use the data collected to render an opinion on the effect of the proposed causeway on current velocities in the embayment and in the adjacent waters.

August 2 and 3 were selected for the study as they corresponded to spring tide conditions for the month. Three drogues were deployed and tracked over 7 intervals on those 2 days (4 on flood tide and 3 on ebb tide). The positions of the drogues were tracked using 2 standard theodolites stationed onshore; Station #1 was located directly inshore of the Barret Rock light, and Station #2 was located on the small point of land extending seaward to the south of Bishops Island (Figure 1). Location shots were taken every 5 to 10 minutes during each deployment, and the drogue tracks were mapped using triangulation and the known locations of the theodolites. Drogue positions on each deployment were then downloaded onto CAD for plotting and analysis.

Conditions were excellent for tracking on both days. On August 2, there was bright sunshine, a slight onshore breeze, and a small chop of about 0.4 m at the start of tracking, with the winds diminishing slowly into the evening hours. On August 3, conditions were clear with bright sunshine, and calm conditions on the water which continued throughout the day. Intermittent fishing vessel traffic was present, and boat waves resulting from these and other vessels ranged up to about 0.8 m in height.

The date, start and finishing times and tide conditions for each deployment are given in Table 1. Figures 2 to 8 illustrate the drogue patterns for each deployment. There are 3 drogue tracks for each deployment, with the following numbering system: the outer drogue (the one furthest offshore) is designated #1, with the middle drogue designated #2 and the inner #3.

DISCUSSION OF RESULTS

The average velocity for each drogue track was determined by a summation of the total distance covered between each location shot, and then dividing this sum by the total elapsed time between deployment and recovery. Incremental velocities between each location shot and peak velocities for each drogue track were also calculated. Average and peak velocities are listed in Table 2, whereas the incremental velocities have been tabulated in tables 3.1 to 3.7, one table for each deployment. Peak velocities on ebb flow ranged up to 0.88 m/s or 1.7 knots (deployment 3 track 1) with peak velocities on flood reaching 0.62 m/s or 1.2 knots (deployment 6, track 1). In all but deployments 1 and 4, the highest velocities were recorded on drogue 1, the drogue closest to the centre of the channel.

Higher average and peak velocities during ebb tide are due to the probable existence of a jet of expanding flow, created as the water moves out of the narrow portion of the channel exiting Prince Rupert Harbour. On flood, the waters converge and constrict as they enter the harbour, which leads to smaller velocities.

The horizontal gradient of ebb flow varies with the age of the ebb tide and steepens as ebb tide progresses. For deployment 1, all drogues travelled at roughly the same velocity, whereas during deployments 2 and 3, the horizontal gradient becomes steeper as the velocity of drogue 1 increased and the velocity of drogues 2 and 3 decreased.

During flood flow, the horizontal gradient tended to flatten as the flood tide progresses. For example, during deployment 5, the average velocity of drogue 1 was 0.35 m/s, with drogue 3 exhibiting a velocity of 0.15 m/s. However, during deployments 6 and 7, the variation in velocities from drogue 1 to drogue 3 decreased.

The existence of large eddies in and around the embayment area during ebb tide was identified during the field work, as evidenced by the decrease in the velocity of drogue 3 and the reversal of flow direction. This is particularly apparent in deployments 2 and 3, where drogue 3 shows a significant decrease in the current velocity adjacent to the shore. Visual observations support the measured velocities and the eddy was found to extend from the beach inshore of Barrett Rock, out to Barrett Rock and then to the south for several hundred metres. The Port Corporation's vessel also drifted to the north when idling in this area during ebb tide.

A further eddy area was identified during deployment 3 which extended about 200 m out from the point of land south of Bishops Island.

During deployment 4, drogues 2 and 3 exhibited flow towards the harbour, which was expected during a flood tide, whereas drogue 1 measured flow continuing out to sea. This outward flow in the deeper part of the channel continued through deployment 4 and did not reverse until approximately 1.5 hours after low tide was reached. This phase lag between the shallower flow nearshore and the flow in the deeper part of the channel is likely a result of the deeper channel providing less frictional resistance to the remaining ebb current, which then possesses more inertia and is more resistant to changes in the flow direction. The shallower flow closer to shore is likely subjected to greater bottom friction resistance which decreases the remaining inertia in the flow.

A subsequent visit was made on September 15 and 16 to collect sediment samples and note geomorphological features at the site. During this visit, tidal currents within the embayment itself were observed using floating debris and logs. Flood currents in the area between Bishop Island and the point were estimated to be about 0.10 to 0.20 m/s, moving generally towards the north. At the north end of the embayment adjacent to Barrett Rock, currents were observed to be flowing into the embayment from the existing inlets, and were estimated to be between 0.1 and 0.2 m/s. The inflow of currents from both the south and the north inlets to the embayment caused the formation of an eddy within the embayment, just to the north of the proposed causeway alignment. Observations indicated that this eddy existed throughout most of the flood tide.

During ebb tide, it was observed that water flowed out of the embayment through the inlet channels at the north and the south. Speeds to the north ranged from about 0.15 to 0.25 m/s, with currents moving to the south at a slightly slower rate.

POSSIBLE CAUSEWAY IMPACTS

Hay & Company are of the opinion that, although the causeway will impact the flow paths within the embayment, these impacts will not be significant. The existence of the extensive eddies and flow reversals during ebb tide indicate that flow from the embayment predominates over the tidal flat area. The emptying and filling of the embayment from several channels suggests that the volume of water flowing through the embayment from one end to the other is not significant, thus the construction of the causeway should not interrupt large flow volumes. Essentially, the causeway will create 2 embayments, where one now exists, and each will still be well flushed at low tide.

Measurements of the surface currents within the embayment suggest a very protected environment. The magnitude of the horizontal velocity gradients suggest that during most stages in the tide, the currents within the embayment are significantly smaller than those found outside in the main channel.

The extension of the causeway past Bishop Island to the exposed outcrops will deflect the tidal currents at that point, and cause a local alteration in the flow regime. However, since the adjacent bottom contours are very steep, we would expect the deflection of flow to not contribute significantly to the local current velocities.

TABLE 1
DROGUE DEPLOYMENT SCHEDULE

Deployment	Date	Start Time	End Time	Tide
1	Aug 2	15:07	17:16	ebb
2	Aug 2	17:35	18:45	ebb
3	Aug 2	18:48	19:52	ebb
4	Aug 2	20:46	21:45	flood
5	Aug 3	11:08	12:35	flood
6	Aug 3	12:50	13:42	flood
7	Aug 3	14:01	15:17	flood

TABLE 2
DROGUE VELOCITIES

Deployment	Drogue #	Average Velocity (m/s)	Peak Velocity (m/s)
1	1	0.25	0.41
	2	0.34	0.48
	3	0.29	0.38
2	1	0.69	0.81
	2	0.59	0.83
	3	0.10	0.30
3	1	0.88	1.1
	2	0.34	0.66
	3	0.07	0.19
4	1	0.22	0.28
	2	0.12	0.16
	3	0.11	0.14
5	1	0.35	0.62
	2	0.24	0.53
	3	0.15	0.55
6	1	0.62	0.76
	2	0.49	0.56
	3	0.41	0.54
7	1	0.25	0.33
	2	0.22	0.32
	3	0.14	0.33

Table 3.1
Incremental Velocities
Deployment 1

Drogue 1			Drogue 2			Drogue 3		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (Min)	V (m/s)
0	15:07		0	15:16		0	15:33	
75.7	15:23	0.079	166.9	15:30	0.20	131.8	15:44	0.20
45.9	15:35	0.064	72.1	15:36	0.20	114.8	15:51	0.27
49.8	15:42	0.12	113	15:43	0.27	120.3	15:58	0.29
53.6	15:49	0.13	126.1	15:50	0.30	143.4	16:05	0.34
92.6	15:57	0.19	155.8	15:57	0.37	176.7	16:13	0.37
109.8	16:06	0.20	144.5	16:04	0.34	119.9	16:19	0.33
98.1	16:12	0.27	178.9	16:12	0.37	159.0	16:26	0.38
104.0	16:18	0.29	160.7	16:18	0.45	135.6	16:34	0.28
135.1	16:25	0.32	199.3	16:26	0.42	119.1	16:42	0.25
194.5	16:33	0.41	203.4	16:33	0.48	149.7	16:51	0.28
137.5	16:40	0.33	222	16:41	0.46	188.9	17:00	0.35
216.4	16:50	0.36				126.9	17:07	0.30
188.5	16:59	0.35						
159.3	17:07	0.33						
220.4	17:16	0.41						

Table 3.2
Incremental Velocities
Deployment 2

Drogue 1 (L)			Drogue 2 (M)			Drogue 3 (R)		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (m/s	V (m/s)	Dis (m)	Time (min)	V (m/s)
0	17:35		0	17:37		0	17:44	
340	17:42	0.81	289.9	17:43	0.81	46.7	17:51	0.11
332.9	17:50	0.69	350.3	17:50	0.83	120.3	18:15	0.08
259.4	17:56	0.72	239.5	17:57	0.57	107.8	18:21	0.30
296.3	18:04	0.62	252.4	18:05	0.61	132.1	18:35	0.16
369.6	18:13	0.68	288.5	18:13	0.60	35.5	18:45	0.06
271.9	18:20	0.65	184.9	18:20	0.44			
			151.1	18:27	0.36			

Table 3.3
Incremental Velocities
Deployment 3

Drogue 1			Drogue 2			Drogue 3		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)
0	18:52		0	18:50		0	18:48	
389.8	19:00	0.81	357.6	18:59	0.66	126.4	18:59	0.19
357.5	19:08	0.74	253.6	19:07	0.53	104	19:47	0.04
467.9	19:18	0.78	261.1	19:17	0.44			
257.1	19:22	1.10	187.8	19:25	0.39			
			112.4	19:35	0.19			
			56.9	19:45	0.10			
			29.5	19:52	0.07			

Table 3.4
Incremental Velocities
Deployment 4

Drogue 3			Drogue 2			Drogue 3		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)
0	20:49		0	20:46		0	20:48	
70.8	20:56	0.17	52.0	20:54	0.11	40.3	20:55	0.10
66.7	21:04	0.14	52.5	21:02	0.11	58.8	21:03	0.12
0	21:09		40.2	21:08	0.11	46.6	21:08	0.16
136.3	21:17	0.28	56.9	21:15	0.14	58.8	21:16	0.12
115.3	21:24	0.27	53.4	21:22	0.13	44.2	21:23	0.11
55.7	21:28	0.23	62.0	21:31	0.11	53.5	21:30	0.13
0	21:36		37.6	21:37	0.10	42.3	21:36	0.12
96.3	21:45	0.18	32.8	21:44	0.08	51.6	21:45	0.10

Table 3.5
Incremental Velocities
Deployment 5

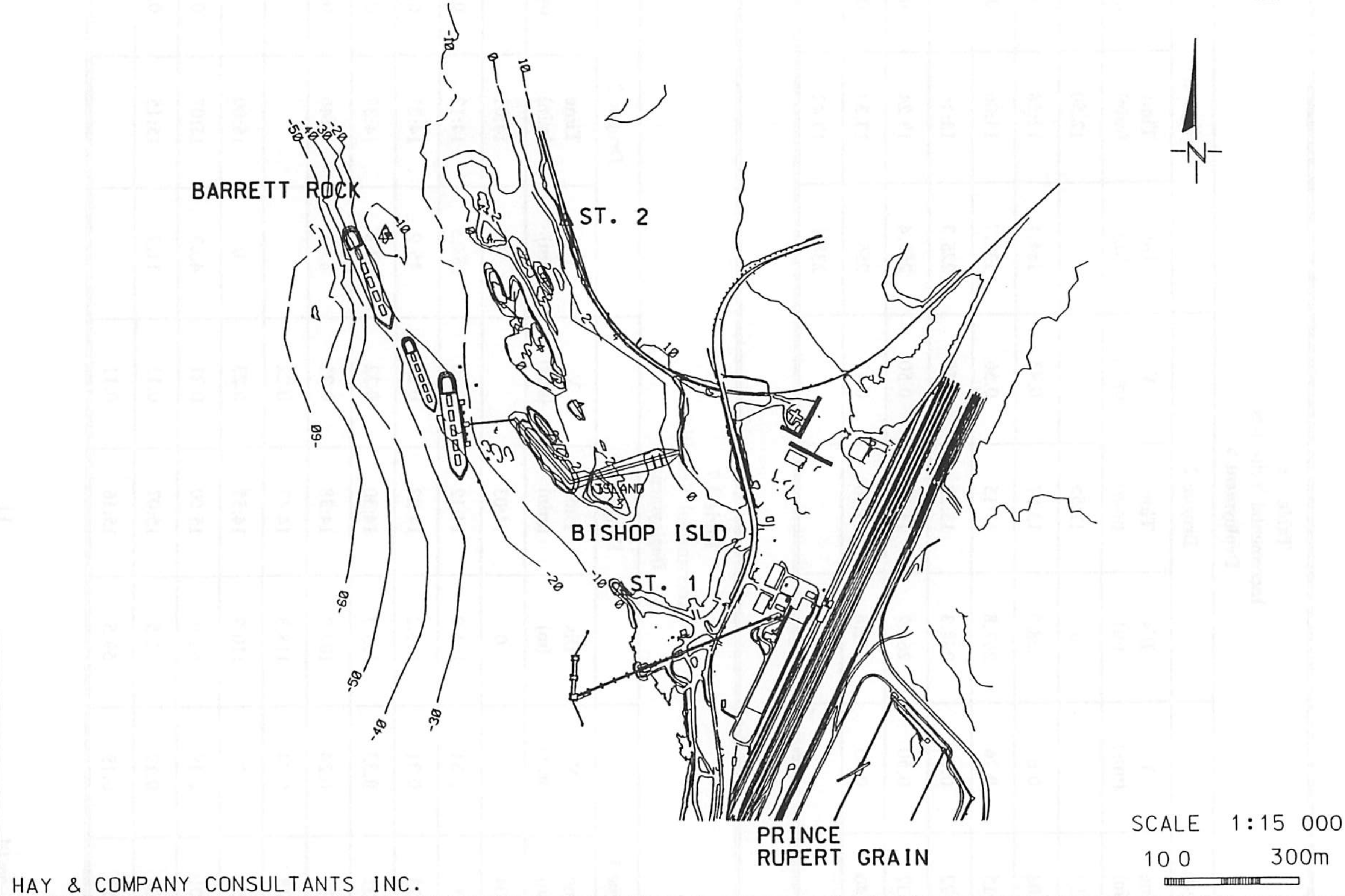
Drogue 1			Drogue 2			Drogue 3		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)
0	11:09		0	10:51		0	10:27	
98.9	11:19	0.16	40.2	11:00	0.07	17.4	10:38	0.03
112.5	11:29	0.19	53.6	11:08	0.11	51.1	10:59	0.04
109.8	11:38	0.20	60.1	11:18	0.10	18.1	11:08	0.03
149.0	11:48	0.25	99.9	11:29	0.15	98.2	11:36	0.20
205.0	11:55	0.49	80.2	11:37	0.17	111.9	11:46	0.19
287.2	12:06	0.44	134.9	11:47	0.22	94.1	11:55	0.17
286.1	12:14	0.60	172.9	11:56	0.32	105.3	12:05	0.18
218.0	12:23	0.40	202.7	12:05	0.38	194.6	12:13	0.41
186.3	12:28	0.62	286.7	12:14	0.53	197.0	12:21	0.41
			201.9	12:22	0.42	203.8	12:29	0.42
			159.8	12:28	0.44	198	12:35	0.55

Table 3.6
Incremental Velocities
Deployment 6

Drogue 1			Drogue 2			Drogue 3		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)
0	12:57		0	12:55		0	12:50	
404.3	13:08	0.61	208.0	13:07	0.43	164.1	12:58	0.34
320.6	13:15	0.76	267.8	13:15	0.56	132.7	13:06	0.27
307.3	13:22	0.73	268.3	13:23	0.56	225.3	13:16	0.38
297.5	13:32	0.50	269.7	13:32	0.50	259.4	13:24	0.54
289.7	13:40	0.60	252.4	13:40	0.47	256.7	13:33	0.48
						238.1	13:42	0.44

Table 3.7
Incremental Velocities
Deployment 7

Drogue 1			Drogue 2			Drogue 3		
Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)	Dis (m)	Time (min)	V (m/s)
0	14:04		0	14:03		0	14:01	
168.4	14:13	0.31	161.9	14:12	0.30	154.5	14:12	0.23
185.1	14:23	0.31	155.2	14:22	0.26	15.9	14:21	0.29
158.5	14:31	0.33	155.7	14:30	0.32	52.3	14:37	0.05
102.6	14:38	0.24	102.9	14:38	0.21	43.1	14:46	0.08
144.6	14:48	0.24	118.3	14:47	0.22			
112.4	14:56	0.23	110.9	14:55	0.23	0	15:00	
55.9	15:01	0.19	61.9	15:00	0.21	43.3	15:07	0.10
81.8	15:08	0.19	61.5	15:07	0.15	11.7	15:15	0.02
103.0	15:17	0.19	59.5	15:16	0.11			



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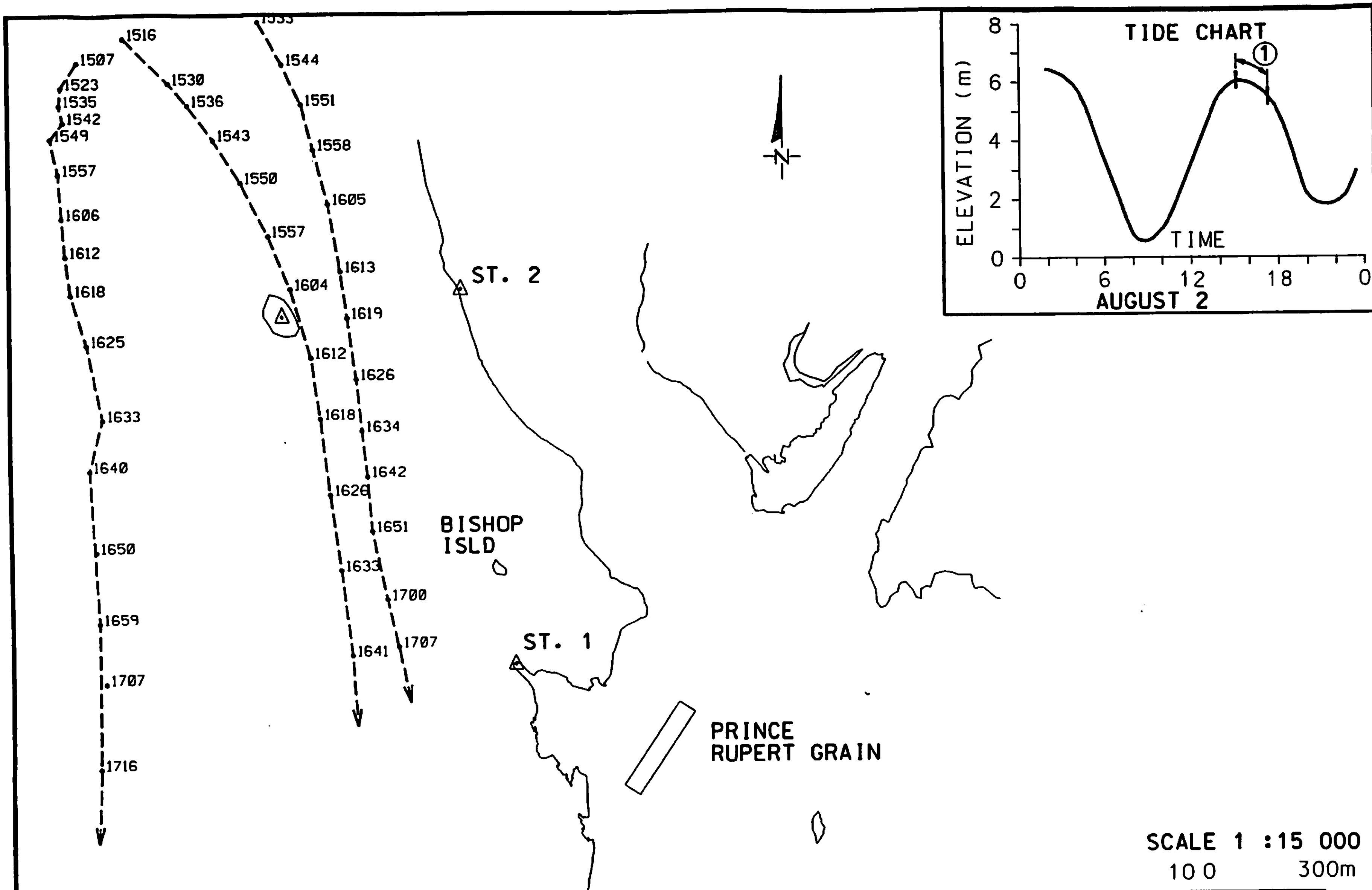
PROPOSED LAYOUT

FIG. 1

PRPC-002 / FIGS.DGN / RFS = DROGUE, HYDROG2D, FIGS & DETAILS.DGN / 1993 NOV 5



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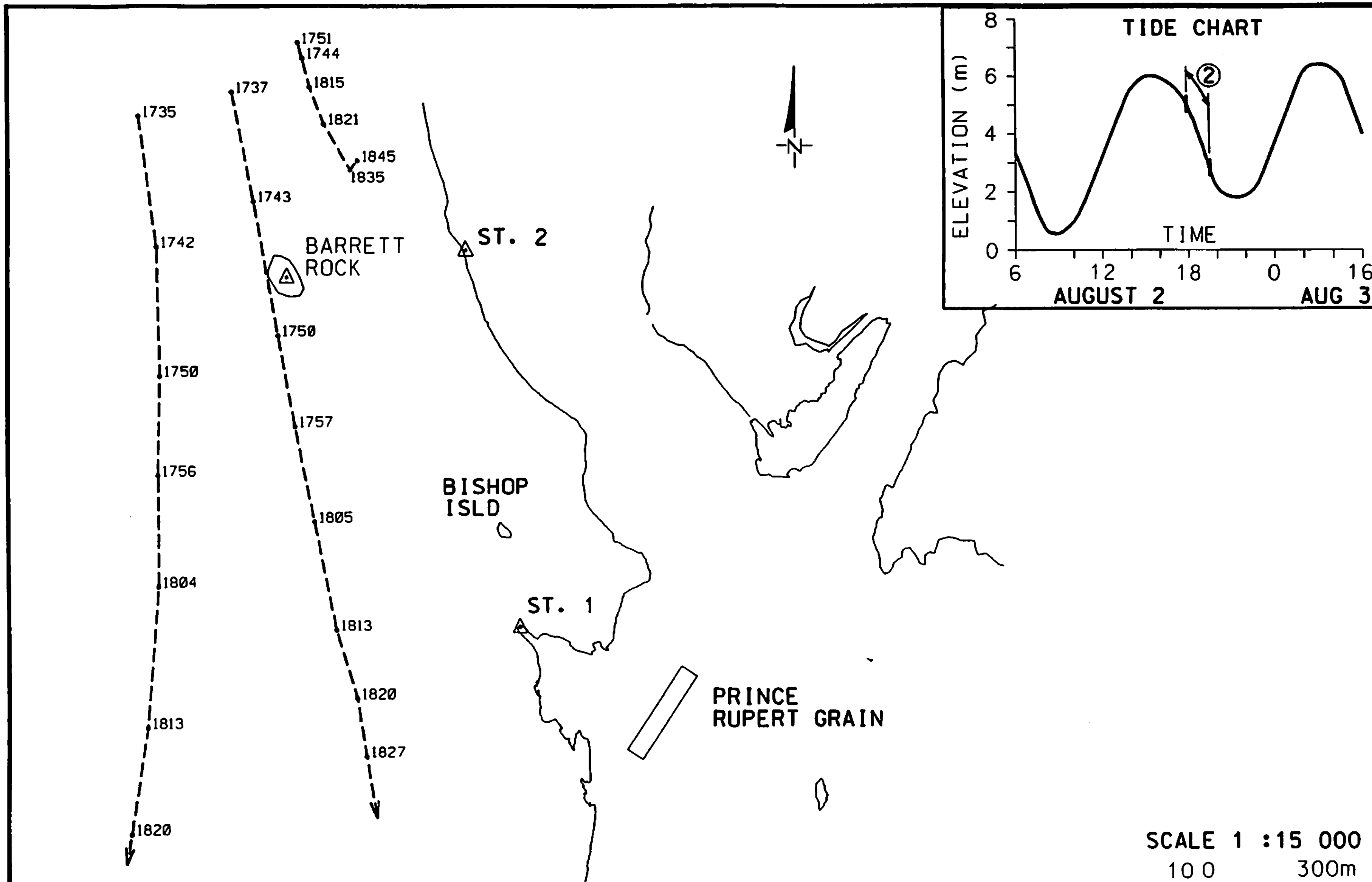
LPG TERMINAL

DROGUE DEPLOYMENT NO. 1

FIG. 2

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5



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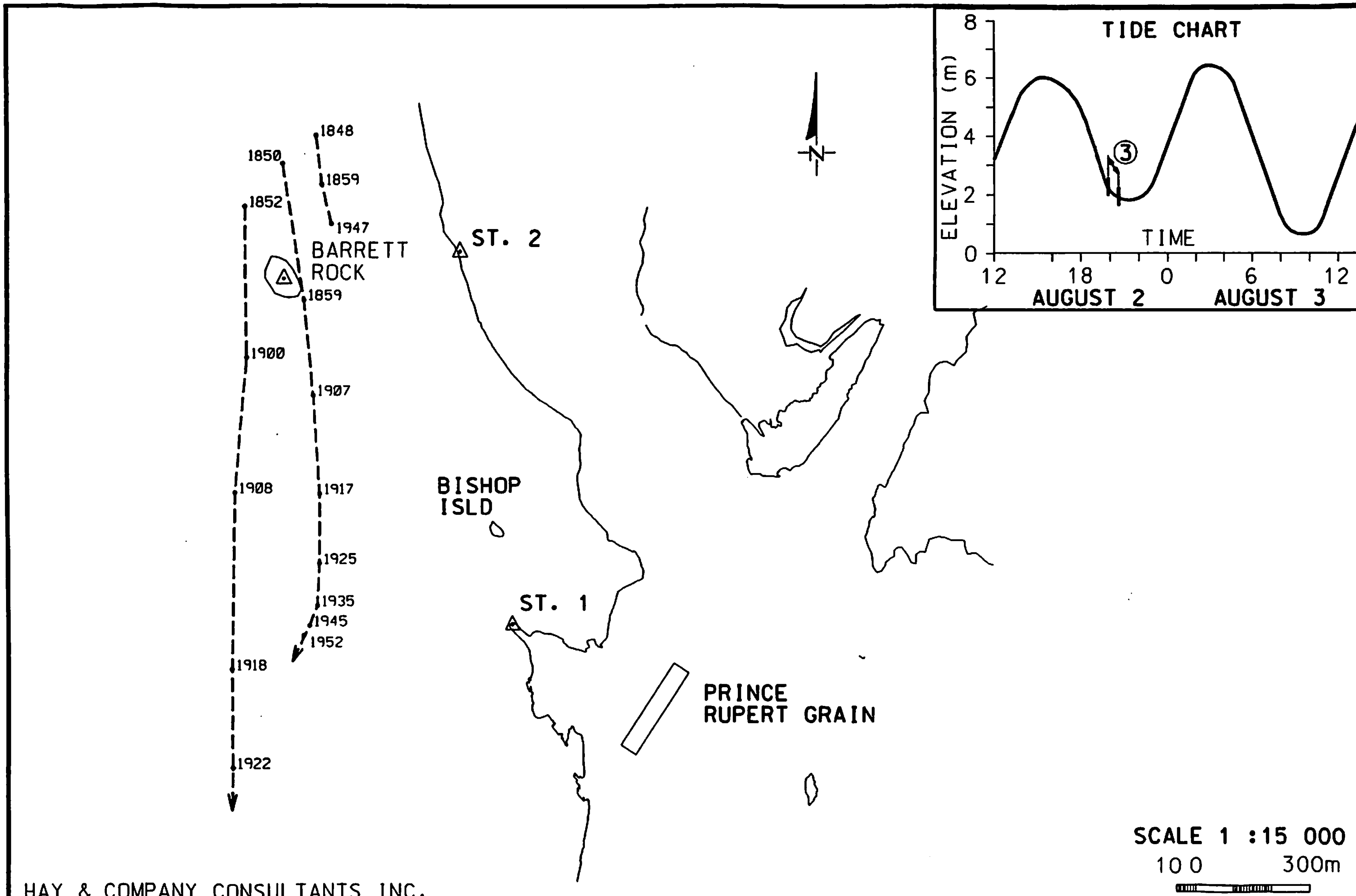
DROGUE DEPLOYMENT NO. 2

FIG. 3

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5



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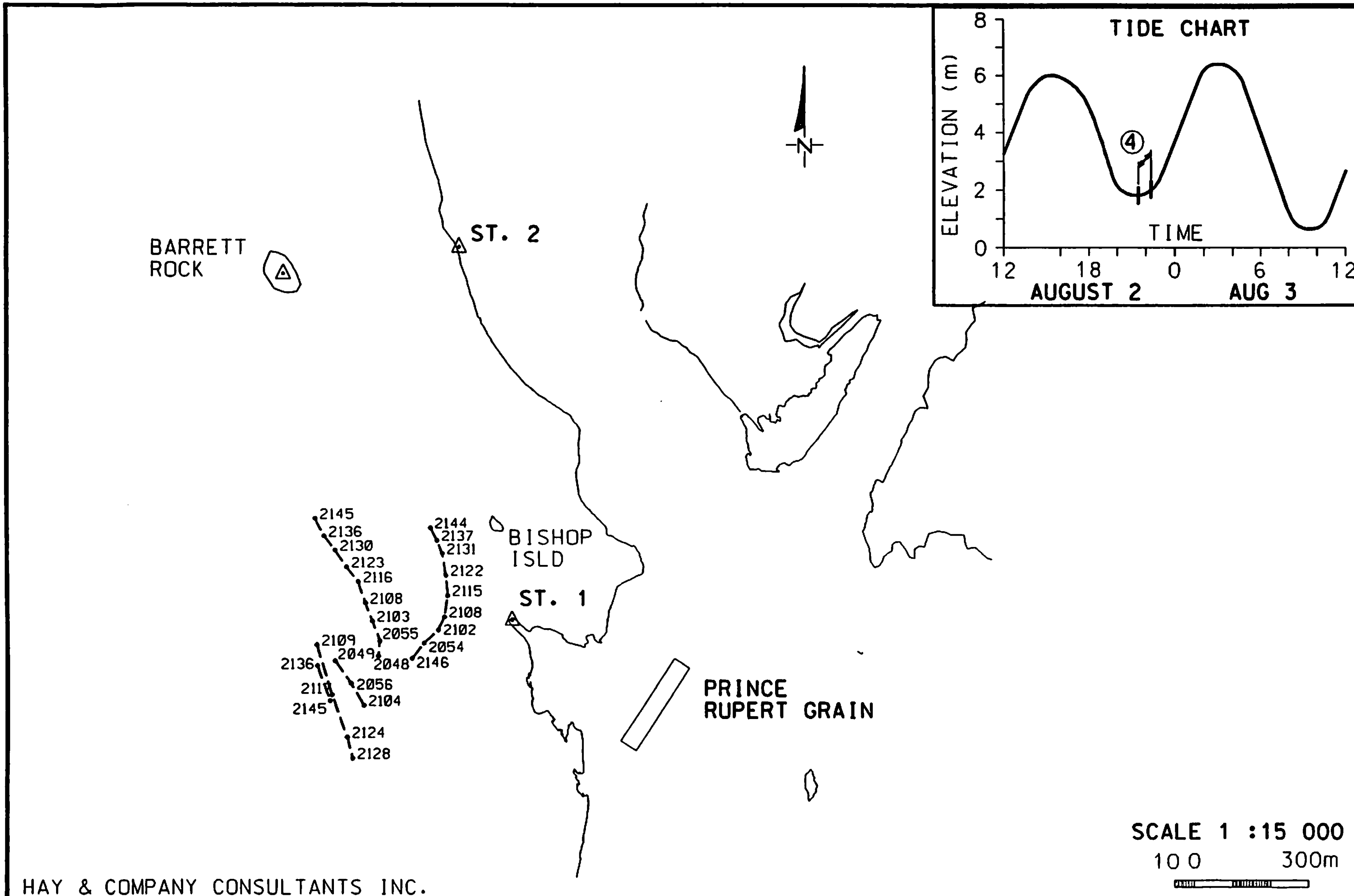
DROGUE DEPLOYMENT NO. 3

FIG. 4

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5



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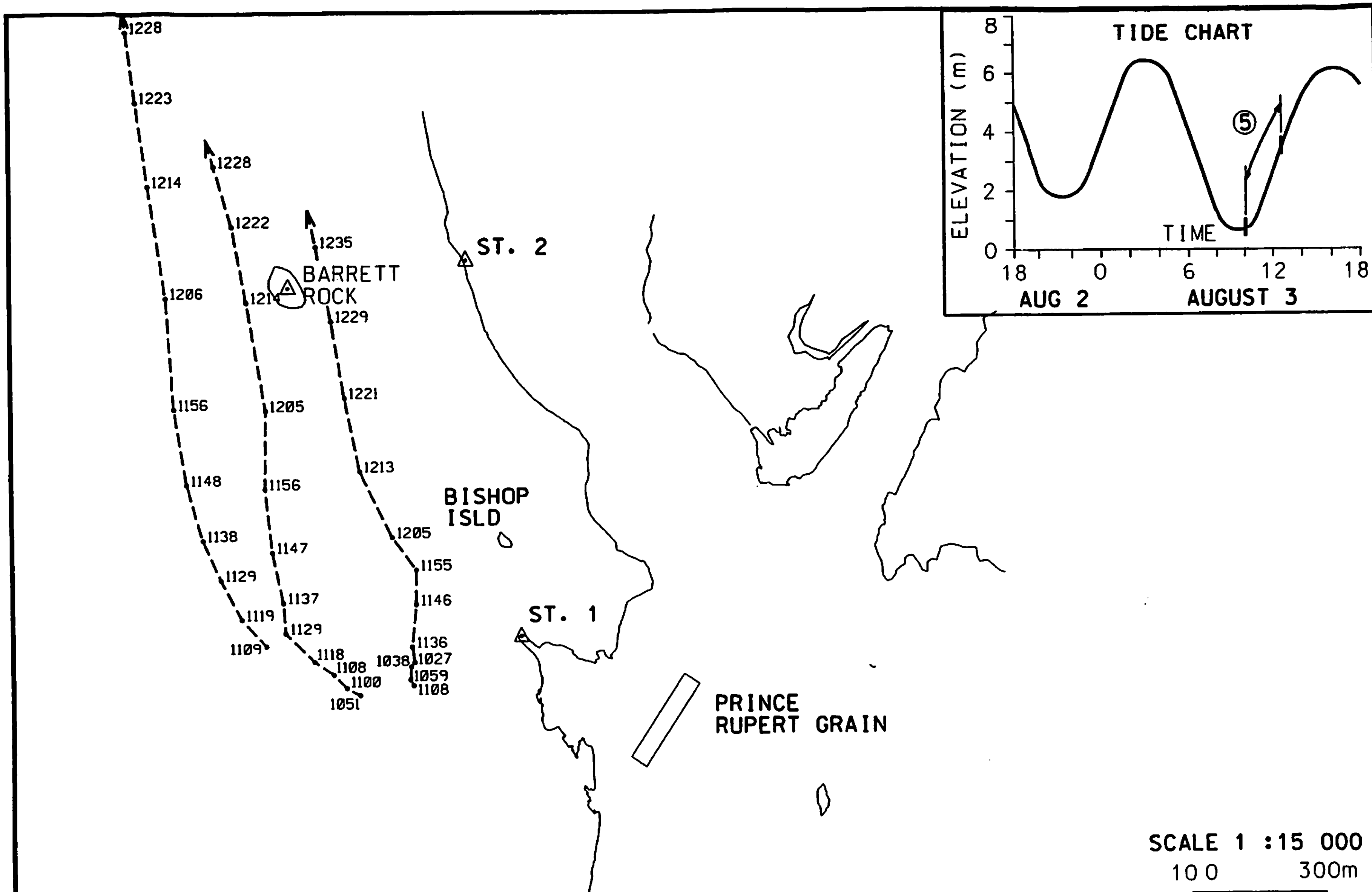
DROGUE DEPLOYMENT NO. 4

FIG. 5

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5



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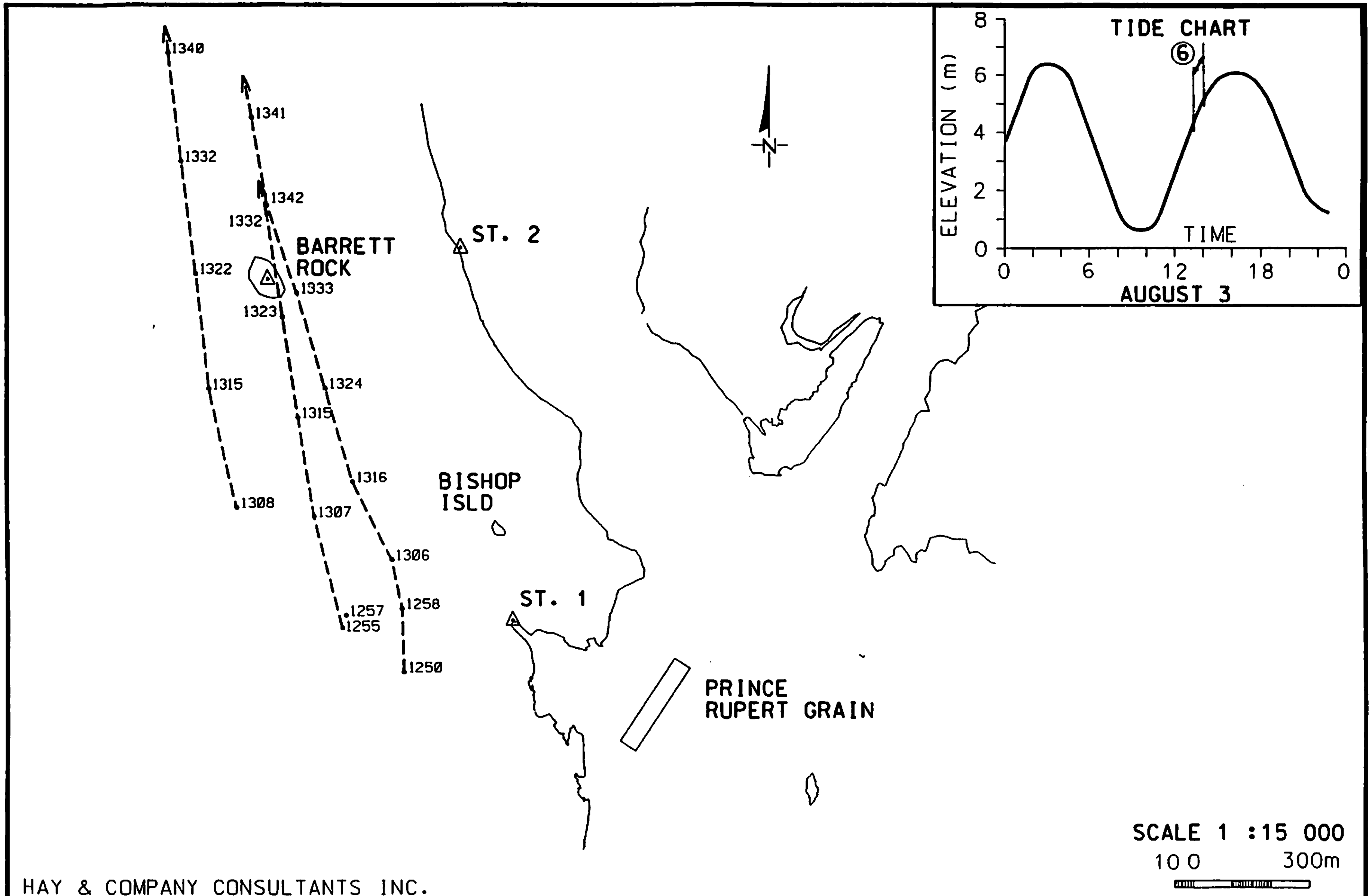
DROGUE DEPLOYMENT NO. 5

FIG. 6

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5



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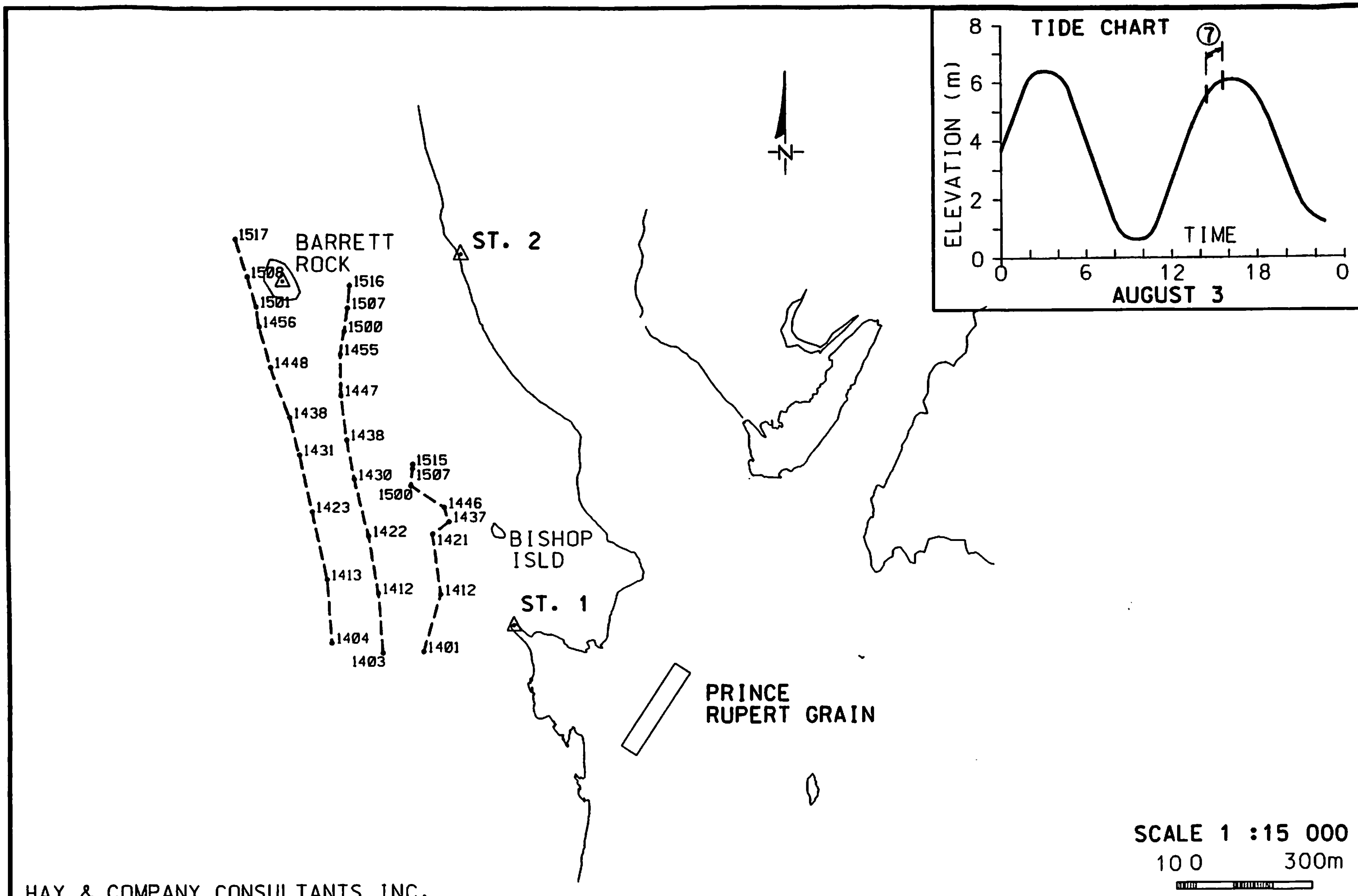
DROGUE DEPLOYMENT NO. 6

FIG. 7

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5



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LPG TERMINAL

DROGUE DEPLOYMENT NO. 7

FIG. 8

PRPC-002 / FIGS.DGN / RFS = DROGUE. HYDROG2D. FIGS & DETAILS.DGN / 1993 NOV 5

COPY

MEMORANDUM

HAY & COMPANY
CONSULTANTS INC.
One West 7th Avenue
Vancouver, B.C.
Canada V5Y 1L5
(604) 875-6391
FAX: 875-8363

FILE: PRPC.003

TO	:	David Shearer, P.Eng.
FROM	:	Peter Morgan, P.Eng.
DATE	:	November 5, 1993
SUBJECT	:	Sedimentation Processes at the Proposed Development Site

This memorandum discusses the geomorphic and sedimentary processes at the proposed LPG development site on Kaien Island and the potential impacts of the causeway on those processes.

INTRODUCTION

In February of 1993, the Prince Rupert Port Corporation retained Hay & Company to provide consultations in oceanography and coastal engineering as part of the environmental assessment of a proposed liquid petroleum gas (LPG) offloading terminal. As part of the assignment, Hay & Company were asked to undertake a site reconnaissance and sediment sampling program to:

- determine the general characteristics of sediments within the proposed development area;
- identify erosion and accretion areas within the development site;
- render an opinion on the potential impacts on sedimentation of the proposed development.

The proposed development site is located at the intersection of Ridley and Kaien Islands, on the east side of the approach channel to Prince Rupert Harbour (Figure 1). The area surrounding the terminal site is characterized by an intertidal zone composed of sand, silt and mud deposits, with a number of exposed bedrock outcrops. This zone extends for about 1 km north of the grain terminal and for a maximum distance of about 0.4 km offshore. All of the bedrock outcrops are underwater at high tide, except for Bishops Island, while during low tides all of the area is exposed, except for a small embayment at the south end.

The proposed development would consist of a causeway extending from the shoreline of Ridley Island to Bishops Island, and then continuing on to rock outcrops lying offshore of Bishops Island. From these outcrops would extend a piled trestle structure, to which the LPG tankers would moor (Figure 1).

To determine the general characteristics of sediments within the exposed embayment, Hay & Company undertook a site visit on September 15 and 16, 1993. The objectives of the site visit were to:

- collect surficial sediment samples in and around the embayment in order to determine the essential characteristics of those sediments;
- collect a detailed visual and photographic record to provide a detailed description of the surficial materials, to identify areas of erosion and accretion within the embayment and determine the probable sources of sediment.

SITE FEATURES

On the northern half of the site, the upper tidal shoreline consists chiefly of riprap, which has been placed as erosion protection for the railway line which runs adjacent to the shoreline. The riprap varies in size, ranging up to about 1.5 m nominal diameter. There are a number of areas where undercutting of the riprap has occurred; it appears that the finer sediments and cobbles have been washed out by wave action and the riprap has dislodged.

The intertidal area is narrow at the north end of the site, with bedrock outcrops predominating alongshore and offshore and tidal flats located in between.

There are several distinct transitions in sediment size and characteristics along a line perpendicular to the shore in this area. At the shoreline, the previously mentioned riprap layer occurs at a slope of about 1.5H or 2H to 1V. Offshore lies a zone of smaller revetment material, on the order of 500 to 600 mm in size, overlying finer sediments, generally at a slope of 6.5H to 1V. This zone extends offshore for about 15 m, at which point a gravel beach exists with a layer of 150 mm minus material overlaying a gravel/sand/mud layer. This gravel beach gives way to tidal flats about 30 to 40 m offshore, which extend across to the exposed bedrock outcrops.

Within the tidal flat channel at the north end of the site, which connects the embayment to the deeper waters offshore, a large 1.5 m diameter boulder is visible. On the north side of this boulder a large sand bar has formed which is aligned with the channel. This sand bar suggests that the predominant direction of transport in this area is to the north, with the lee of the boulder acting as a potential trap for sediments.

Just to the north of the intersection of Ridley Island and Kaien Island stand 2 historical gun placements constructed during World War II. These gun placements are situated directly on the exposed riprap face of the shoreline. The slope under both placements exhibits evidence of undercutting and erosion, which indicates that there are occasions when wave energy is high enough to dislodge and move these materials.

South towards the intersection of Ridley Island and Kaien Island a large sandy beach exists. It appears that this beach has formed due to wave action causing littoral transport in both the south and north direction, with the transported materials then accreting in this area. Visual inspection of surface currents in this area during flood tide indicated that currents from the north and south do eddy and mix in this region, which also suggests that this is a region of sediment deposition. It is likely that wave energy also propagates around Bishops Island to the south and the exposed outcrops to the north, resulting in transport of sediments into this region. Above the sand beach, the cobble and revetment deposits still predominate. Review of oblique air photos taken by Tera Planning at low tide during the summer of 1993 indicates that this accretional feature extends across the embayment to the outer rock outcrops and effectively divides the embayment into 2 separate regions, which are not connected at low tide.

Moving further to the south, the northwest tip of Kaien Island is essentially all exposed bedrock which rises to an elevation of 60 m and higher. The shoreline consists of exposed bedrock with an intermittent veneer of gravel and cobble, which is likely moved about under wave conditions at high tide.

The proposed alignment for the causeway runs across bedrock to a short strip of mudflat with exposed bedrock outcrops, and then on to Bishops Island. Just to the north of the proposed causeway, adjacent to the accreting beach, there is a relict ceramic tile pipeline which is exposed for about 20 m. The pipe is aligned northeast/southwest and heads straight towards Bishops Island; it appears that the pipe does extend some distance offshore, but it is impossible to say how far because only a short portion is exposed.

The shoreline along the southern part of the embayment is mostly fill which may have been placed as part of the expansion for Prince Rupert Grain. This material appears to be a blasted fill or quarry tailings, and is protected against erosion by coarser rock up to a nominal diameter of about 0.7 m. The material has been placed at a steep slope of about 1.5H to 1V and there are a number of areas where sloughing and erosion have occurred. The shoreline fill has a high content of finer material, such as sand and gravel, and the sloughing of this material has provided sediments for waves to mobilize and erode. In particular, one large slough failure exists on the south edge, the bulk of which has occurred above mean water level. Driftwood has been scattered around this region and what appears to be a temporary boat launch has been constructed. At high tide, the exposed sediments in this failure area are exposed to erosion by wave action. There are, in the southern part of the embayment, fewer tidal flats and more sand bars and rock outcrop.

SEDIMENT SAMPLES

Eight surficial sediment samples were collected during the site visit; the locations of each sample are noted in Figure 2. These locations were selected so as to provide a characterization of the sediments throughout the mudflat area. Sample sizes were 8 to 10 kg, were taken using a small shovel, tagged, and double bagged in plastic sample bags for transport. Analyses for grain size and texture were completed in Vancouver by Soilcon Laboratories.

Sand samples only were taken; gravel and cobble samples were not collected as the size of sample required for accurate sizing of the native material would have been large (on the order of 100 to 200 kg). Only visual observations of the gravel and cobble sizes were made.

Grain sizes and uniformity coefficients for the sediment samples are given in Table 1.

The D_{50} size is defined as the size that 50% of the particles, by weight, are smaller.

The uniformity coefficient is defined as;

$$\frac{D_{60}}{D_{10}}$$

D_{60} and D_{10} can be defined in a similar way to D_{50}. The higher the value of the coefficient of uniformity, the larger the range of particle sizes in the soil.

TABLE 1

SURFICIAL SEDIMENT

CHARACTERISTICS

Sample #	D_{50} (mm)	Uniformity	Classification
1	0.20	2.88	Sand
2	0.13	2.78	Sand
3	0.15	3.52	Sand
4	0.18	3.39	Sand
5	0.18	3.39	Sand
6	0.13	13.6	Sand
7	0.18	8.3	Sand
8	0.44	5.2	Sand

All collected sediment samples were classified as coarse grained, poorly graded sand using the USGS classification system.

Figures 3, 4 and 5 illustrate the grain size distribution curves. Review of these figures and Table 1 indicate that the samples all are very similar in size and texture, except for #8. This similarity in sizes suggests that most of the tidal flats are exposed to a similar level of wave and current energy. Samples #1 and #5 were collected on the sandy beach located at the intersection of Kaien and Ridley Islands, with #5 from further offshore. Sample #2 was collected adjacent to the bar and boulder, whereas Samples #3 and #4 were collected offshore from the southerly gun. Samples #6 and #7 were collected in the small embayment at the south of the site, and the decrease sediment size moving offshore is reasonable, as the level of wave and current energy should decrease.

Sample #8 was taken from the bar formation adjacent to the large slough failure on the south side of the embayment. The larger grain size suggests that this area has a higher level of wave or current energy and that there is a local source for these coarser sediments, which is probably the eroding slough area.

SOURCES OF SEDIMENTS

Initially, it was thought that the primary source of littoral sediments found within the embayment was the Skeena River, whose plume of sediments has been observed to extend to the entrance channel to Prince Rupert Harbour. However, upon completion of the site visit and review, it is most likely that the largest source of sediments for erosion and deposition would be the embankments and shorelines surrounding the site. The site reconnaissance indicated several local slope failures and erosional features including:

- the undercutting of the WWII gun placements;
- undercutting and local failures of the revetment and riprap protecting the rail line;
- the progressive shingling of the shoreline adjacent to the revetment embankment which follows the rail line, and the layer of gravel, sand and silt which lies underneath these gravel areas;
- the large slough failure at the south end of the site, lying to the east of the point.

Each of these features suggests that a significant amount of gravel, sand and silt has been mobilized at various times and moved about under waves and possibly currents. The gravelly deposits are generally found at the toe of the slopes, whereas the sands and silts are more easily moved under smaller waves and are thus mobilized more frequently and transported further.

There are 3 areas where deposition is occurring (Figure 2):

1 The beach and accretional zone lying to the north of the proposed causeway.

   As previously discussed, oblique aerial photos taken at low tide in the spring of 1993 by Tera Planning indicate that the elevation of this sand flat is higher than the surrounding tidal flat elevation. Thus, during certain low tides this area can be entirely exposed, effectively dividing the embayment into 2 separate embayments.

2 The gravel and sand berms which have formed at the south edge of the site.

These berms consist primarily of sand and also have a large gravel component in some areas. They lie adjacent to the large slough failure where the placed material (the blasted fill) has slumped and failed at or above the MWL. It would seem reasonable that the materials within this slump failure have been reworked by waves and shaped into the existing bars. Sediment sample 8, which was collected on the bar, is much coarser than the other samples collected on the tidal flat areas.

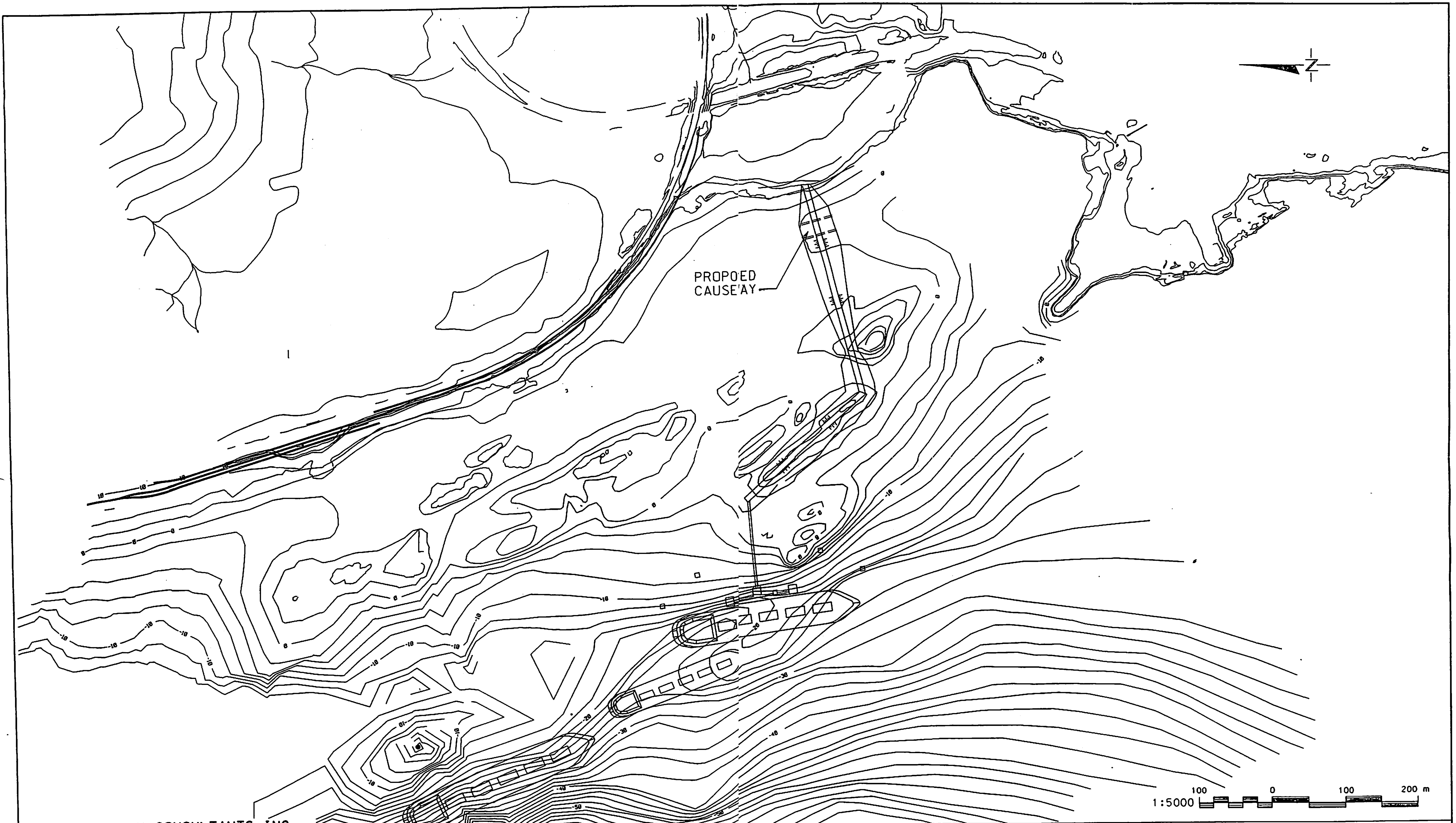
3 The sand bar at the north end of the site

This sand bar, located to the north of the large boulder, consists of a finer sand than found elsewhere on the flats. This suggests a low energy environment and that the boulder functions as a trap for sediments being transported to the north.

POSSIBLE CAUSEWAY IMPACTS

Hay & Company are of the opinion that although the causeway will impact the current flow paths within the embayment, these impacts will not be significant. Essentially, the causeway will create 2 embayments, where one now exists, and each embayment will be well flushed at low tide. We would expect the sandy beach deposit located to the north of the causeway to migrate to the south, as the waves and currents that re work those sediments are constrained by the causeway. Those sediments being delivered to that beach from the south will now be deposited against the south side of the causeway , whereas those delivered to the beach from the north will now be carried further to the causeway location. The effect will be accretion on both sides of the causeway, however, that accretion will have a minimal effect on the local bathymetry.

We would expect that the slough failure at the south side of the site would continue to be reworked by wave energy at high tide, thus feeding the existing bars in the area.



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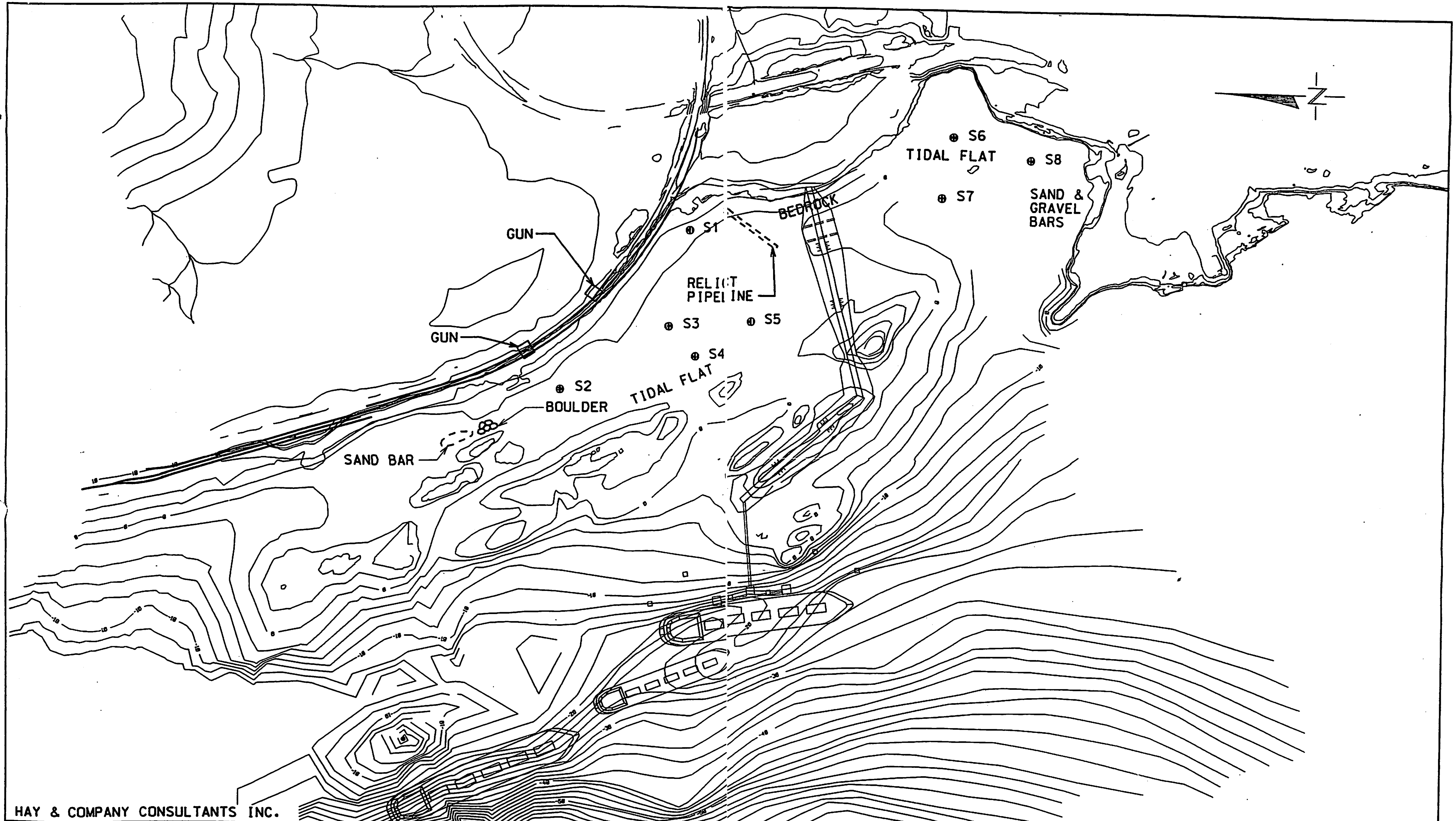
LPG TERMINAL EXPANSION

PROOSED CAUSEWAY AND TERMINAL CONFIGURATION

FIG. 1

CAD FILE/ PRPC-003/ FIG3.DGN /RF = HYDROG.DGN / NOV.03.1993



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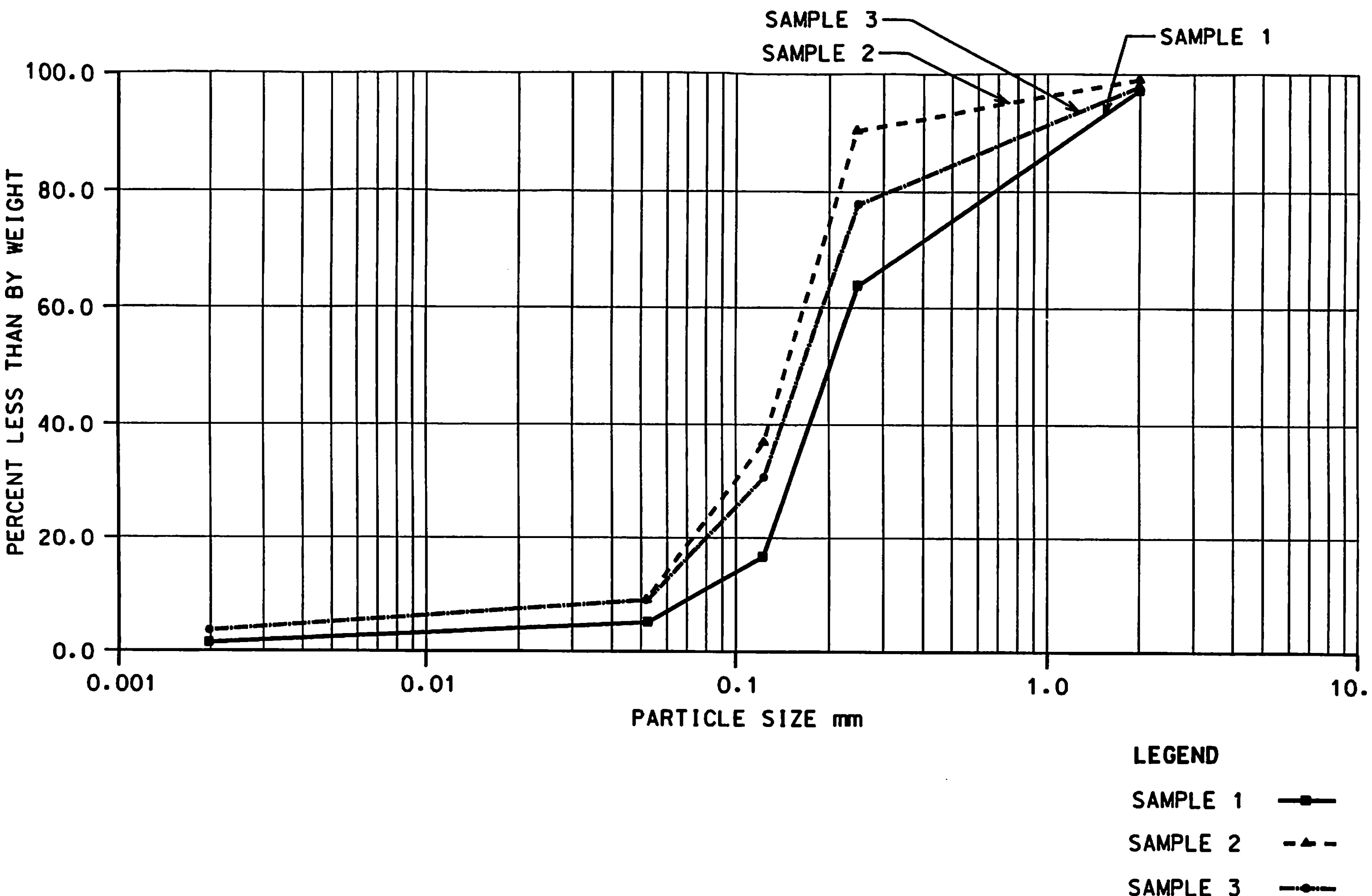
LPG TERMINAL EXPANSION

SEDIMENT SAMPLE LOCATIONS

FIG. 2

CAD FILE/ PRPC-003/F1&2-3D.DGN/RF = HYDROG.DGN / NOV.03.1993



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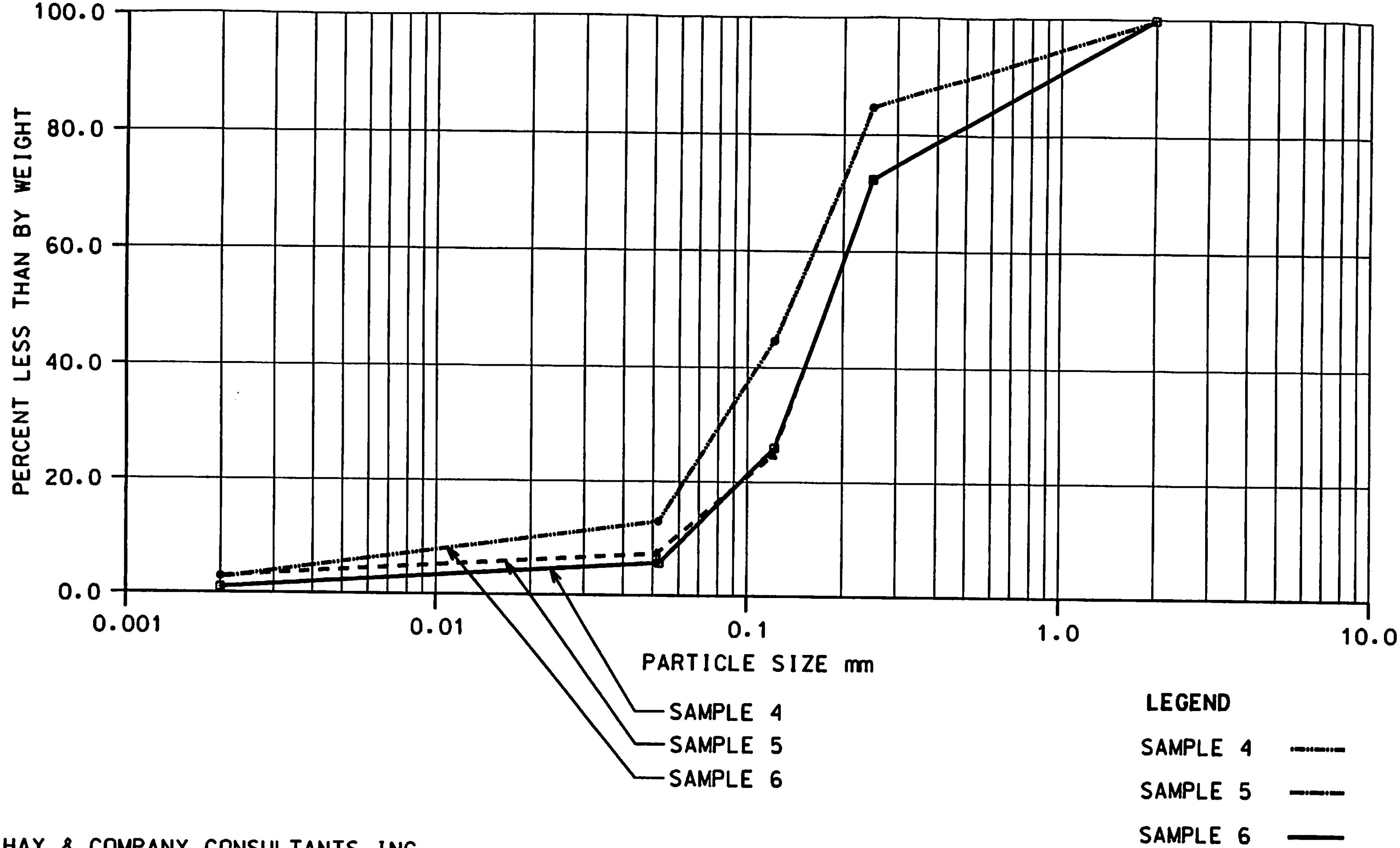
LPG TERMINAL EXPANSION

GRAIN SIZE CURVES
SAMPLES 1, 2 & 3

FIG. 3

PRPC-003/GUMGRAPH.DGN/OCT.29.1993



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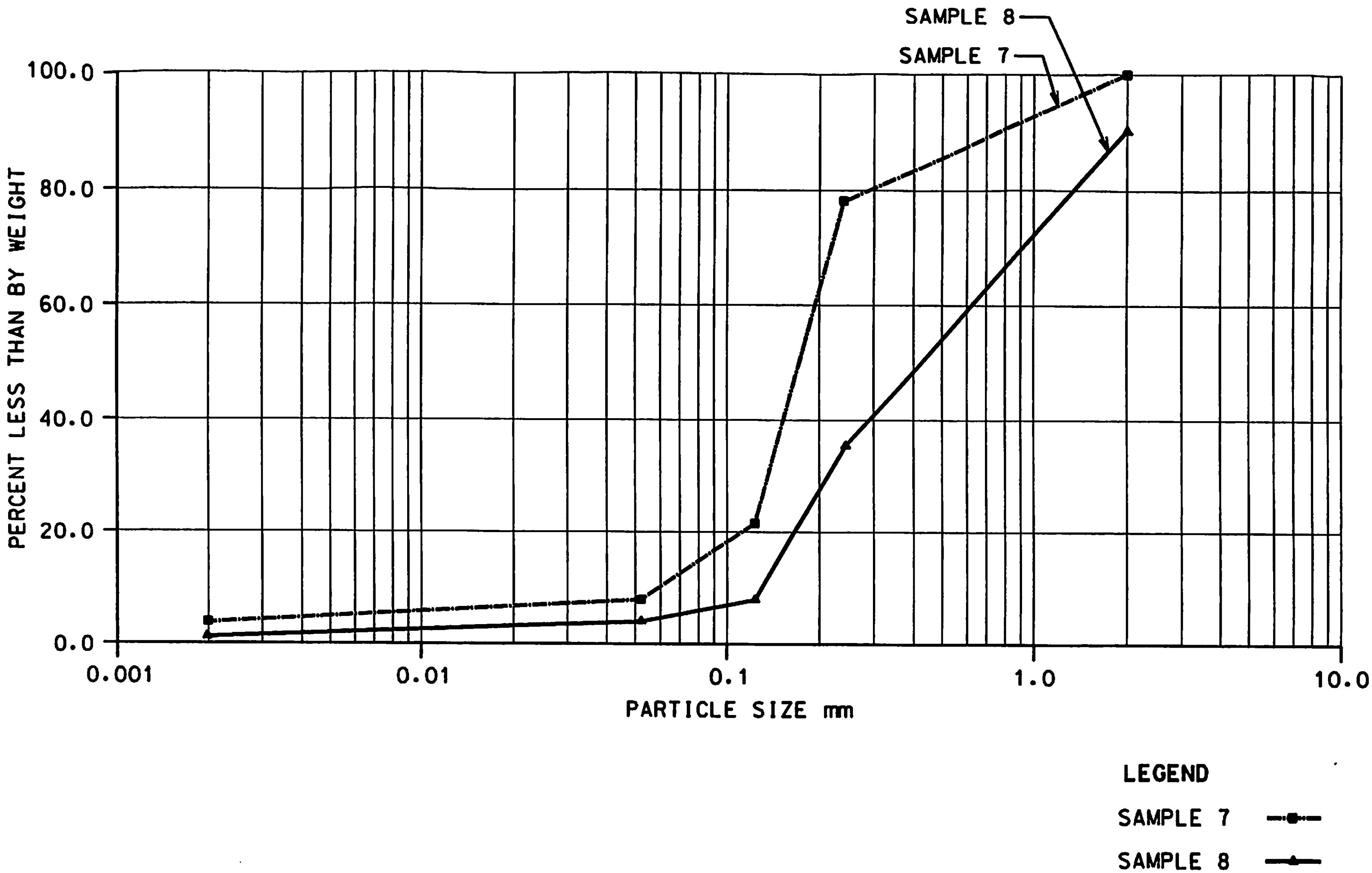
GRAIN SIZE CURVES
SAMPLES 4,5 & 6

FIG. 4

PRPC-003/GUMGRAPH.DGN/OCT.29.1993



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LPG TERMINAL EXPANSION

GRAIN SIZE CURVES
SAMPLES 7 & 8

FIG. 5

PRPC-003/GUMGRAPH.DGN/OCT.29.1993

Appendix D

FAIRVIEW TERMINAL EELGRASS TRANSPLANT PROGRAM UPDATE

memoranda and letters prepared by
HAY & COMPANY CONSULTANTS INC
and
PAUL HARRISON, MARINE ECOLOGIST

DEC 01 1992

HAY & COMPANY
CONSULTANTS INC.
One West 7th Avenue
Vancouver, B.C.
Canada V5Y 1L5
(604) 875-6391
Fax: 875-8363

November 24, 1992

File: PRPC.01

File #318C.

David's Copy.

Prince Rupert Port Corporation
110 3rd Avenue West
Prince Rupert, B.C.
V8J 1K8

Attention: Mr. D.G. Shearer
Manager, Engineering and Maintenance

Dear Sir:

Re: Eelgrass Transplant Site

The purpose of this letter is to summarize some observations, conclusions and recommendations regarding the eelgrass transplant site developed in conjunction with the expansion of the Fairview Terminal.

BACKGROUND

A number of locations were investigated in 1988 as possible sites to develop eelgrass beds, with consideration to tidal elevation, substrate composition, substrate stability and exposure to waves and currents. Conceptual designs were developed for two sites; one north, and one south, of Phillip's Point on the east shore of Digby Island. The conceptual designs envisaged a horseshoe - shaped embayment cut back about 50 m into the tidal flats at an elevation of between 0.5 to 1.0 m above Low Tide. The design envisaged a 0.4 m thick blanket of fine sand would be placed as substrate in the embayment.

The southern site was selected for development. Excavation of an area about 45 m in length and 35 m into the tidal flats was undertaken in the Fall of 1989. Some difficulty was apparently encountered in excavating the till of the inter-tidal area such that the desired subgrade elevations could not be achieved. Dredgeate spoil was spread over the area as a subgrade for the eelgrass transplants. Transplanting of eelgrass shoots from the Pillsbury Cove area was undertaken in the Summer of 1990. Information on the composition of the dredgeate, or the thickness of placement, was not available for our review.

DUNCAN HAY
M.S., Dip. H.E. (Delft), P.Eng.

S. ROBERT M. GARDINER
Ph. D., P.Eng.

After construction, monitoring of the eelgrass transplant area was initiated by Mr.Ron Kistritz on behalf of the Port Corporation. Steel pins embedded in the substrate along five transect lines served as a basis for locating observations and assessing changes at the site.

The site monitoring indicated some erosion of the substrate and subsequent loss of eelgrass transplants. Hay & Company were contacted by the Port Corporation in August 1992 and requested to visit the site and comment upon the coastal processes with the view to recommending any measures that would enhance the growth of eelgrass.

The site was visited by Mr.Duncan Hay, P.Eng., on August 28, 1992 together with Mr. David Shearer, P.Eng., of the Port Corporation. Five substrate samples were collected later by the Port Corporation and forwarded to Hay & Company for grain size analysis. Survey data was also provided by the Port Corporation giving the 'as-built' substrate elevations on the site and elevations in August 1992. Photographs of the site during and immediately after construction were made available for review by Tera Planning Ltd.

SITE OBSERVATIONS

The following observations were made during the site visit of August 1992:

- The natural substrate of the area is predominately a surface layer of gravel to boulder sized material with pockets of sands and silts overlying till. Larger sub-angular boulders dot the surface as lag deposits left in place on the wave-cut intertidal foreshore bench.

- The transplant area (receptor site) is a rectangular area bounded on three sides by low rock berms comprised of boulders pushed aside during excavation of the bed. The seaward side does not have a rock berm.

- The surface of the transplant area is higher in the central portion than along the sides adjacent to the rock berms. The surface material varied on the site, generally being gravelly in the central higher portions with pockets of sandy-silt, to a greater proportion of fine sand in the lower elevations. A shallow excavation of about 300 mm, at elevation 0.6 m above low tide, indicated a gravelly substrate with sand and shell fragments.

- Eelgrass on the receptor site was located primarily in the areas of low elevations adjacent to the rock berms, near the seaward edge, Figure 1. Eelgrass was sparse to non-existent in the central area of the site. It was estimated that about 15 to 20 percent of the surface area was covered with eelgrass.

- A small, low, natural berm of coarse sand and gravel had developed in the central position of the site, parallel to the seaward edge. The berm was at about elevation 1 m above low tide.

- Immediately south of the receptor site, between the site and a navigation light, was an area of dense eelgrass growth. This navigation light is located on the end of a natural 'spit' formed by large boulders. The surface elevation between this 'spit' and the receptor site forms a slight depression through which there was a small stream draining the upland. At the time of the site visits, which followed a relatively dry summer, the stream was emerging from the beach sediments about half-way up the intertidal foreshore. Near the low tide area, and possibly up to about 0.5 m above the low tide, was a large deposit of fine to medium sand which supported the eelgrass bed. The thickness of the sand deposit appeared to be about 300 mm, based upon the depth of cut the stream had made through the sand deposit.

- The density of the eelgrass immediately south of the site was greater than that observed at Pillsbury Cove, or the south end of Digby Island, during the site visit.

- The tidal current was flowing north at, and immediately following, low tide.

REVIEW OF DATA

Surface contours provided by the Port Corporation are attached as Figures 2 and 3. A comparison of 1990 and 1992 elevations at the grid points shown on the Figures is given in Table 1. Although there are some small areas of accretion, the tabulation indicates general erosion of the surface, with the greatest erosion occurring along the seaward edge of the site.

TABLE 1

FAIRVIEW TERMINAL EELGRASS TRANSPLANT AREA
SITE GRID ELEVATION CHANGES

LINE	STATION	1990	1992	NET CHANGE
N+22.5	E+0	1.20	1.10	-0.10
	E+5	1.10	0.90	-0.20
	E+10	1.00	0.91	-0.09
	E+15	0.84	0.87	0.03
	E+20	0.63	0.79	0.16
	E+25	0.46	0.17	-0.29
N+12.5	E+0	1.29	1.18	-0.11
	E+5	1.21	1.06	-0.15
	E+10	1.12	0.98	-0.14
	E+15	1.06	0.87	-0.19
	E+20	0.94	0.76	-0.18
	E+25	0.57	0.05	-0.52
CL	E+0	1.46	1.40	-0.06
	E+5	1.46	1.39	-0.07
	E+10	1.50	1.38	-0.12
	E+15	1.36	1.34	-0.02
	E+20	1.15	0.85	-0.30
	E+25	0.55	0.23	-0.32
S+12	E+0	1.45	1.27	-0.18
	E+5	1.35	1.19	-0.16
	E+10	1.30	1.31	0.01
	E+15	1.20	1.08	-0.12
	E+20	0.90	0.83	-0.07
	E+25	0.17	0.37	0.20
S+24	E+0	—	—	—
	E+5	—	—	—
	E+10	1.35	1.06	-0.29
	E+15	1.17	0.85	-0.32
	E+20	0.88	0.63	-0.25
	E+25	0.50	0.46	-0.04

A comparison of the contours indicates a net lòss of material of approximately 150 m^3, representing an average overall erosion depth of 0.1 m. The net erosion is made up of approximately 190 m^3 of erosion and 40 m^3 of deposition.

Assuming the 'as-built' survey was undertaken in 1990 prior to the transplanting, the survey data would indicate eelgrass has survived at elevations less than 1 m above low tide in areas where there had been erosion, yet has not survived in areas above 1 m in areas where there has been little, or no, erosion.

The grain size distributions of five samples forwarded by the Port Corporation are shown on Figure 4. Labels identifying the location and particulars of each sample were smudged by moisture so only the legible identifications are shown. The following observations are drawn from Figure 4.

- Sample 2, identified as being in an area with eelgrass was medium - sized sand.

- Sample 4, taken from the centre of the site where there was no eelgrass, contained only about 30 percent of fine to medium sand.

- Sample 1, adjacent to the site, (taken presumably in the eelgrass bed area south of the site) is comprised predominately of medium - sized sand,

The location of sample 3, which is primarily silt, is not known. The other samples indicate the importance of having a substrate of medium sized sand, or less, to support eelgrass.

DISCUSSION

The feasibility of developing a productive eelgrass bed at the site has perhaps been challenged by the loss of a significant number of the transplants. However, the density of the natural eelgrass beds to the south of the receptor site would indicate very strongly that eelgrass can thrive in the area.

A question was raised as to whether the eelgrass bed to the south could have developed as a result of deposition of sediments eroded from the receptor site. This does not appear likely to be the case for a number of reasons, including:

- oblique aerial photos show the sandy substrate and eelgrass beds existed south of the site prior to the transplanting;

- the northward flowing tidal currents, complied with the larger waves from the south, would predominate over southward flowing tidal currents which occur at higher tides. The net direction of sediment transport, in our opinion, would likely be offshore and/or northward;

- there is a small area of net accretion of sand along the northern edge of the site.

It is significant to note that the eelgrass bed to the south is apparently not hampered by wave action and tidal currents, at least at the elevation where it is thriving. The substrate in the area of active eelgrass growth is fine sand, which raised the question as to the origin and stability of this sand, and why a suitable substrate was not maintained at the receptor site?

A sandy substrate can be achieved by one or a combination of two ways:

- a constant supply of sand to replace any lost by wave or current erosion; or,

- a trapped pocket of sand.

The sand substrate to the south is likely supplied by the small stream in the area. This stream moves sand from the higher energy area of the upper tidal foreshore to the lower energy area of the lower tidal foreshore. The position of the stream at low tide may vary from year to year, resulting in some downcuttting of the sand deposits, but the loss of sand is likely replenished by the stream. It is possible that the rock berms constructed in conjunction with the receptor site has assisted in trapping sands south of the site.

The intent of the conceptual design for the receptor site was to create a pocket to trap sand that was placed. Keys to trapping the sand were the elevation of the bed and the pocket shape initially proposed for the site. Achieving these was apparently hampered by construction difficulties. Furthermore, the dredgeate material placed on the receptor site appears to have contained gravel which armoured the bed as silts and sands were removed, resulting in a substrate that is not suitable for the growth of eelgrass.

OPTIONS FOR EELGRASS BED DEVELOPMENT

The following five options are offered for consideration and discussion:

OPTION 1. RECEPTOR SITE REMAINS AS IS

This option would leave the receptor site as it is, without any physical modifications. It is likely that some pockets of fine sand will remain at the site for many years, however there will be a general trend toward a coarser substrate, primarily because the underlying material of sediments contains gravel. If nothing is done we would estimate that over the long term about 5 - 10 % of the bed would remain with a shallow substrate of fine to medium sand.

OPTION 2. EXCAVATE EXISTING RECEPTOR SITE

This option would involve a reconfiguration of the existing receptor site to lower the central portions of the area and extend the receptor site shoreward. It would consists of three steps:

- lowering the existing high central area by about 1 m;
- excavating the central portion of the receptor site shoreward by about 20 m to form a semi - circular embayment with a subgrade elevation less than 0.6 m above low tide;
- importing fine to medium sand to cover the newly excavated area.

Eelgrass could be transplanted or natural colonization could be relied upon.

The volume of excavation required would be approximately 1000 m^3 and the volume of sand would be about 500 m^3.

The disadvantage of this option is that excavation of the substrate will be difficult, requiring heavy excavations and dozers.

The advantages are that the sand would be placed in a lower energy environment and at an elevation where eelgrass is seen to thrive close by.

OPTION 3. EXCAVATE A PORTION OF EXISTING RECEPTOR SITE AND ELEVATE THE SEAWARD EDGE

The objective of this option would be to work within the area of the existing receptor site but lower the central portion and construct a berm along the seaward edge to trap sand more effectively and retain some water at low tide. It would consist of three steps:

- lowering the existing higher central area by about 1 m;
- placing excavated boulders, and importing additional rock, if necessary, as a 1 to 5 m berm along the seaward edge at low tide;
- importing fine to medium sand to cover the newly excavated area.

The volume of excavation required would be about 400 m^3 and the volume of sand about 200 m^3. Some water may drain through the rock berm at low tide, but the formation of dendritic channels would be curtailed.

OPTION 4. ELEVATE THE SEAWARD EDGE OF THE RECEPTOR SITE

The objective of this option would be to create a more efficient trap for sand by creating a disk shaped site that retains water a low tide but not excavating the central portion. Work would include:

- constructing a rock berm at about the low tide level connecting to the existing berms that run perpendicular to the shoreline. The berm would be about 1 to 1.5 m high comprised of a range of rock sizes. Rocks could be imported or moved from the shoreward berm at the site;
- importing five to medium sand to cover the gravelly areas to a depth of about 300 mm. About 150 m^3 of sand would be required.

The advantage of this option is that it would be less costly than options 2 & 3. The disadvantage is that the growth of eelgrass may not be as prolific as occurs naturally adjacent to the site because of higher substrate elevations.

OPTION 5. RELOCATE THE RECEPTOR SITE

Another option, considering the potential disadvantages of conditions at the existing site, would be to develop eelgrass beds elsewhere, perhaps at the south end of Digby Island.

However, this option is perhaps better part of a longer range plan that can draw on the experience gained from the existing site. Subsurface exploration to assess the ease of construction should be included in detailed site assessments.

CONCLUSION

Of the options suggested, our preference would be to berm the seaward edge of the receptor site, lower the central area, and import additional sand (option 3). This option has some risks, however I think doing nothing is likely unacceptable to the regulatory agencies, and moving to another site is premature.

Of the options involving some construction at the site, option 2 would be most expensive and option 4 would be least expensive. The cost of option 3 would be between the cost of options 2 and 4.

We would be pleased to be of assistance to the Port Corporation in more detailed engineering and/or assessments of any of the options discussed. The volume of excavation and fill given in this letter are very approximate.

Yours very truly,

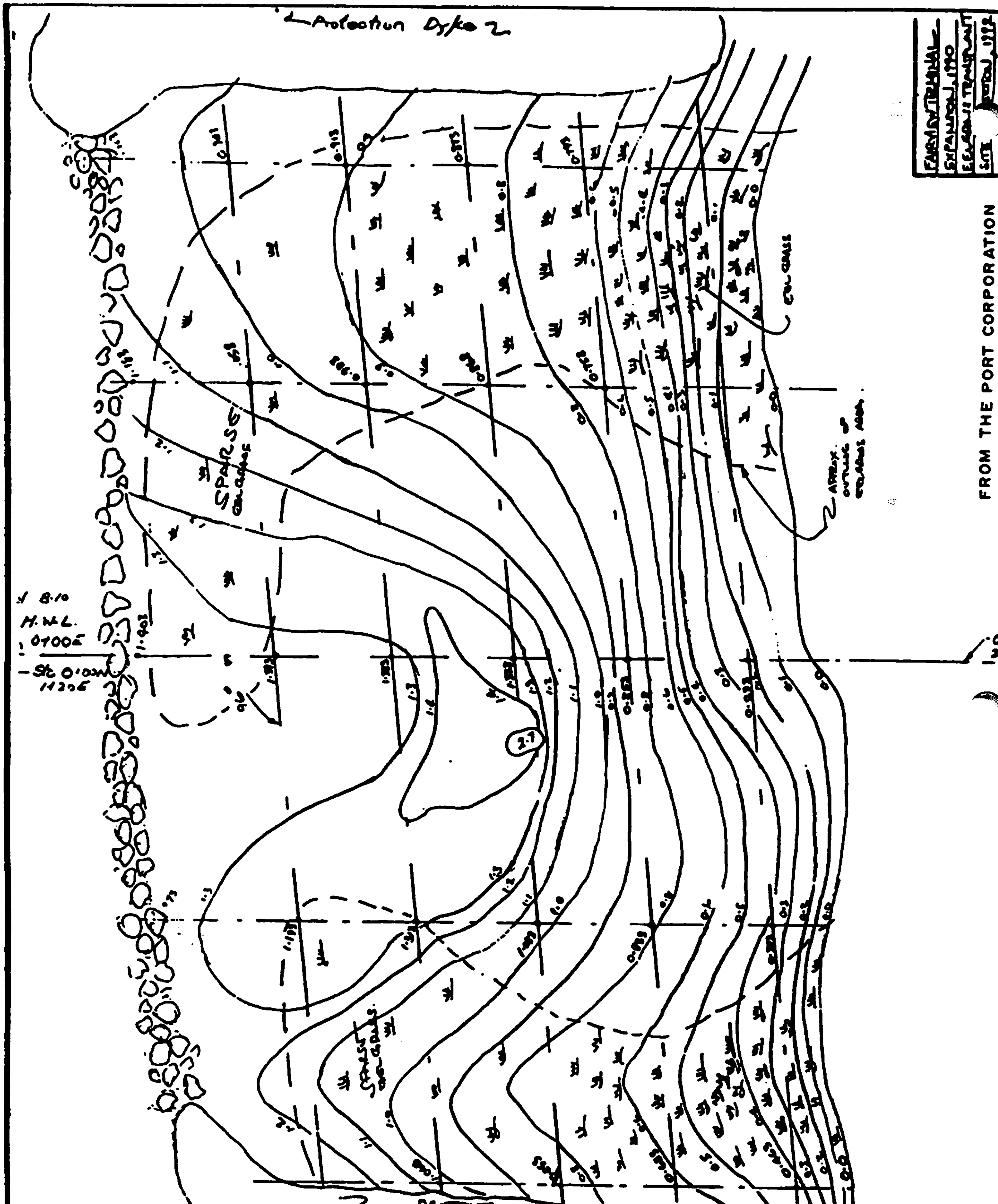
HAY & COMPANY CONSULTANTS INC.

Duncan Hay, P.Eng.
President

/lg

Attach.

cc.: Mr. Ian Rokeby
Mr. R. Kistritz



HAY & COMPANY CONSULTANTS INC.

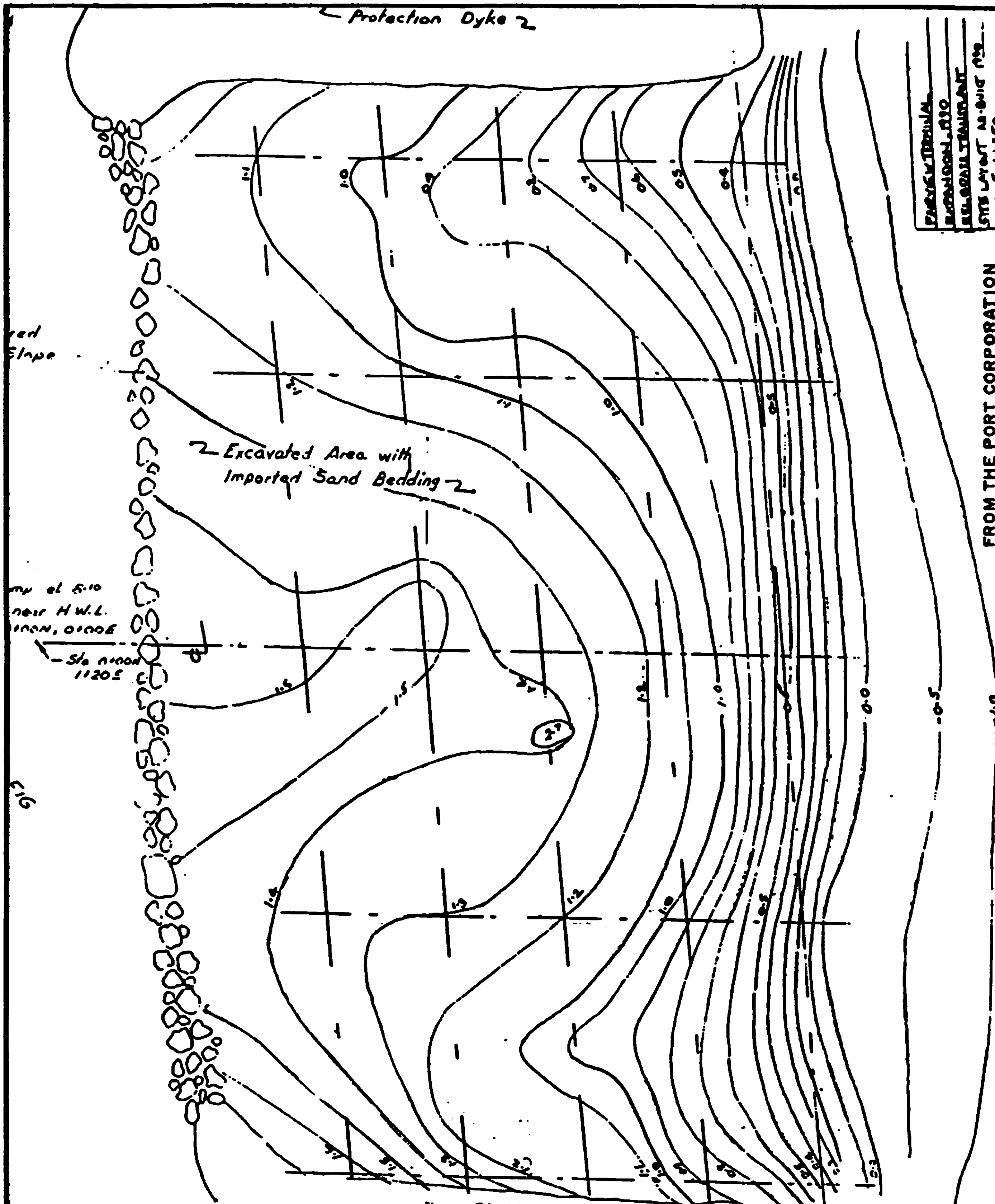
PRINCE RUPERT PORT CORPORATION

EEL GRASS RECEPTOR SITE

AREA OF EEL GRASS
AUGUST 1992

FIG. 1

PRPC-01/FIGS.DGN/1992 NOV. 19



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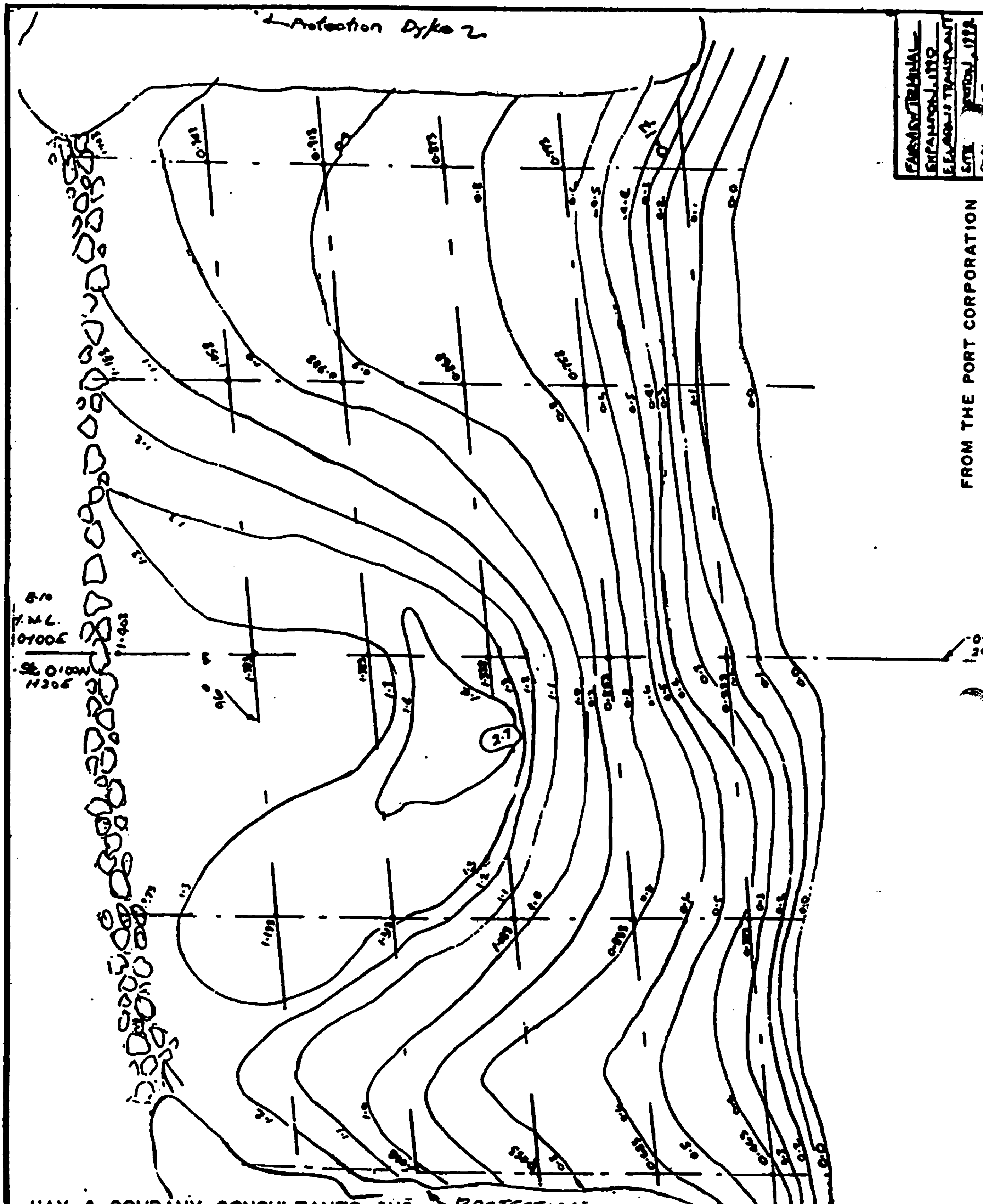
PRINCE RUPERT PORT CORPORATION

EEL GRASS RECEPTOR SITE

'AS - BUILT' ELEVATIONS

FIG. 2

PRPC-01/FIGS.DGN/1992 NOV. 19



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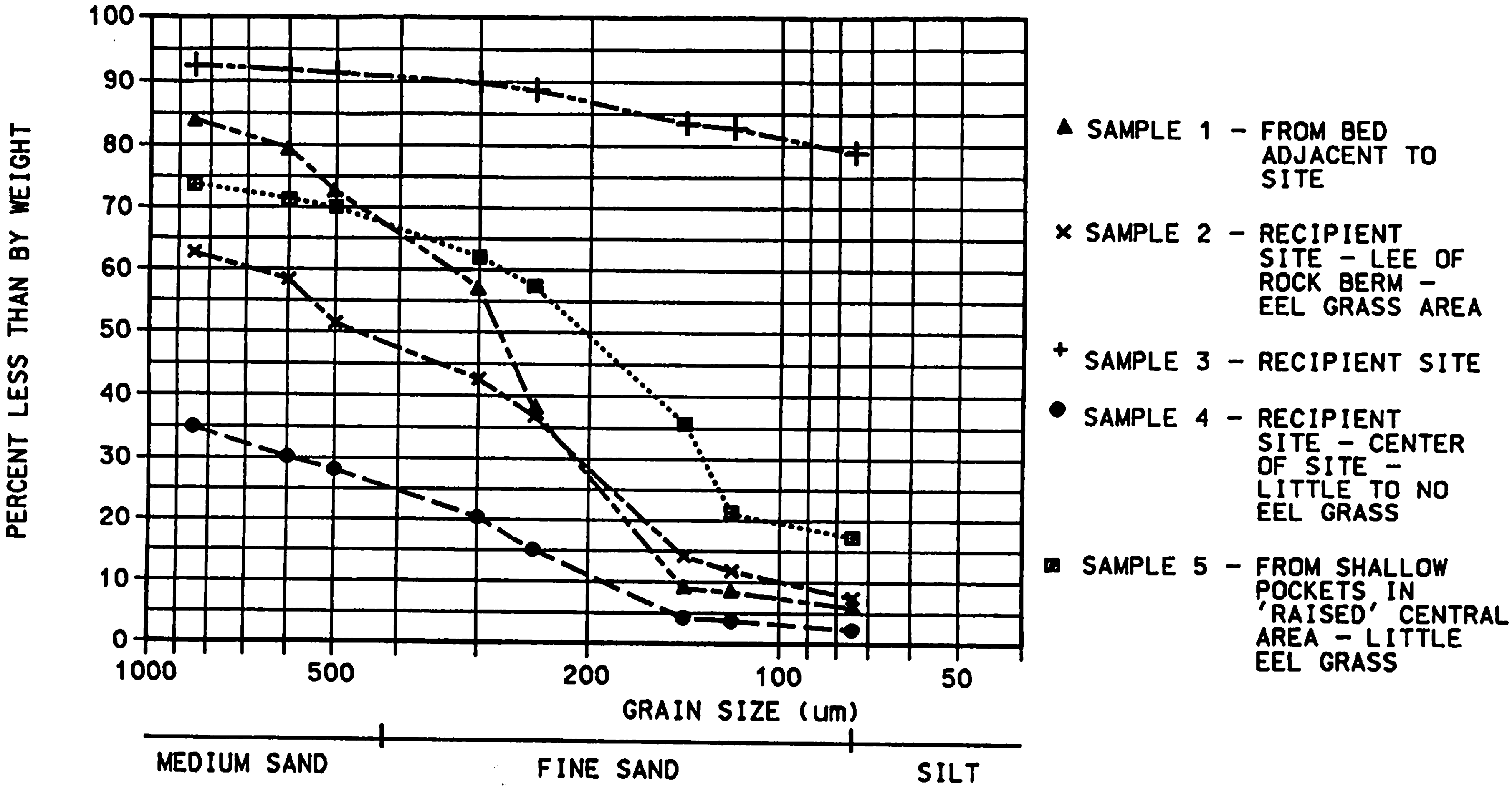
EEL GRASS RECEPTOR SITE **1992 ELEVATIONS**

FIG. 3

PRPC-01/FIGS.DGN/1992 NOV. 19



HAY & COMPANY CONSULTANTS INC.

PRINCE RUPERT PORT CORPORATION

EEL GRASS RECEPTOR SITE

GRAIN - SIZE ANALYSIS

FIG. 4

PRPC-01/FIGS.DGN/1992 NOV. 19

HAY & COMPANY
CONSULTANTS INC.
One West 7th Avenue
Vancouver, B.C.
Canada V5Y 1L5
(604) 875-6391
Fax: 875-8363

December 4, 1992

File: PRPC-01A

Prince Rupert Port Corporation
110 3rd Avenue West
Prince Rupert, B.C.
V8J 1K8

Attention: Mr. David Shearer, P.Eng.

Dear Sir:

Re: Habitat Compensation - Review of Erosion of Eel Grass Habitat Site

As per our letter of November 27, 1992 we have completed our analysis of storm winds incident on the eel grass habitat site.

A requirement of environmental regulatory agencies with respect to the site was that it be capable of withstanding a 1 hour in 10 year storm event. The first phase of the analysis, and the subject of this letter, was to establish whether a storm having a recurrence interval less frequent (more severe) than the 1 hr in 10 year event had occurred since construction of the eel grass habitat site.

Waves incident on the site are generated by wind induced shear stresses at the water surface. Waves with a magnitude greater than that corresponding to the 1 hour in 10 year recurrence interval can only be generated by winds speeds with an equivalent or less frequent recurrence interval. The effect that waves have on sediment erosion or transport at a site depends upon the orientation of the waves and their energy, which is a function of both wave height and duration.

This analysis centred on the direct dependence of wave magnitude on wind speed and used wind speed as a measure of storm severity. Specific purposes of this analysis included:

1. to establish the wind speed having a recurrence interval of 1 hour in 10 years by direction;
2. to establish whether winds since the time of construction exceeded the 1 hour in 10 year speed for each particular direction.

Wind data was obtained from the Ministry of Environment Atmospheric Environment Service for Prince Rupert Airport situated approximately 6 km northwest of the compensation site. The period of record extends from 1962 to 1992. The entire period of record was analyzed to establish the 1 hour in 10 year recurrence interval wind speed for each direction. The results are presented on table 1.

DUNCAN HAY
M.S., Dip. H.E. (Delft), P.Eng.

B. ROBERT M. GARDINER
Ph. D., P.Eng.

Table 1 1 Hour in 10 Year Recurrence Interval Wind Speeds by Direction			
Direction	Speed (KPH)	Direction	Speed (KPH)
N	47	S	90
NE	47	SW	70
E	78	W	67
SE	89	NW	62

Once the 1 hour in 10 year wind speeds had been established, the wind data for the period following construction of the eel grass beds was analyzed to determine the maximum recorded event for each of the above directions. Winds below 40 kph were ignored as this threshold level is well below the minimum 1 hour in 10 year recurrence level. The results of the analysis are presented in table 2.

Table 2 Max. Recorded Wind Speed since October 1989 by Direction (Speeds less than 40 kph disregarded)		
Direction	Speed (KPH)	Date/Time of Occurrence
N	None	N/A
NE	None	N/A
E	None	N/A
SE	65	05 Feb 91 1800 hrs 23 Dec 91 1100 hrs
S	74	12 Nov 90 1700 hrs
SW	52	08 Dec 91 1900 hrs
W	48	16 Jan 91 2000 hrs
NW	44	09 Jan 91 0800 hrs

By comparing the maximum recorded wind speeds of table 2 to the wind speeds of table 1 we conclude that maximum wind speeds in the vicinity of the eel grass habitat site did not exceed the 1 hour in 10 year recurrence level. The absence of 1 hour in 10 year winds implies that local wind generated wave heights incident on the site also did not exceed the 1 hour in 10 year magnitude.

This analysis would indicate that a single storm more severe than a 1 in 10 year storm has not occurred since construction of the eel grass beds. However, it is possible that a combined effect of a series of smaller storms resulted in cumulative wave energy in excess of the 1 in 10 year level of wave energy. Thus it is conceivable that more sediment could be transported by waves produced by relatively smaller storms acting for a longer period of time than by a large short duration storm. From a cumulative energy perspective, the level associated with a 1 hour in 10 year recurrence interval could have been exceeded even though maximum wind speeds and maximum wave heights during the same period did not exceed magnitudes associated with a similar probability of exceedance.

Should the Port Corporation wish to extend the analysis beyond the level undertaken so far, Hay & Company would suggest that an analysis of the wind energy at the site be undertaken. The analysis would consist of a numerical summation on an annual basis of the incident wind energy, the product of the square of the wind velocity and its duration from each direction, for the period of wind record, 1962 to eel bed construction in 1989. An annual energy level associated with a probability of occurrence equivalent to 1 hour in 10 years would be derived and compared with cumulative annual wind energy for the period since construction. This analysis will require a slight modification to our computer program upon which the wind analysis to date was undertaken, and then running the data through the program followed by an extreme value analysis.

To undertake this additional analysis would require approximately 5 working days and would require approximately $ 3,000 above the $ 1,500 we have spent to date analyzing the winds. The $ 3,000 estimate includes approximately $ 500 for disbursements to purchase the required additional wind data from the Ministry of Environment.

We have appreciated the opportunity to assist the Port Corporation with this project. Please call if you wish to discuss any aspect of the analysis undertaken.

Yours very truly,

HAY & COMPANY CONSULTANTS INC.

Duncan Hay, P.Eng.
President

RE/lg

JKNHL-

Paul G. Harrison, Ph.D., R.P.Bio.
Marine Ecologist

3818 W. 15th Ave., Vancouver, B.C. V6R 2Z9
Tel. 822-4681 (w), 224-5300 (h) Fax. 822-6089

Dec. 1, 1992

D. G. Shearer, P.Eng.
Manager, Engineering & Maintenance
Prince Rupert Port Corporation
110 3rd Avenue West
Prince Rupert V8J 1K8

Dear Mr. Shearer:

Thank you for the opportunity to provide further input into your ongoing project concerning eelgrass on Digby Island. I have reviewed the photographs and notes that I took when I visited, and I have had a lengthy telephone conversation with Duncan Hay about his evaluation of the site. I now submit the following comments in the hopes that they may help you decide how to proceed.

1. *Can Eelgrass Grow in the Area ?*

This question is of fundamental importance because there can be sites that appear even to an educated eye to be suitable habitat but which cannot support eelgrass - for reasons that often are difficult to determine. The existence of a healthy natural bed of eelgrass to the south of the transplant site tells us that eelgrass can grow under the ambient conditions of climate; tides, waves, and currents; and substrate texture. Comments from your staff indicate that the natural vegetation has expanded since the transplant was initiated; this is an indication that no major environmental factor with wide-ranging effects is limiting the growth of the plant.

2. *Why has Eelgrass Not Flourished in the Transplant Site ?*

a) First, I note that in some small areas eelgrass is growing well. This is true at lower elevations at the southern end of the site; the further north and landward one goes, the more depauperate or nonexistent is the vegetation. However, even where eelgrass is most luxuriant, much of the vegetation retains the pattern of the original planting lines; plants have not expanded uniformly into the intervening substrate. There is also evidence of erosion (i.e., exposed rhizomes) even in the area of good eelgrass growth. Success, even in a limited part of the site, indicates that transplanting was carried out with the utmost care.

...2

b) At higher elevations, the eelgrass vegetation had the 'typical' appearance of a stressed intertidal population. Many individual plants were short and the shoot density was low. Again, some plants were being eroded. In my experience, these features occur commonly in marginal habitats, i.e., where length of exposure to the air at low tide and/or speed of drainage of the substrate on the ebbing tide exceed the plant's tolerance. Unfortunately, there are few reliable quantitative estimates of the plant's tolerance to those two aspects of drying. My own experience on Roberts Bank revealed the critical importance of those two factors for the survival of transplanted eelgrass, but I think that site-specific studies may be necessary to determine the critical values because of the interacting effects of climate, tidal amplitude and pattern, and wave regime.

c) The substrate and the elevation appear to be the two key factors working against the success of the plants. I understand from Duncan Hay that for various reasons, these two aspects of the developed site did not match the design criteria. Whereas the requested maximum elevation was +1 m, the actual elevation reaches +1.5 m. Whereas 400 mm of sand was requested, the fill was mostly shell and gravel. As noted in the previous paragraph, eelgrass appears to be sensitive to drying (of both its belowground and aboveground parts). Thus, the coarse sediment may drain so quickly at low tide that it allows the belowground parts of the plants to be damaged. This aspect requires further investigation because it will be dependent on weather and seasonal climatic changes. I also understand that erosion has removed approximately 0.1 m of the fill (generally the finest material) and that sorting has led to an armouring of the surface by gravel. Finally, the shape of the site, with a more or less straight edge facing the channel, appears to make it difficult for sand to be trapped. My impression is that, if left alone, the site will not become uniformly suitable for eelgrass and may even become less suitable than at present.

3. *What Can Be Learned From the Natural Eelgrass Bed ?*

Since eelgrass is growing well at the site adjacent to the transplant site, it would be instructive to compare the two habitats. Much of what I will relate is speculation, but some of it may be worthwhile investigating in field studies. Overall, I wonder if the success of eelgrass in the natural bed is the result of the interacting factors discussed above that contribute to the retention of water in the substrate of the intertidal zone ?

First, the substrate in the natural eelgrass bed appears to be of a finer texture than that in the transplant site. Is the presence of sand a result of the shape of the site; i.e., does it provide a slight backwater where sand can be deposited ? Is sand washed from higher elevations on the shore, by natural freshwater flow perhaps augmented by heavy rains, as Duncan Hay suggested ?

Second, is there a difference in elevation that could provide a clue as to the maximum elevation tolerated by eelgrass in the immediate locality ?

...3

Third, is the recently noted, but unquantified, increase in the natural eelgrass vegetation an ongoing process or a short-term phenomenon ? Little is known about causes of natural year-to-year variations in seagrass populations, but I do know of some evidence that major changes can occur in the location and density of eelgrass beds on a year-to-year basis. Longer term monitoring is required before conclusions can be drawn about the health and stability of an eelgrass bed. As stated above, however, I do not think it likely that the transplanted vegetation will suddenly expand if the physical habitat remains unchanged.

4. *Conclusion*

Since most of the factors limiting the growth of eelgrass at the site in question are physical in nature it would be presumptuous of me, a biologist and ecologist, to suggest remedies. I understand that Duncan Hay will suggest several options requiring physical alterations to the site. I can only make two comments. First, no biologist can produce a flourishing eelgrass bed if the physical habitat is suboptimal. Second, more field studies are needed in natural eelgrass beds to determine the tolerable ranges for key physical environmental factors (alone and in combination). Reliance on qualitative data and data from other sites that differ in aspects of climate, tides, etc. has proven risky.

I hope that these comments will clarify my impression of the problem. I wish you luck with future efforts to promote eelgrass growth. I have enclosed an invoice for my services.

Sincerely,

PG Harrison

Paul G. Harrison