APPENDIX C:

EXISTING AQUATIC ENVIRONMENT

Prepared for:

NORTHCOAST ENVIRONMENTAL ANALYSIS TEAM

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NEAT

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CHAPTER C1

C1.0 INTRODUCTION

This appendix presents information on existing aquatic environments and organisms within the study area. These background data provide information utilized to assess impacts of the proposed superport on aquatic environments. The impacts themselves, conclusions and recommendations from aquatic studies are presented in other portions of this report. This appendix outlines the regional and site-specific environments and organisms only.

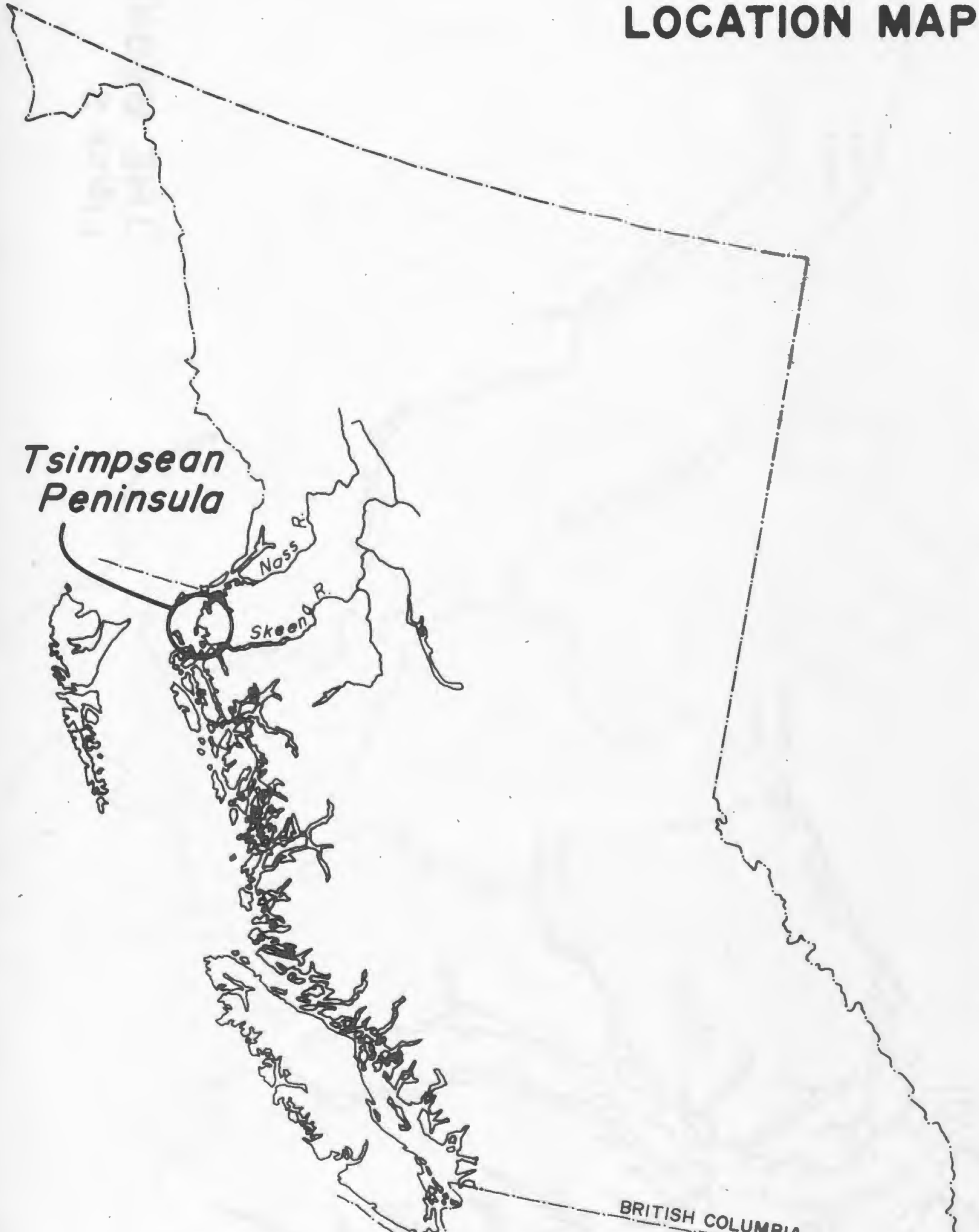
The focus of this appendix is on the freshwater, estuarine and marine environments in the area. In addition, the organisms and biological communities associated with these aquatic environments are studied. Specific emphasis is placed on organisms such as fishes, crabs, and other fauna utilized by the human population.

The specific study area is limited to the Tsimpsean Peninsula bounded by Work Channel, Chatham Sound, and the Skeena River. This definition of the study area is less appropriate for aquatic studies than it might be for terrestrial work. Regional aquatic environments can be understood only with a more extensive definition of the study area.

Figure 1 identifies the study area in relation to the Province, and Figure 2 places the Tsimpsean Peninsula and its aquatic environments in the context of the region. To understand the aquatic environments of the area, the two major river systems (the Skeena and the Nass and their major channels) and Chatham Sound are included. The dominant characteristic of aquatic environments in the study region is Chatham Sound, an essentially estuarine environment receiving effluents from the Skeena and Nass Rivers, and numerous minor watercourses on the Tsimpsean Peninsula itself.

Aquatic studies were carried out by review of published scientific literature, discussions with knowledgeable government officials and other individuals, and field reconnaissance of the area by members of the study team from all disciplines. In addition, field programs, including analysis of samples collected and data produced, were carried out for freshwater biological and estuarine and marine studies. No new hydrological data were collected during this study.

Figure 1
LOCATION MAP



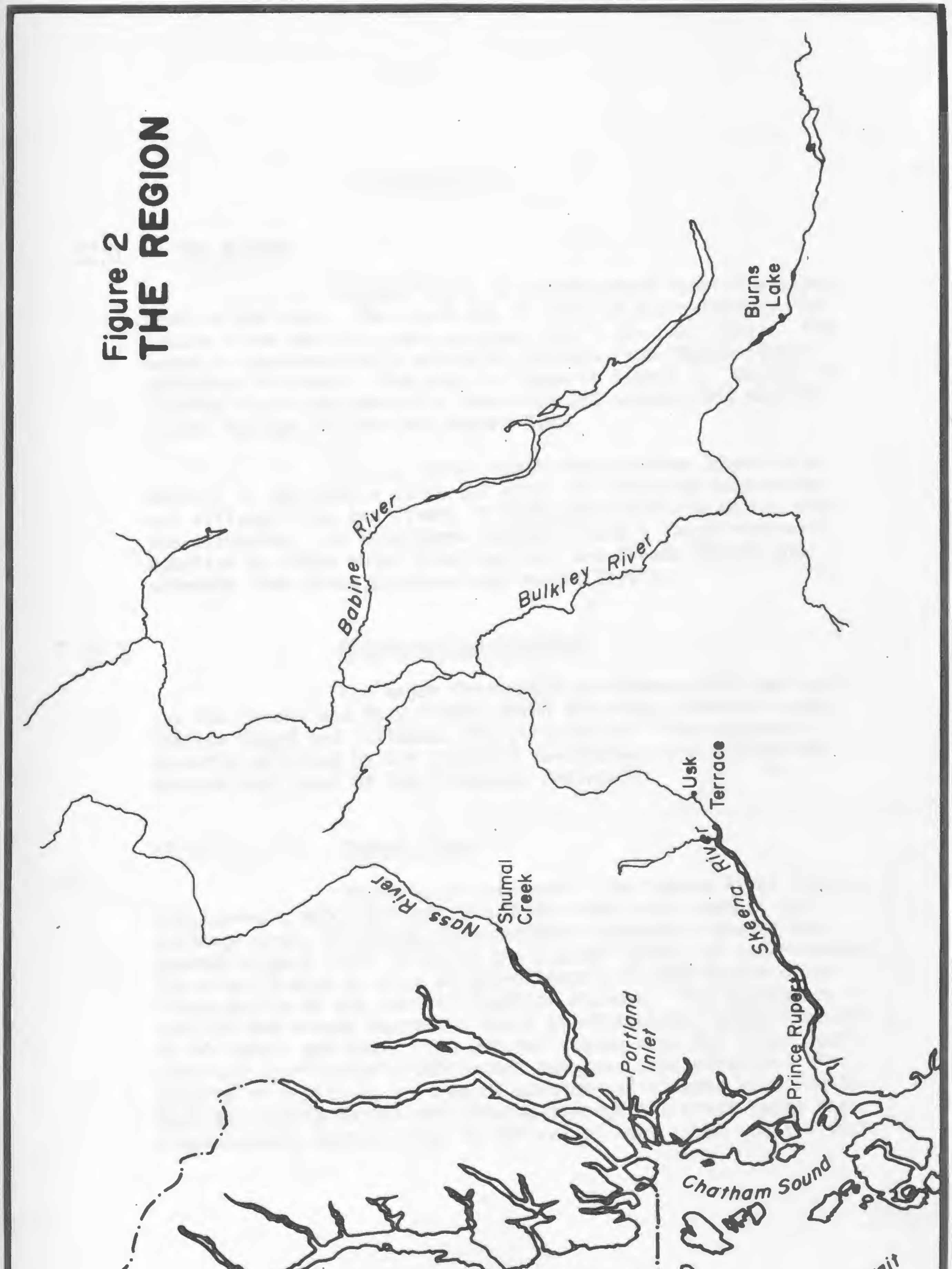


Figure 2
THE REGION

CHAPTER C2

C2.0 THE REGION

Chatham Sound is the dominant aquatic environment in the area. The sound has an area of approximately 600 square miles and is a semi-enclosed basin *(Trites, 1956)*. The sound is separated by a series of islands from Hecate Strait and Dixon Entrance. The area is shown in Figure 2. Depths in Chatham Sound are generally less than 200 meters, but most of Dundas Passage is over 400 meters deep.

Trites (1956) notes that Chatham Sound is an estuary in the modern sense but with its irregular boundaries and effluent from two rivers is more complicated than the simple estuaries. He considered Chatham Sound a large reservoir supplied by fresh water from the Nass and Skeena Rivers and seawater from Dixon Entrance and Hecate Strait.

C2.1 Freshwater Environments

The major freshwater environments of the area are the Skeena and Nass Rivers which discharge directly into Chatham Sound and influence its circulation. Watercourses directly affected by the proposed development are the smaller streams and lakes of the Tsimpsean Peninsula.

C2.1.1 Skeena River

Physical Environment: The Skeena River can be considered a major British Columbian river with respect to drainage area, discharge, and sediment transport, and is the second largest river entering the coastal waters of the Province. The river drains an area of approximately 20,000 square miles lying mostly in the central interior plateau. The headwaters rise in the Skeena Mountains where precipitation ranges from 20 to 40 inches per year. The coastal region near the river mouth receives approximately 150 inches per year precipitation. This pattern of rising in an area of continental climate with low to moderate precipitation and flowing through the coast range into progressively wetter areas is typical of many north coast rivers.

The hydrograph of the Skeena River at Usk for a typical flow year (1950) is shown in Figure 3. Figure 4 shows the hydrograph for 1948, the year of the maximum recorded flood peak. These figures demonstrate that the major runoff occurs around June each year and results from snow melt runoff. Both years also show small rainfall flood peaks in the fall.

Figure 5 shows the flood frequency curve for the Skeena River. It indicates that the largest recorded flood was 330,000 cfs in 1948 while the median flood is about 167,000 cfs. The minimum recorded flood peak was 102,000 cfs in 1944. The lowest recorded flow was 1830 cfs. Average discharge of the Skeena at Usk is 32,400 cfs.

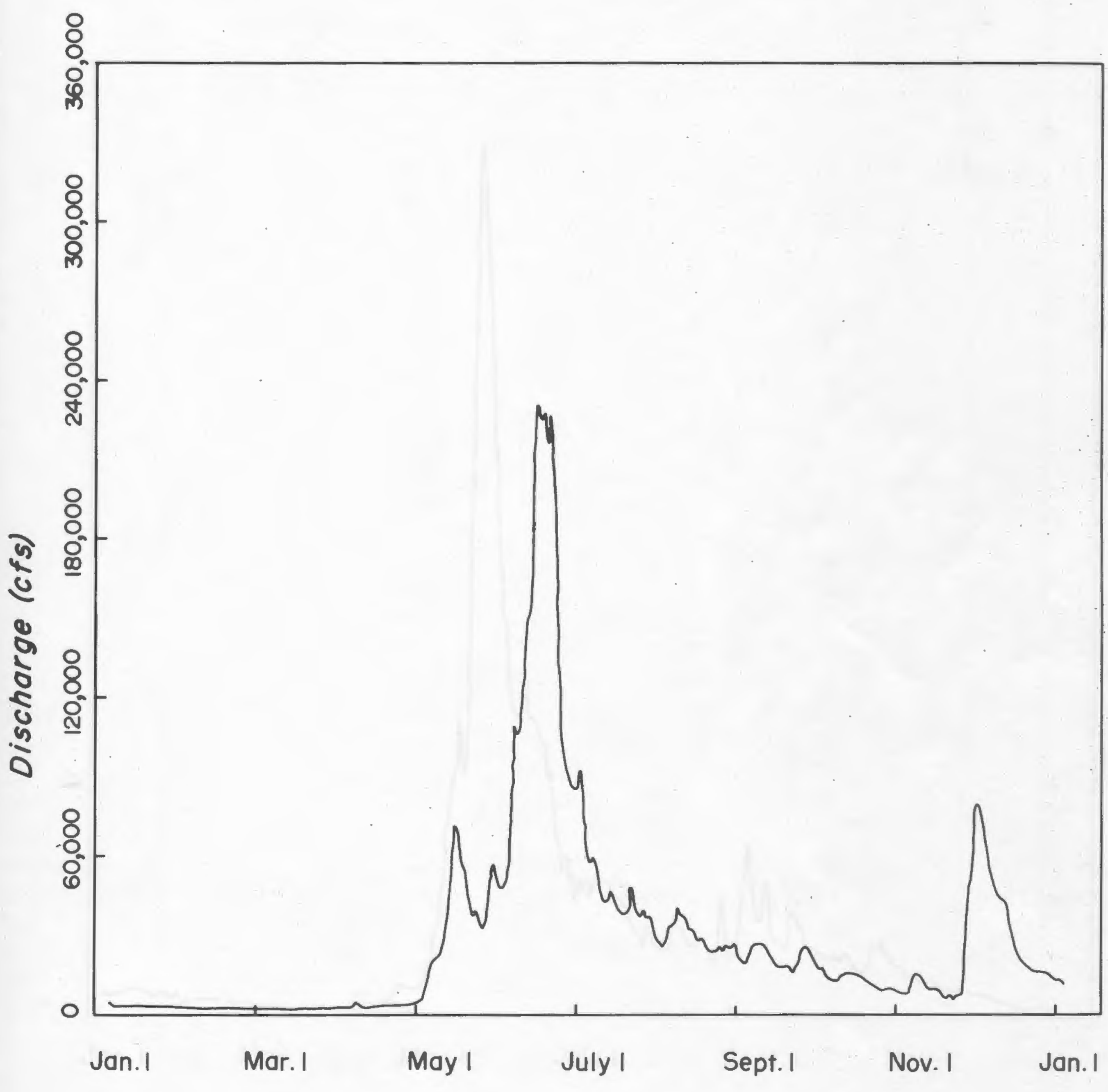
In general, the river can be seen to respond quite directly to inputs of water either from rainfall or snow melt. There are only two large lakes in the drainage, both on tributary streams, so that little control of peak flows is observed.

The lower Skeena River occupies a glacial fiord which has been filled with sediments to a point only a few feet below the surface. The river channel has been described as being in a state of youthful erosion with high cut banks that recede annually in several sections. The Skeena has no delta above normal tide levels. Several areas of shallow mud and sand flats have been deposited around the mouth, the largest being Flora Bank. Further upstream, the Skeena bed consists of gravel. No data have been collected on the amount or size of sediments carried by the Skeena.

Biological Characteristics: Thirty-one species of fish are found in the Skeena River watershed *(Scott and Crossman, 1973;* see Annex C-1). Fish populations in the system include all five North American species of Pacific salmon, steelhead, Dolly Varden, cutthroat, rainbow, lake trout, and several other species. Of the 31 species, 15 are anadromous and 5 are typically coastal. Thirteen of the species found in the Skeena are also distributed east of the Rockies. These are the minnows, suckers, whitefish, chars, and burbot. Representatives of the perch and pike families are not found in the Skeena system.

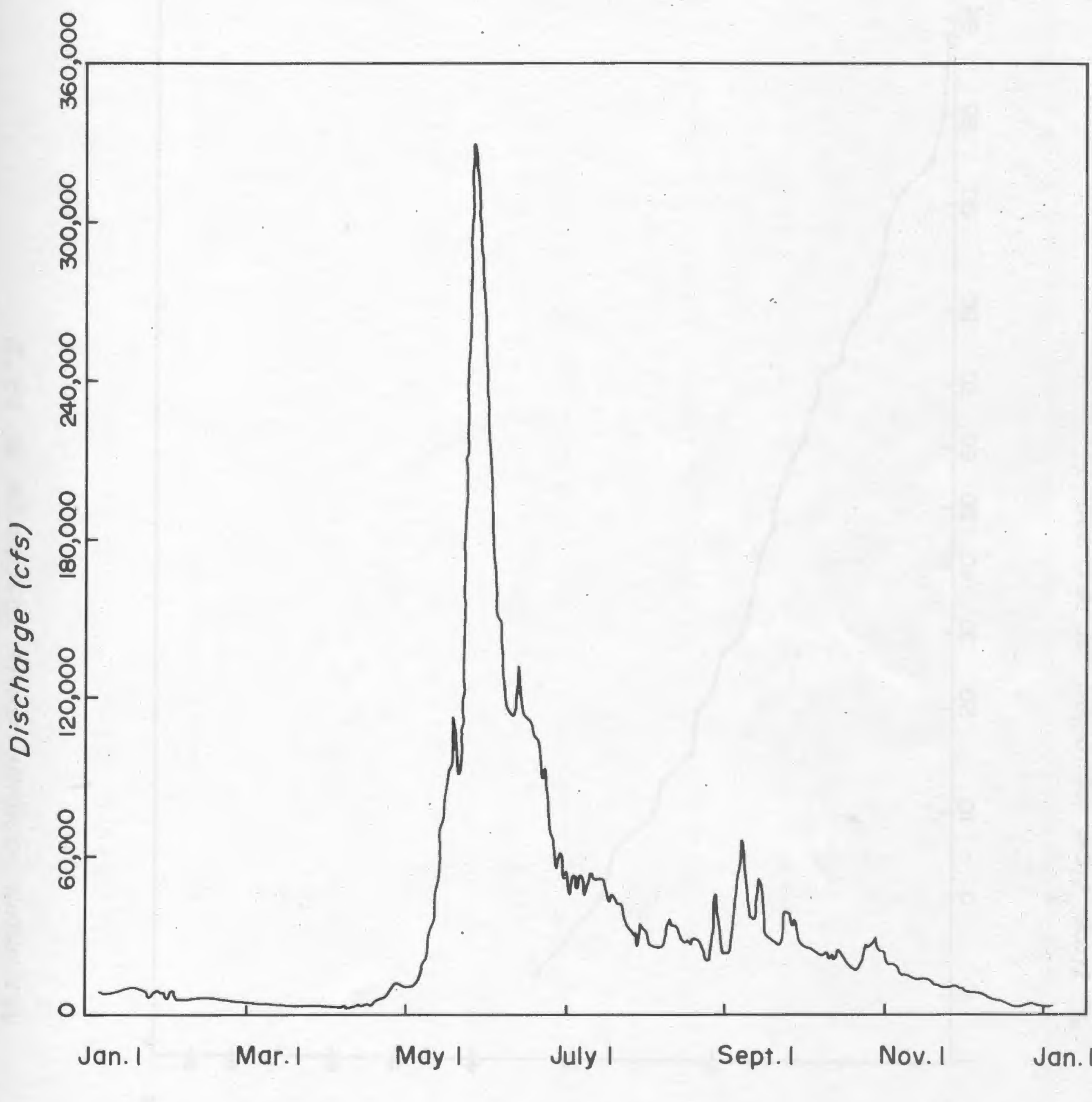
The Skeena accommodates 30 major salmon runs. Pinks are by far the most abundant species, followed by sockeye,

Fig. 3 - SKEENA RIVER HYDROGRAPH, 1950.



Typical flow year, 1950.

Fig. 4 - SKEENA RIVER HYDROGRAPH, 1948.



Maximum flow year, 1948.

Maximum annual daily discharge to 1972

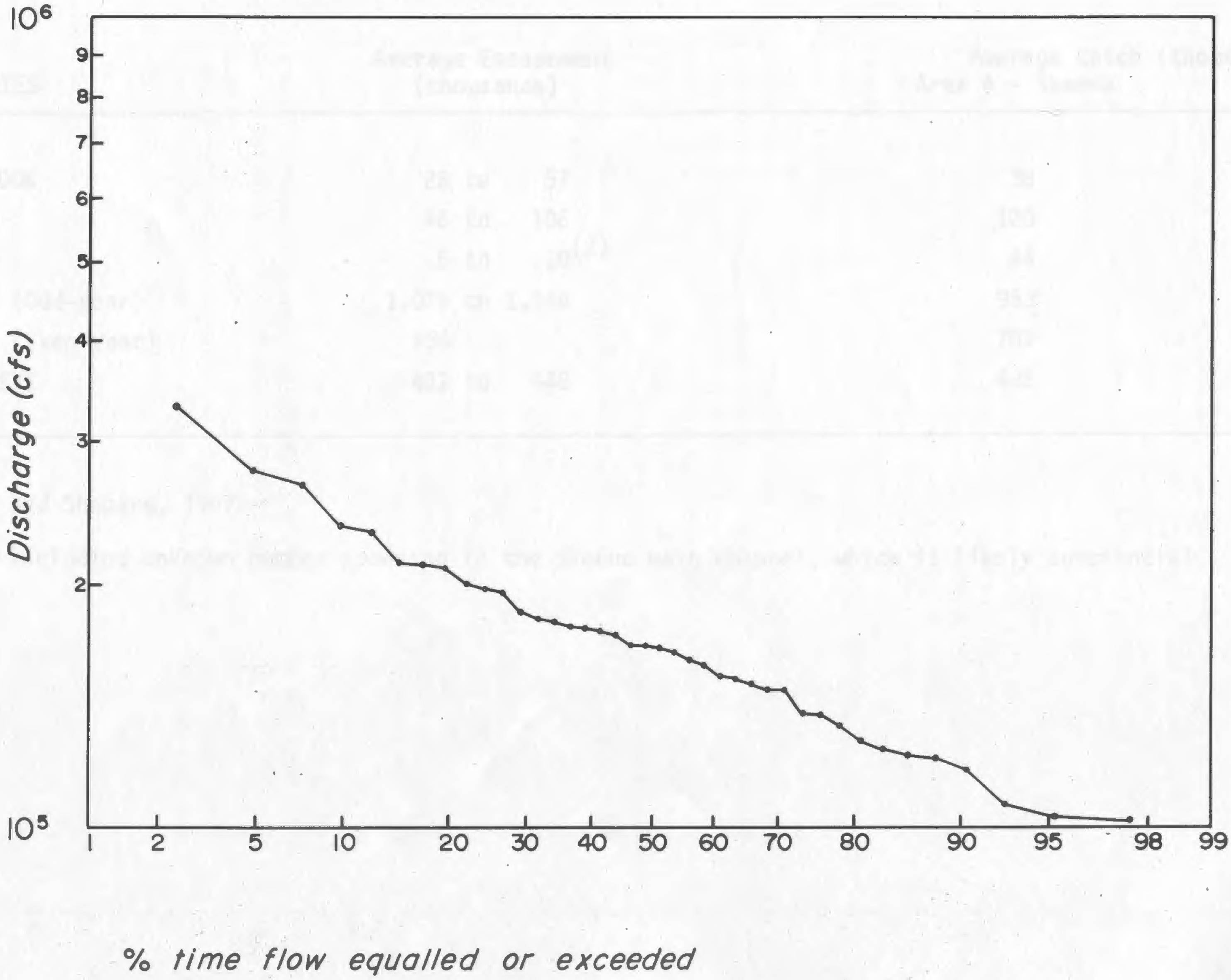


TABLE 1

CATCH AND ESCAPEMENT STATISTICS FOR SKEENA RIVER SALMON(1)

SPECIES	Average Escapement (thousands)	Average Catch (thousands) Area 4 - Skeena	All B.C.
CHINOOK	28 to 57	38	874
COHO	46 to 106	120	3,040
CHUM	5 to 10(2)	44	2,800
PINK (Odd-year)	1,026 to 1,149	953	13,950
PINK (Even-year)	454	707	9,400
SOCKEYE	412 to 448	485	6,440

(1) Aro and Shepard, 1967

(2) Not including unknown number spawning in the Skeena main channel, which is likely substantial.

coho, chinook, and a relatively few chum (see Table 1). In odd numbered years, pink salmon can number up to 1,149,000 spawners in addition to the commercial catch of 953,000 fish. Sockeye are considered the most important species due to high landed values.

Salmon populations have declined in the past six decades to about half of pre-1910 stock sizes. Regulation of commercial fishery has moderated the rate of decline, but since the mid-1950's salmon populations have again been reduced. Production of pinks and sockeye is presently being increased by enhancement programs such as the Fulton River spawning channel. Further enhancement projects are anticipated to increase the number of young salmon moving to the sea by a factor of two or more.

Sport fisheries in the Skeena River system center on steelhead *(Reid, 1974)*. Anglers travel long distances to fish the Morice and Bulkley Rivers, which rank seventh and tenth respectively by catch among British Columbia steelhead rivers. Coho and chinook salmon are also important in the sport fishery. Other sport species include resident rainbow trout, cutthroat trout, Dolly Varden, lake trout and mountain whitefish.

Life History Phases: To relate the biology of Skeena fishes to potential port development, a review of major life history components for different groups of fish species is required. Since none of the alternative port sites are in freshwater, only anadromous species of importance to humans are considered.

Pacific salmon are fall spawners, moving into streams from mid-summer to fall. Generally, the further they go inland to spawn, the earlier they move into the rivers. Spawning takes place from late August to November, with the peak of spawning activity varying between species, runs and years. Dolly Varden also spawn in late fall, but do not usually migrate long distances.

Habitat requirements for spawning always include gravel and, except for lake spawning sockeye, flowing water. Optimum conditions vary between species and with fish size. Coho can spawn in tiny streams with rubble substrate and flow of less than one cubic foot per second. Chinook salmon are capable of moving boulders up to 15 inches in diameter and digging a redd over a yard deep. The greatest numbers of fish and the greatest rate of survival are associated with spawning channel type, conditions of steady flows and well percolated gravels of intermediate size. All Pacific salmon die after spawning.

Incubation of salmon eggs and larvae takes place over the winter months. Larvae hatch in the spring, and remain in the stream gravel for a period of several weeks prior to emergence. The fry of pink and chum salmon leave the streams and proceed directly to the sea in early May. During a similar period, sockeye fry move downstream with the spring runoff to a lake where they remain for one to two years. Coho and chinook fry remain in the streams for one to three years before migrating to the sea. Coho, chinook and sockeye juveniles undergo a transformation from parr to smolt stages in their second or third summers. Shortly after this transformation they begin moving downstream, and develop a tolerance for sea water. Dolly Varden follow a pattern similar to coho and chinook salmon.

Steelhead and coastal cutthroat trout are spring spawners, moving into streams from December through July, and spawning between late February and July. Steelhead are divided into summer and winter runs according to the time they move into freshwater. Winter steelhead spawn in early spring, and summer steelhead spawn in early summer. Cutthroat spawn in late spring.

Habitat requirements for steelhead are similar to those of chinook and coho salmon, but initially phased to opposite seasons. Steelhead and cutthroat juveniles remain in fresh water for at least one year and compete with salmon juveniles for food and habitat. They apparently exhibit similar tendencies regarding tolerance to salinity. The seaward migration of steelhead and cutthroat smolts occurs in the spring or early summer, concurrently with salmon juveniles and the spring freshet.

The embryos and larvae of all Pacific salmon are intolerant of sea water (or stenohaline). The embryos of pink and chum salmon, which spawn in coastal stream mouths, have a greater tolerance to moderate salinity than those of coho, chinook or sockeye, and can apparently withstand periods of inundation with dilute sea water. At the fry stage, pink and chum salmon are fully tolerant of sea water (or euryhaline), whereas the fry of coho, chinook and sockeye must remain in fresh water *(Weisbart, 1968; Kashiwagi and Sato, 1969; Williams, 1969)*. Pink and chum salmon are therefore able to utilize small coastal streams for spawning, without regard to habitat requirements for a one to three year freshwater residency. Chinook and sockeye are restricted to larger streams with abundant habitat, such as in systems with large lakes, and coho are known for their ability to seek out and thrive in extremely small and diverse kinds of habitat. It is in the seaward migration of juvenile salmon and steelhead smolts that estuaries (in the dynamic and biological sense) are of importance for salmon production.

Seaward migration of coho, chinook, sockeye, and steelhead in the Skeena is closely associated with the spring freshet. During the freshet, discharge is at a maximum and consequently the size of the area of reduced salinity in the estuary is maximized.

Studies on acclimation of young salmonids to sea water have shown that the fry of pink salmon are tolerant of sea water, whereas sockeye and coho smolts require an extended period, several days to a few weeks, to gradually develop a tolerance for higher salinities as their osmoregulatory processes reverse. The demand for estuarine conditions may increase substantially as salmon enhancement programs, now beginning in the Skeena tributaries, multiply the salmon populations migrating down the Skeena.

Brief but intense predation is imposed on young salmon in the first few days of life in the estuary by larger juvenile salmon, herring and other fishes *(Parker, 1971; Ito and Parker, 1971)*. The salmon fry must outgrow their predators or face severe losses. This predation is a major influence in the genetic selection of size in salmon. Thus the productivity of the estuary is vital to salmon populations, not only for feeding *per se*, but to minimize early mortality from predation.

Salmon stocks under commercial fishing pressure are more vulnerable to serious effects from unusual weather or other environment disturbances. A very dry winter with high mortality of pink salmon, for example, can depress the stocks in that cycle for 20 years or more *(see Milne, 1955)*. Similarly, the estuary in the Skeena may not be fully utilized in most years, but under certain weather or Skeena discharge conditions, salmon production may depend entirely on areas such as Flora Bank for certain physical conditions. The diversity of habitat available for all phases of the life history is a major factor in salmon survival under adverse conditions.

C2.1.2 Nass River

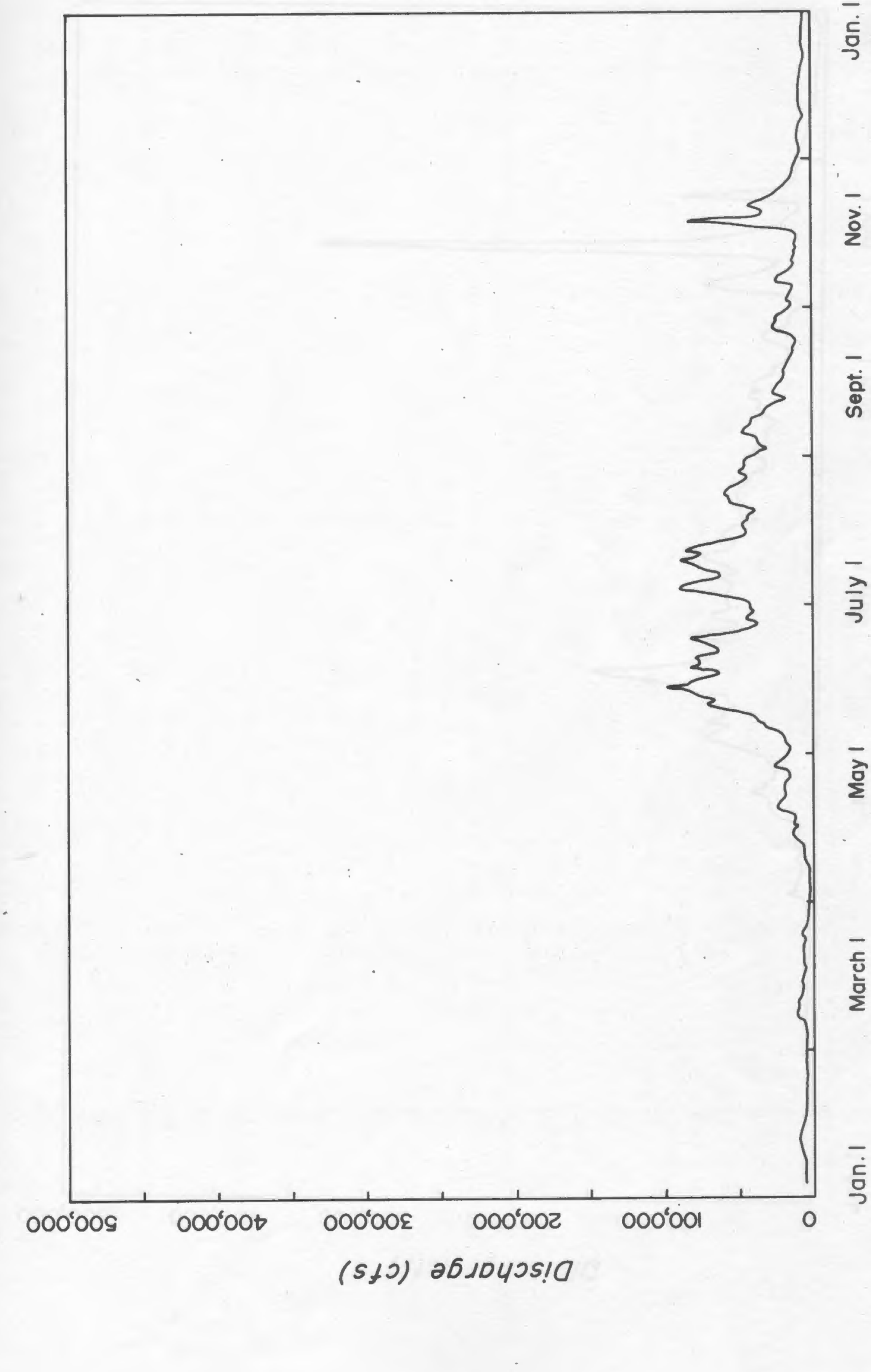
The Nass River is the second major river flowing into Chatham Sound. The effluent of the Nass flows through Nass Bay and into northern Chatham Sound via Portland Inlet. Especially during freshets the Nass can significantly affect the circulation of water in Chatham Sound.

Physical Characteristics: The drainage area of about 7,900 square miles lies in the Skeena Mountains between the main branch of the Skeena River and the coast. Precipitation in the headwaters averages about 40 inches per year increasing toward 150 inches near the river mouth. Relative wetness of the basin is indicated by the hydrologic data collected from the Nass above Shumal Creek which shows an average flow of 3.85 cfs per square mile of drainage area as compared to 2.0 cfs per square mile for the Skeena at Usk.

Figure 6 shows the hydrograph for the Nass above Shumal Creek for a typical low flow year, 1965. The hydrograph for the year of the largest recorded flood peak, 1961, is shown in Figure 7. The 1961 flood peak of 334,000 cfs was 100,000 cfs higher than the next largest recorded and was the result of a major fall rain storm. The largest recorded spring flood was 192,000 cfs in 1936, whereas the 1948 flood, which resulted from a very large snowfall accumulation, was 158,000 cfs. Thus, although snowpack accumulation can result in large volume floods, the major peaks are produced by rain and contain relatively small volumes of water. The median flood is about 115,000 cfs and the lowest peak recorded is 71,000 cfs. Minimum recorded flow is 860 cfs. The flood frequency curve is shown on Figure 8.

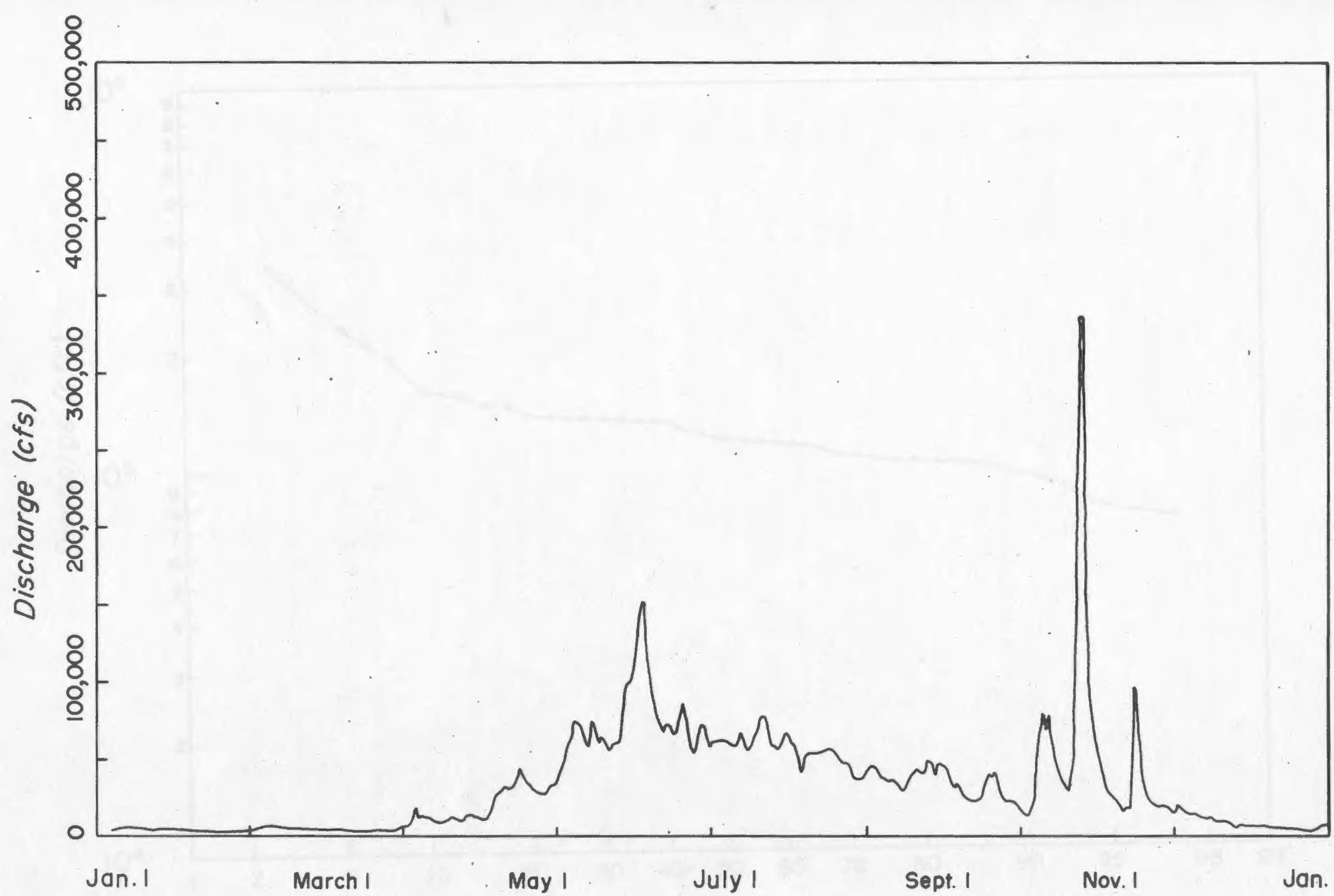
As with the Skeena, no data has been obtained on sediment loads. As smaller areas of the interior plateau are drained, the suspended sediment content of the Nass is probably less than the Skeena. However, the basin contains significant areas of glaciers which are a large source of sands and gravels. Thus, the quantity of bed load carried is probably quite large.

Fig. 6 - NASS RIVER HYDROGRAPH, 1965.

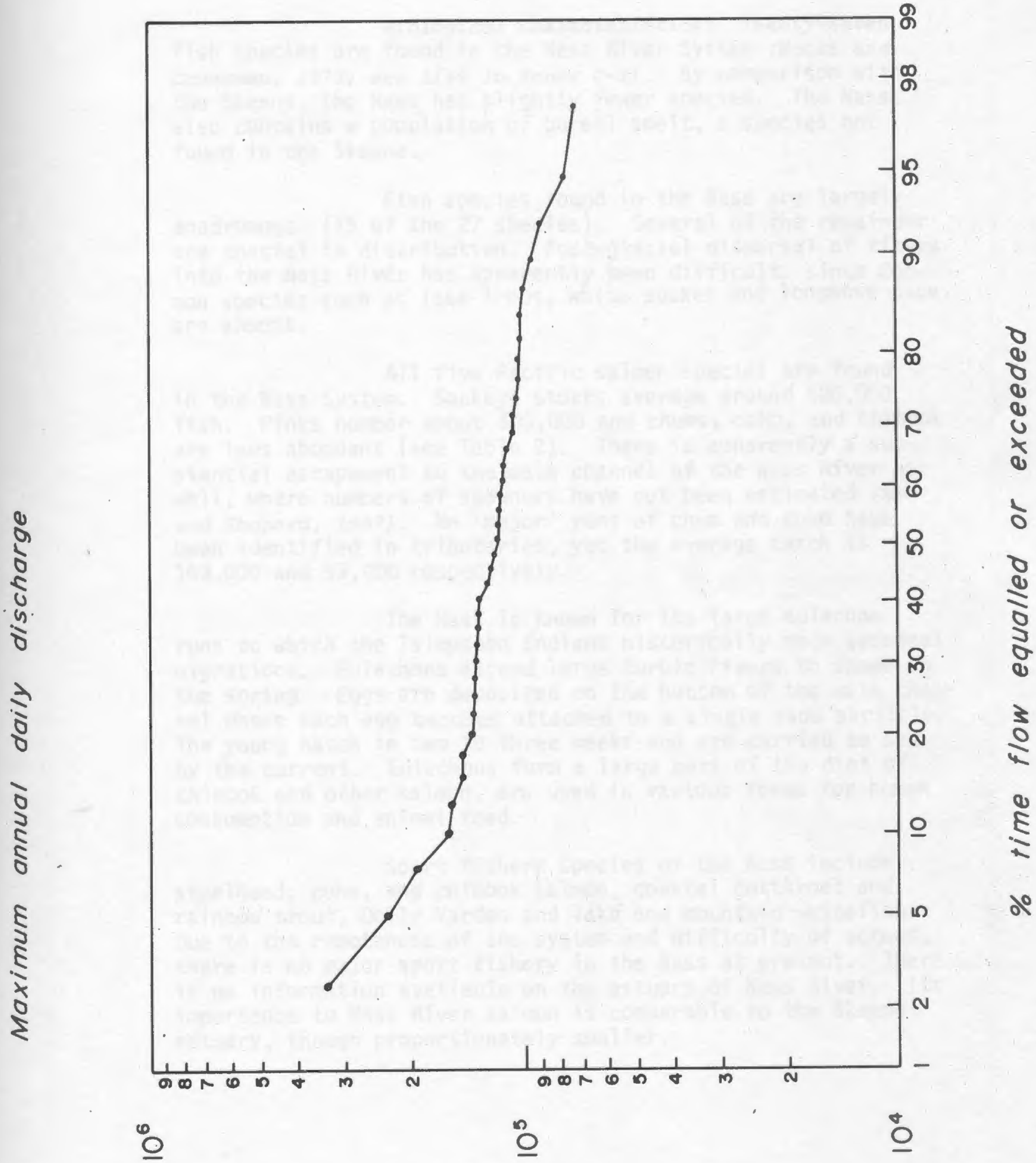


Typical flow year, 1965.

Fig. 7 - NASS RIVER HYDROGRAPH, 1961.



Maximum flow year, 1961.


Maximum annual daily discharge
% time flow equalled or exceeded
Discharge (cfs)
10^6
10^5
10^4
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99

Biological Characteristics: Twenty-seven fish species are found in the Nass River System *(Scott and Crossman, 1973; see list in Annex C-1)*. By comparison with the Skeena, the Nass has slightly fewer species. The Nass also contains a population of boreal smelt, a species not found in the Skeena.

Fish species found in the Nass are largely anadromous (15 of the 27 species). Several of the remainder are coastal in distribution. Post-glacial dispersal of fishes into the Nass River has apparently been difficult, since common species such as lake trout, white sucker and longnose dace, are absent.

All five Pacific salmon species are found in the Nass System. Sockeye stocks average around 400,000 fish. Pinks number about 500,000 and chums, coho, and chinook are less abundant (see Table 2). There is apparently a substantial escapement to the main channel of the Nass River as well, where numbers of spawners have not been estimated *(Aro and Shepard, 1967)*. No 'major' runs of chum and coho have been identified in tributaries, yet the average catch is 153,000 and 99,000 respectively.

The Nass is known for its large eulachon runs to which the Tsimpsean Indians historically made seasonal migrations. Eulachons ascend large turbid rivers to spawn in the spring. Eggs are deposited on the bottom of the main channel where each egg becomes attached to a single sand particle. The young hatch in two to three weeks and are carried to sea by the current. Eulachons form a large part of the diet of chinook and other salmon, are used in various forms for human consumption and animal feed.

Sport fishery species of the Nass include steelhead, coho, and chinook salmon, coastal cutthroat and rainbow trout, Dolly Varden and lake and mountain whitefish. Due to the remoteness of the system and difficulty of access, there is no major sport fishery in the Nass at present. There is no information available on the estuary of Nass River. Its importance to Nass River salmon is comparable to the Skeena estuary, though proportionately smaller.

TABLE 2

CATCH AND ESCAPEMENT STATISTICS FOR NASS RIVER SALMON[1]

SPECIES	AVERAGE ESCAPEMENT (thousands)	AVERAGE CATCH (thousands)
SOCKEYE	206.	179.5 - 189.5
PINK - ODD YEAR	475.	10. - 20. (2)
PINK - EVEN YEAR	481.	20. - 50. (2)
CHUM	153.	(2)
COHO	99.	(2)
CHINOOK	25.	1.5 - 3. (2)

(1) Aro and Shepard (1967).

(2) Not including unknown number spawning in the Nass main channel, which is substantial.

C2.1.3 Smaller Watersheds

There are approximately 20 watersheds in the Tsimpsean Peninsula study area. Figure 9 shows the boundaries of the watersheds and names of the major creeks and lakes in the study area.

Physical Characteristics: The watersheds of the study area are small, ranging in size from less than one to approximately 32 square miles. Stream lengths range from less than 0.1 to approximately 7.2 miles. Annex C-1 provides details of stream lengths and drainage area for each of these watersheds in the study area.

Surficial geology, soil types and vegetation patterns are described in detail elsewhere in this report. Although much of the study area is covered with coastal muskeg, most of the drainage basins of importance have only limited muskeg areas. One notable exception is Wolf Creek.

Large areas within the study area contain exposed bedrock or very thin overburden. There are only limited areas of alluvial material with the exception of Skeena deposits. The small alluvial deposits are generally found at creek mouths.

The most common substrate in streams of the area is boulders, usually in shallow pools along fairly straight runs which in freshet conditions have high velocities. In these sections gravel is almost absent, occurring only in small isolated patches. The soft-layered rocks derived from local bedrock tend to split rather than roll in a current, resulting in both stable bed material, and where material is deposited, an extremely rough surface on rubble or gravel bars. Gravel derived from harder rocks, including glacial material, forms a more typical, rounded stream gravel, which is carried downstream by high freshet velocities. This results in a distribution of gravel suitable for salmonid spawning as follows:

- in smaller tributaries with low gradient;
- immediately above the high tide level, where stream velocity drops;
- in the inter-tidal zone of the stream bed where tidal action alternately slows velocities and distributes bed material.

FIGURE 9 Map of Watersheds and Streams

Included in accompanying map folio.

Large pools, favourable for resident fish populations, are scarce, and are formed by three processes:

- bedrock sills forming groins which define the upper end of a pool;
- log jams, which vary in size and permanence;
- gravel or rubble bars deposited at various levels in the tidally influenced stream mouths.

There are seven lakes over one mile in length within the study area. Four of these (Georgetown, Woodworth, Diana, and Minerva Lakes) lie in northwest-southeast valleys parallel to Work Channel. The other three lakes (Shawatlan, Prudhomme, and Rainbow) lie in the northeast-southwest cross valley parallel to Prince Rupert Harbour. Lake morphometry can be expected to differ significantly according to the drainage physiography; no bathymetric data are presently available, however. In addition, there are over two dozen small lakes and ponds in the area, of which ten are named on the most recent 1:50,000 topographic maps. All of the larger lakes, except Minerva Lake, are presently controlled for water supply purposes.

The shoreline of lakes in the study area can be divided into two major types: forested, steep slopes over bedrock or boulders, or muskeg over gradual slopes. Muskeg usually surrounds the smaller lakes as well as larger lakes, such as Georgetown Lake along shallow or low-relief shores. In the steep-shored lakes, such as Woodworth and Prudhomme, plant production is limited by a lack of substrate in the euphotic zone, as well as by wave action and impoundment for water supplies. Aquatic plants found in both types of lakes include yellow pond lily, liverwort, and quilwort.

A notable exception to the two lake types noted above is Neaxtoalk Lake which has a freshwater marsh community unique in the region. The normal lake surface is at or just below the highest tide levels, and the outlet flows through a very narrow canyon. These factors contribute to a three to four foot rise in the water level at infrequent periods during the year. The fluctuation in water levels apparently inhibits muskeg formation, resulting in a wide, gently sloping shore of compacted organic deposits, covered by dense grasses and sedges. Shoals in mid-lake contain bullrushes in a shallow littoral zone that has submergent vegetation. The presence of widgeon-grass at the west end of the lake indicates at least periodic brackish water conditions.

Hydrology: There is no adequate data available on stream flows within the study region. The Water Survey of Canada presently maintains flow recording stations only on Diana Creek and Kloiya River. Since these stations were established after water supply dams were built by Canadian Cellulose, data from these stations reflects the effects of stream regulation and is of little use in determining unregulated stream flows.

Limited flow data from inactive stations on Boneyard Creek, Union Creek and Thulme River were used to provide information on variations in stream flow and for verification of estimated precipitation amounts. Union Creek and Thulme River are located outside the study area on the east side of Work Channel.

Stream discharges have been estimated on the basis of available precipitation data because of the lack of flow data. Precipitation data presented in Volume 7 of this report was utilized, and supplemented by precipitation data from Fall River, Naas Harbour, and unpublished Canadian Cellulose data from Kloiya Dam and Rainbow Lodge. The reliability of the unpublished data are unknown.

The Prince Rupert precipitation pattern is typical of north coastal areas with highest rainfall in October and November. At higher elevations, winter precipitation falls as snow, resulting in a spring flood peak as well as a fall peak. Precipitation ranges from approximately 90 to 120 inches per year, with over four inches in each average month, and up to 29 inches in October, the wettest month. Severe flooding of the small streams is usually associated with the fall rain storms.

Due to rainfall and the moderate climate, vegetation in the area is lush. Poor drainage in much of the area results in bog or muskeg growth with a high capacity for water retention. During periods of high precipitation the vegetation becomes water saturated, and begins releasing the entire subsequent rainfall as runoff. This results in sudden freshets.

Annex C-2 provides the details of calculations carried out to estimate average monthly flows, flood flows and minimum flows in streams in the study area. This annex should be consulted for the details of the calculation procedures and limitations of the available data.

The results of the analyses showing mean monthly stream flows and flood flows are shown in Figures 10 through 16 for the following creeks:

Stumaun Creek (main fork)
Stumaun Creek (west fork)
Pearl Harbour (Lahon) Creek
Georgetown Creek (above Georgetown Lake)
McNichol Creek
Wolf Creek
Lachmach River

In general, all streams, with the exception of the Lachmach River, show highest average flows during the fall rains. The Lachmach River shows a high average flow during May and June, reflecting the higher basin elevations and the resultant increased effect of snowmelt in that drainage. All other creeks also show spring floods, although on the average these floods do not reach the heights of the fall flows. Peak floods on all streams are the result of intense fall rainstorms which occur most frequently in October.

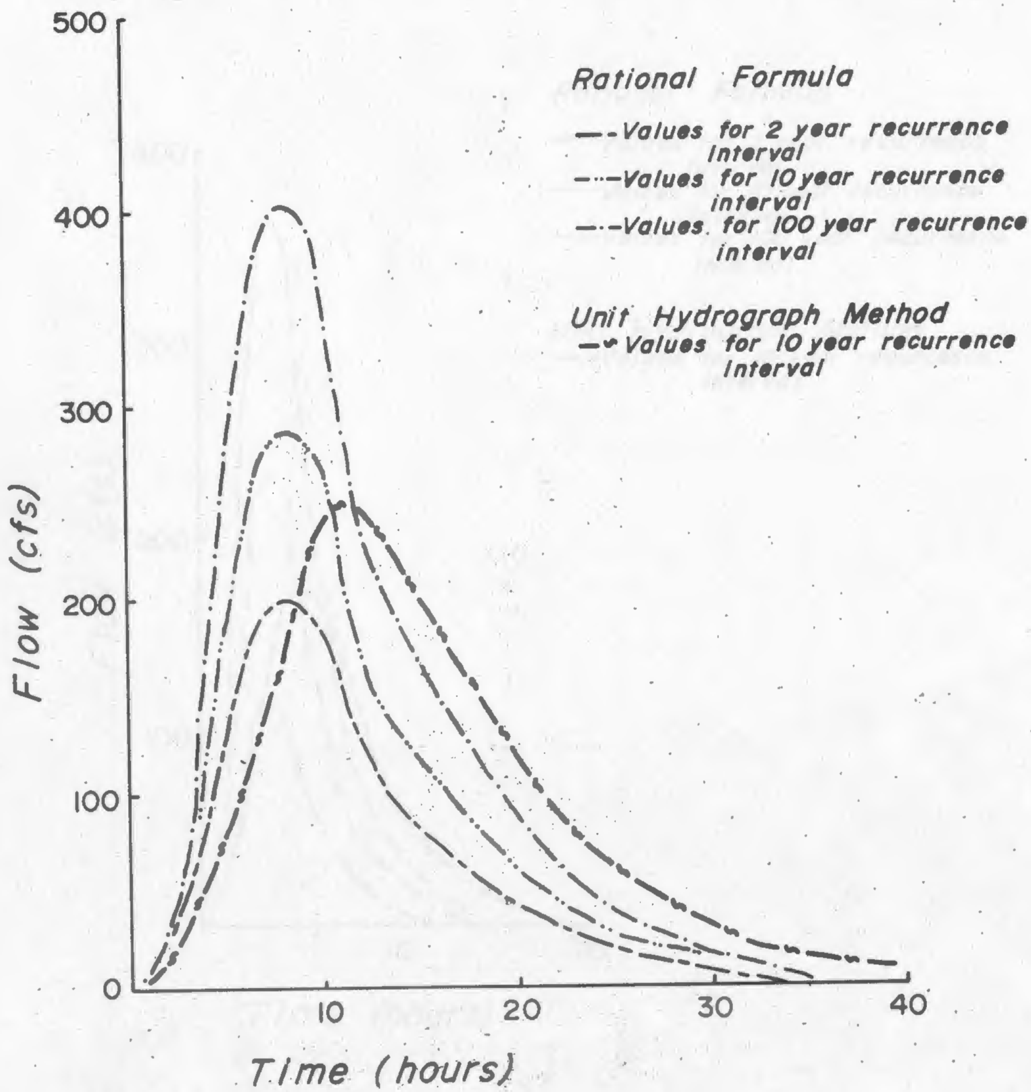
Response of the streams to rainfall varies, depending upon the size of the stream and basin. Individual figures should be consulted for the details of estimated mean monthly and flood flows in each of these streams.

Water Quality: Except during freshets, stream water consists largely of seepage from the dense vegetation, especially sphagnum mosses which occur in thick mats. This results in all streams in the study area having a high organic content. Waters of the streams are rich brown in colour and have a surface film that foams with turbulence.

Water quality analyses were conducted on samples from Stumaun Creek and Neaxtoalk Lake during the studies in October 1974. The results are shown in Table 3. The data indicate low to moderate dissolved solid contents ranging from 14 to 112 parts per million. These waters had low pH ranging from 4.5 to 6.2 and moderate organics content (8.1 to 22.1 ppm). Lake surveys conducted on Prudhomme and Rainbow Lakes by the British Columbia Fish and Wildlife Branch in 1952 and 1972 indicated low dissolved solids, (4 to 40 ppm), pH ranging from 5.5 to 6.8, and Secchi disc transparencies of approximately ten feet. Details of methods utilized in 1974 are presented in Annex C-1.

Fig.10- STUMAUN CREEK

Calculated Flood Hydrographs



Estimated Mean Monthly Flow

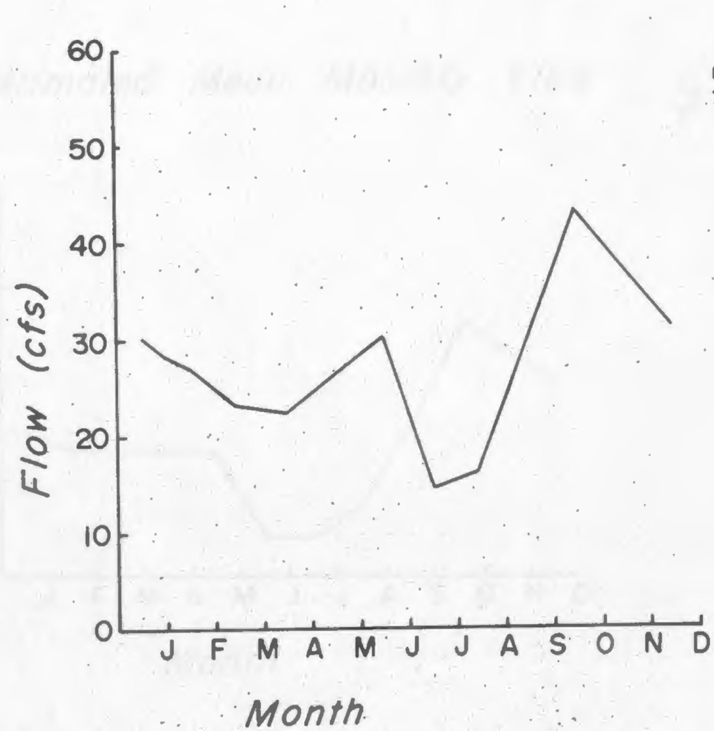
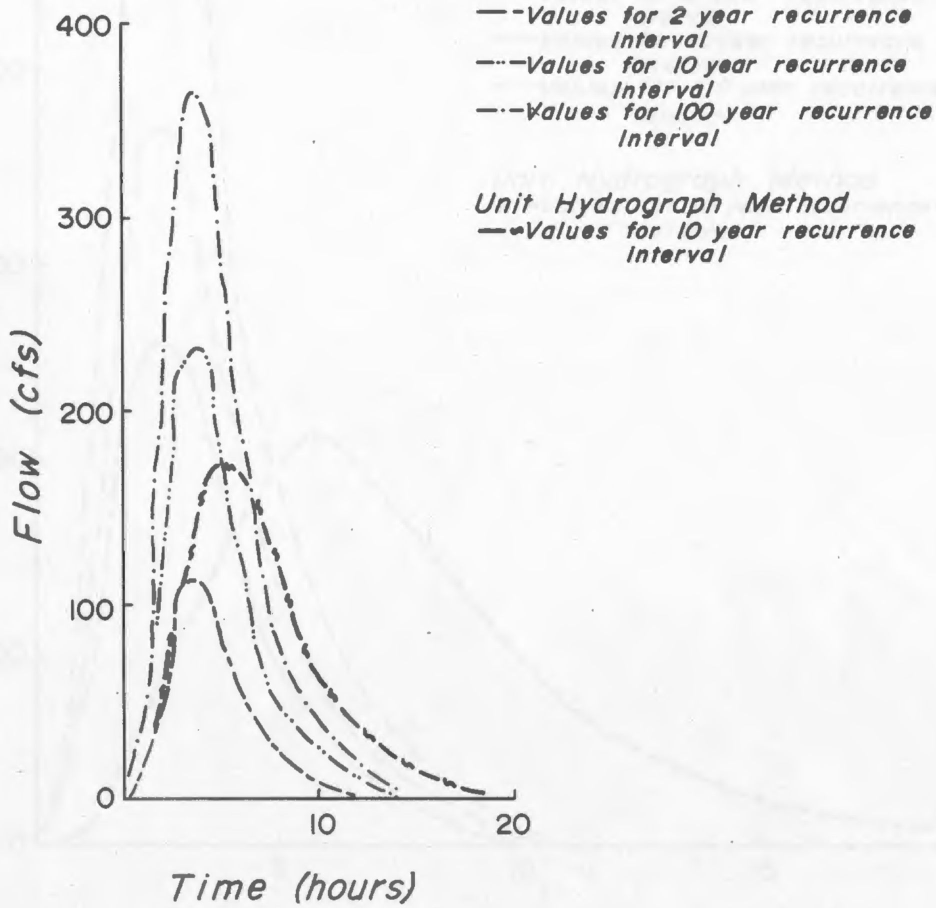


Fig. 11- STUMAUN CREEK - WEST FORK - HYDROGRAPHS

Calculated Flood Hydrographs



Estimated Mean Monthly Flow

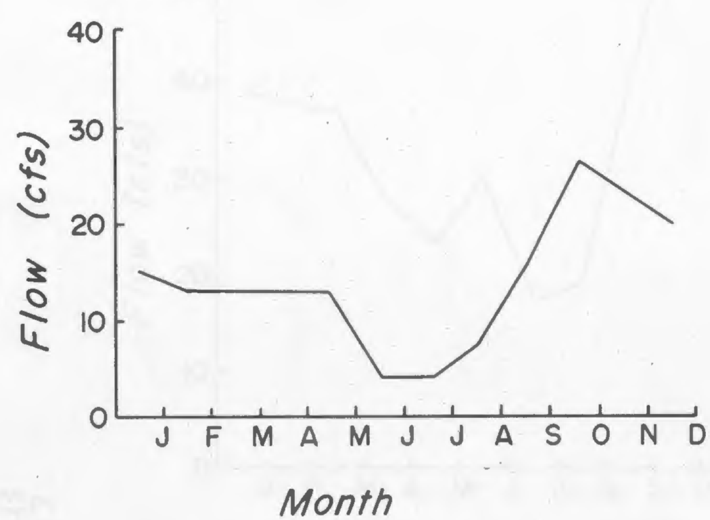
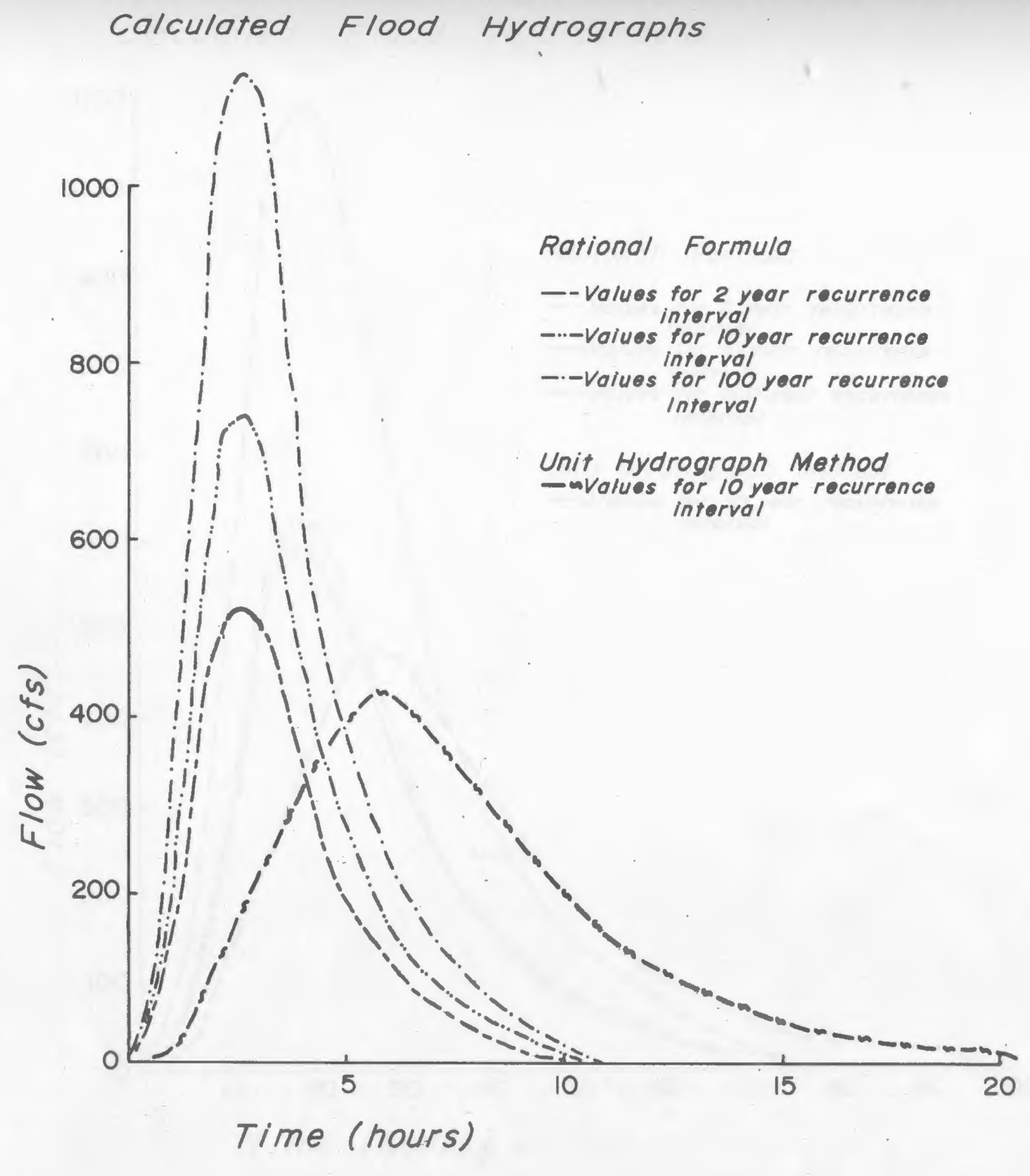


Fig. 12- LAHON (PEARL HARBOUR) CREEK-HYDROGRAPHS



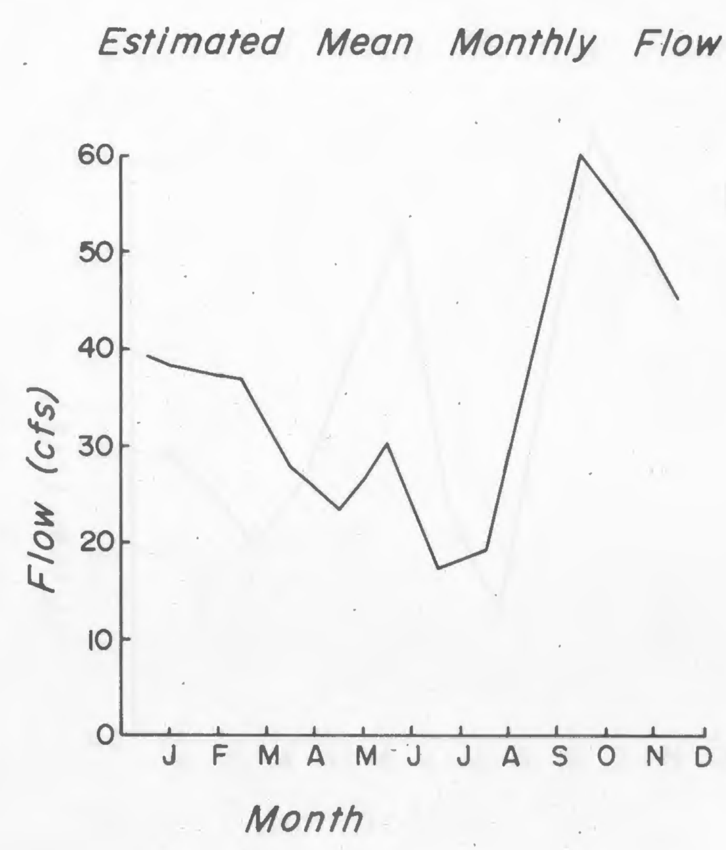
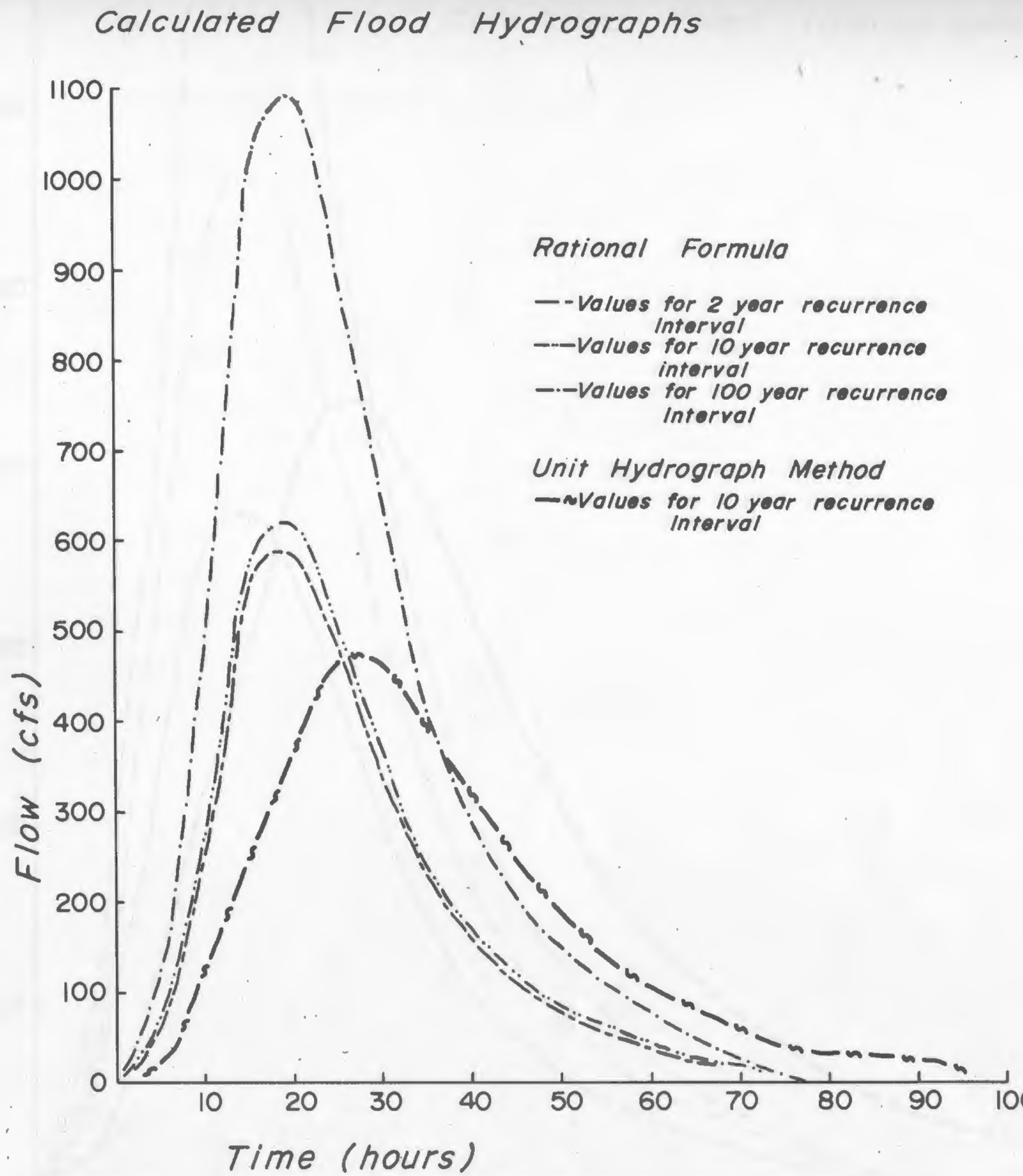
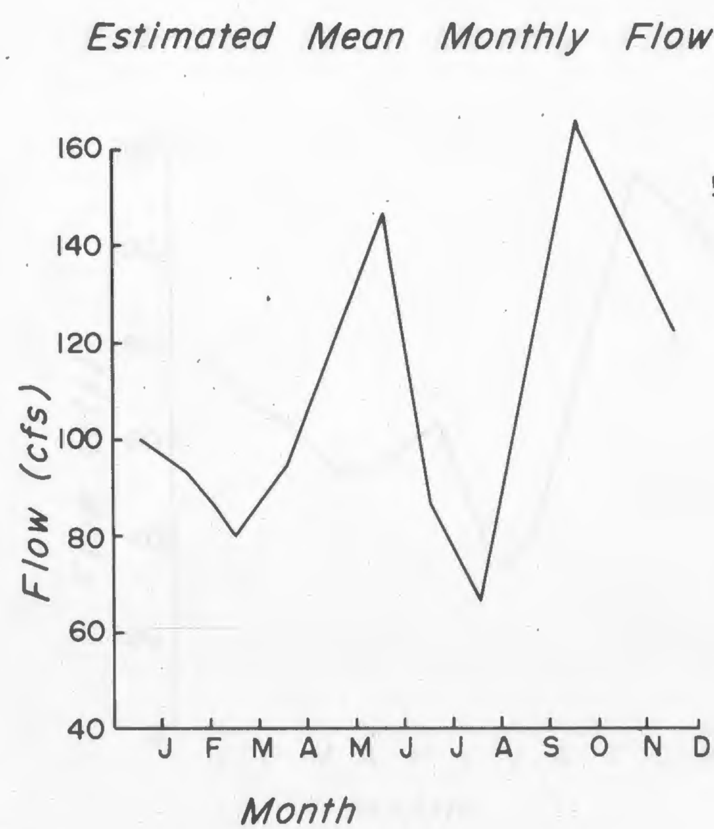
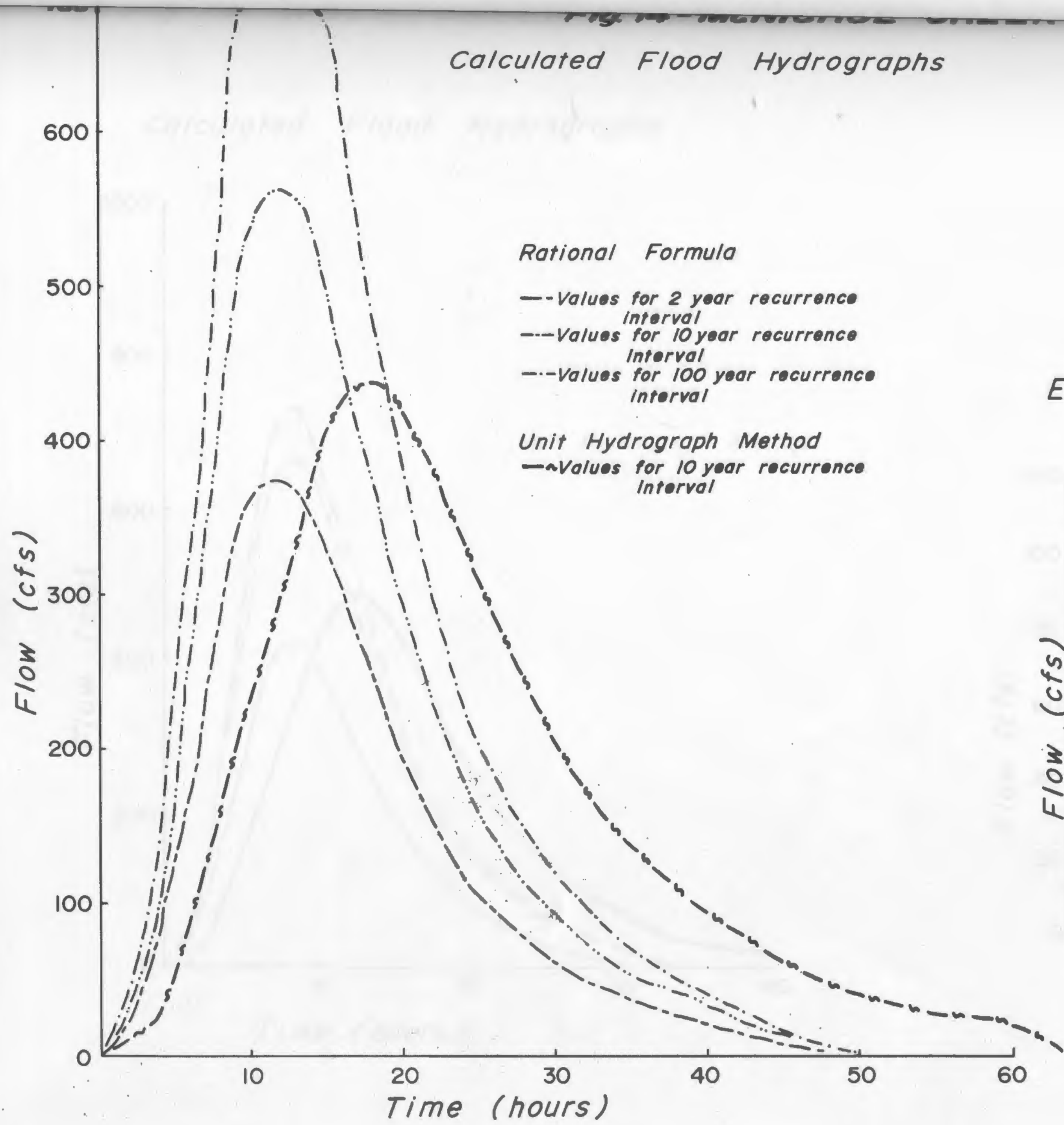


Fig. 13 - GEORGETOWN CREEK (above Georgetown Lake) - HYDROGRAPHS





Calculated Flood Hydrographs



Estimated Mean Monthly Flow

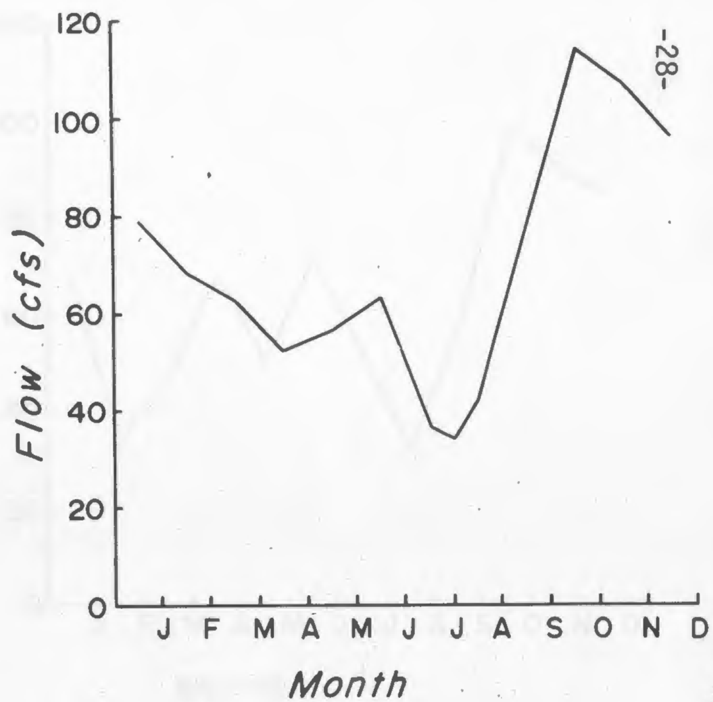
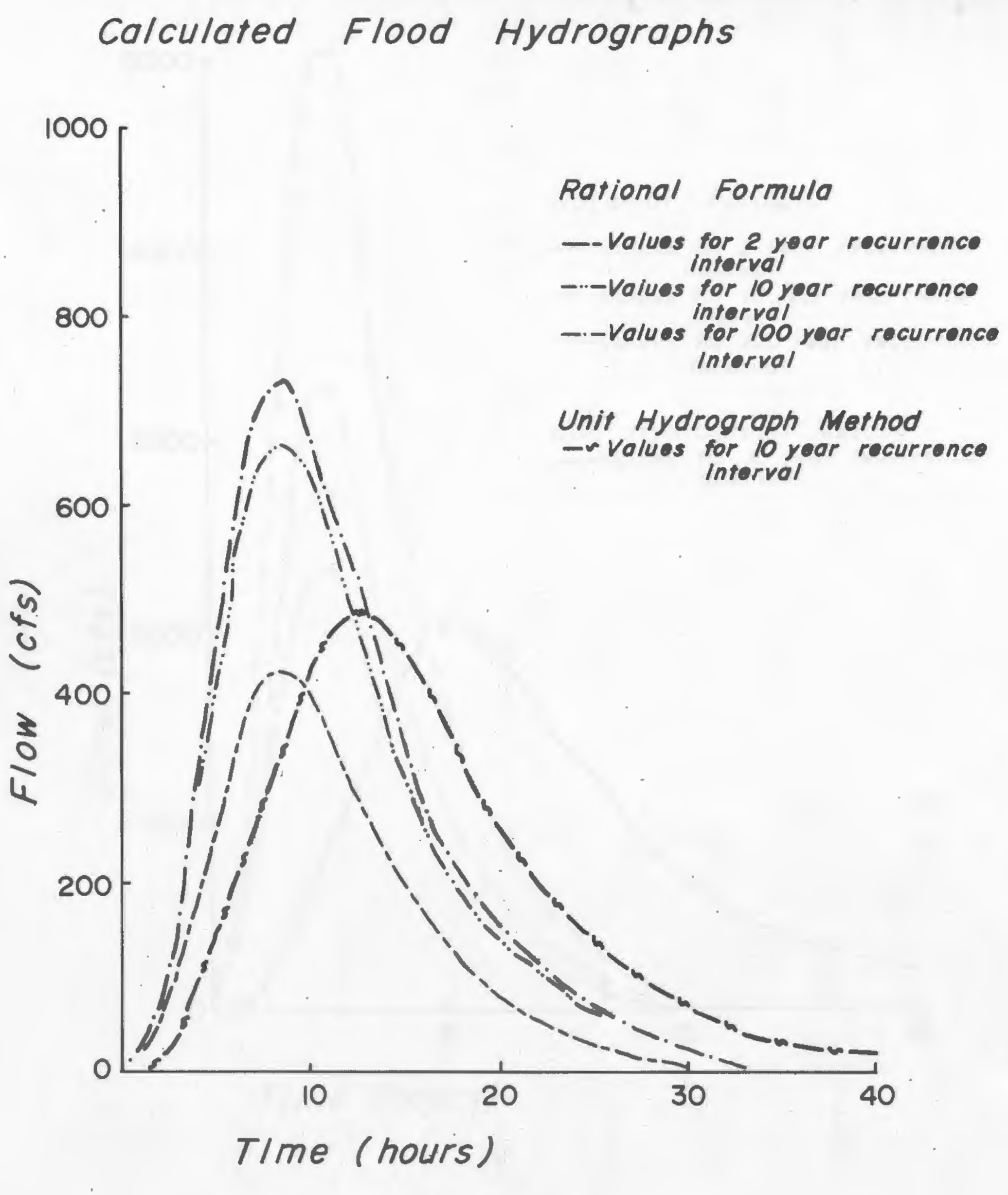


Fig. 15- WOLF CREEK-HYDROGRAPHS



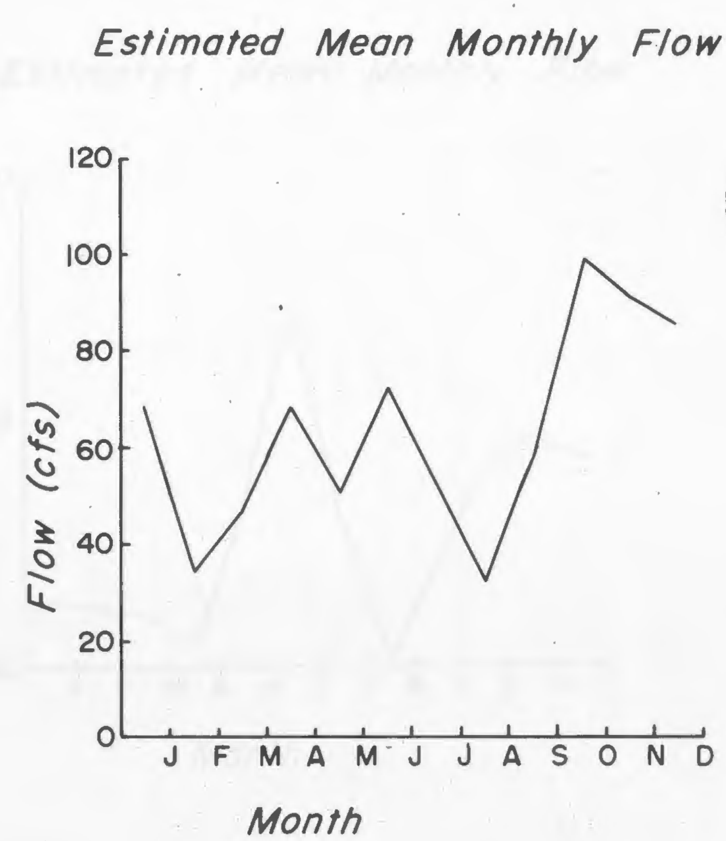
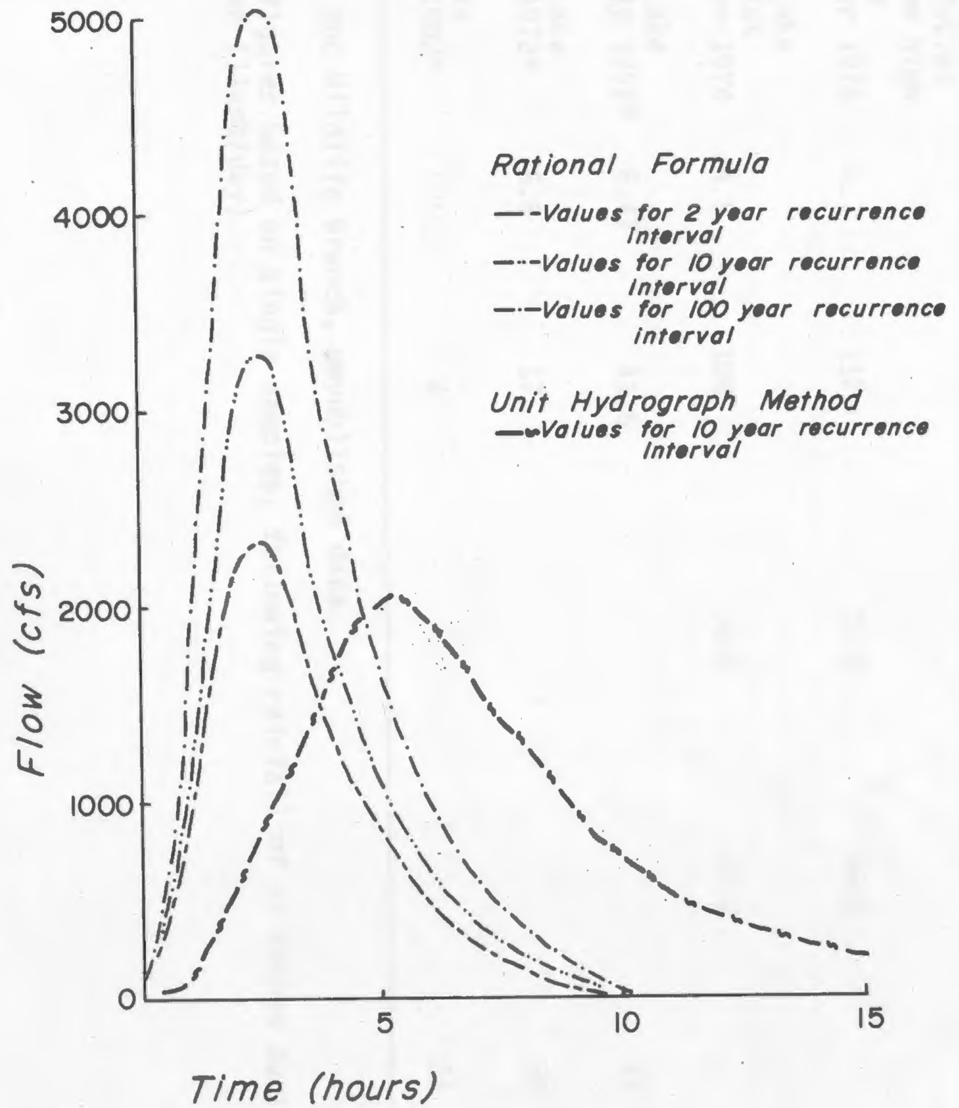


Fig. 16 – LACHMACH RIVER – HYDROGRAPHS

Calculated Flood Hydrographs



Estimated Mean Monthly Flow

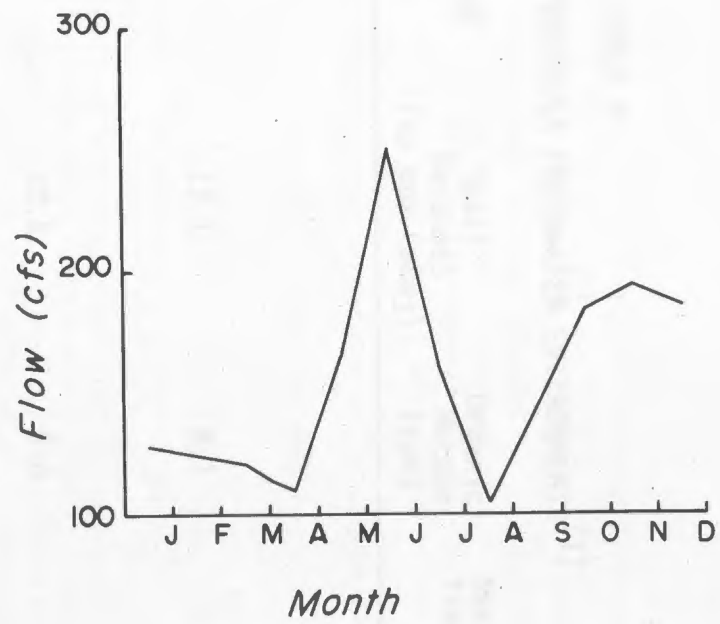


TABLE 3

WATER QUALITY IN TSIMPSEAN PENINSULA FRESHWATER ENVIRONMENTS(1)

	pH	Total Dissolved Solids (ppm)	Total Hardness (as ppm $CaCO_3$)	Organic Matter (ppm)	Secchi Disc Transparency (feet)
Stumaun Creek near mouth in West Fork 26 October 1974	5.3	14	12.1	8.1	
Stumaun Creek ½ mile upstream in West Fork 26 October 1974	6.2	34	12.5	9.8	
Neaxtoalk Outlet 100' below high tide line 25 October 1974	4.7	112	15.9	20.8	
Neaxtoalk Lake near outlet 25 October 1974	4.5	108	14.4	22.1	
Prudhomme Lake 17-20 July 1952*	6.47	41.6			11
Prudhomme Lake 26 July 1972*	5.5	17			10
Rainbow Lake 18 July 1952*		4			24

*B.C. Fish and Wildlife Branch, unpublished data.

(1) 1974 figures based on single samples, following rainfall of 25 inches during October (1inch/day).

Biological Characteristics: Aquatic invertebrate populations were sampled in Stumaun Creek and McNichol Creek during October 1974. In general the dominant taxonomic groups were stonefly *(Plecoptera)* nymphs and mayfly *(Ephemeroptera)* nymphs in Stumaun Creek. Caddisfly *(Tricoptera)* larvae were predominant in McNichol Creek. Stumaun Creek was found to contain more diverse invertebrate communities though they were less dense than those in McNichol Creek. Table 4 presents the details of the findings; methods are detailed in Annex C-1.

Fishes found in the streams of the Tsimpsean Peninsula include all five North American species of Pacific salmon. In addition, steelhead trout, rainbow trout, sea run and resident cutthroat trout, and Dolly Varden are found. Non sport species include the three spine stickleback, prickly sculpin and mountain whitefish. Two of the streams in the Tsimpsean Peninsula are among the 344 in British Columbia that contain 'major' runs of salmon *(Aro and Shepard, 1967)*. The Kloiya (Cloyah) River supports a major run of chinook salmon, while Diana Creek supports major runs of sockeye and coho salmon.

Five other streams in the Tsimpsean Peninsula support significant salmon runs. These are the Lachmach River, Silver Creek, McNichol Creek, Pearl Harbour (Lahon) Creek, and Stumaun Creek. Runs in these streams include chums, pinks, coho, and smaller numbers of chinook and sockeye. Species of recreational value include Dolly Varden and coastal cutthroat trout which inhabit most streams in the area. No freshwater fish sampling program was undertaken during the present study.

TABLE 4

SUMMARY OF BENTHIC FAUNAL CHARACTERISTICS OF TWO TSIMPSEAN PENINSULA STREAMS (3)

CHARACTERISTICS	STUMAUN CREEK 26 October 1974	McNICHOL CREEK 24 October 1974
Faunal density	8.6/sq. ft. 90.8/sq. m.	56.2/sq. ft. 593.5/sq. m.
Average number of taxa	6.0	6.8
Average DI_t [1]	4.56	2.4
Range of DI_t	3.3 to 5.76	0.45 to 3.71
Major Taxonomic groups represented:(4) -most abundant	Plecoptera (stonefly) nymphs	Trichoptera (caddisfly) larvae
	Ephemeroptera (mayfly) nymphs	
	Chironomidae (Midge) larvae & adults	Plecoptera (stonefly) nymphs
	Nematoda (roundworms)	Ephemeroptera (mayfly) nymphs
		Diptera (true flies[2]) larvae
	Diptera (true flies[2]) adults	
	Trichoptera (caddisfly) larvae	
	Pelecypoda (freshwater clam)	

[1] Sequential Comparison Index of Diversity - Cairns *et al* 1971

[2] excluding Chironomidae (Midge) larvae and adults.

[3] based on 5 square foot Surber samples at one station near the mouth of each stream.

[4] specimens preserved for possible future reference and identification.

C2.2 Estuarine/Marine Environments

Physical Characteristics: The predominant aquatic environment in the study region is Chatham Sound. The sound itself is essentially a large estuary whose surface circulation is determined primarily by the effluents from the Nass and Skeena Rivers. Water movements are also affected by the semi-diurnal mixed tides of Chatham Sound *(Trites, 1956)*. That is, there are two high tides and two low tides each day with no two being equal in height. The tidal amplitude is large, resulting in considerable daily movement of water to and from bays and inlets. The winds in the area affect the movements of surface waters as well.

Water circulation patterns in areas of large freshwater inflow are quite different from other coastal areas. The freshwater, which is less dense than sea water, remains at the surface in a layer of varying depth. Forced seaward by the continuing discharge, the fresh layer entrains the coastal seawater beneath it, and the mixed layer also moves seaward. The surface salinity increases as the water moves seaward and the mixing of salt and freshwater proceeds. To make up the volume of seawater removed by entrainment with the fresh layer, more sea water is drawn towards the river mouth from below the mixed zone. This is the classical salt wedge, most clearly seen in inlets receiving large rivers. Thus, salt water moves upward along the bottom towards the river mouth, and fresh and mixed water moves seaward in surface layers.

Prince Rupert Harbour does not receive effluents from any major rivers; consequently, it does not demonstrate the classical salt wedge circulation of coastal inlets. The situation is rather reversed, the surface salinity decreasing toward the mouth of the inlet, which receives sea water considerably diluted by the freshwater of the Skeena River. The layer of reduced salinity is generally less than ten meters deep. One effect of this stratified, highly stable regime is to suppress vertical mixing.

The transmissibility (clarity) of the brackish surface layer in Prince Rupert Harbour waters was less than ten per cent at the surface in October 1974; it was less than one per cent at stations near the mouth of the harbour. The deeper water was cleaner with transmissibility of about 50 per cent. Transmissibility data are shown in Annex C-3.

Data taken by *Waldichuk (1968)* demonstrate a north-south oscillation of currents in phase with the rise and fall of the tides in the mouth of Prince Rupert Harbour. Surface currents reached almost two knots while bottom currents were generally slower in late October 1964 (see Annex C-3).

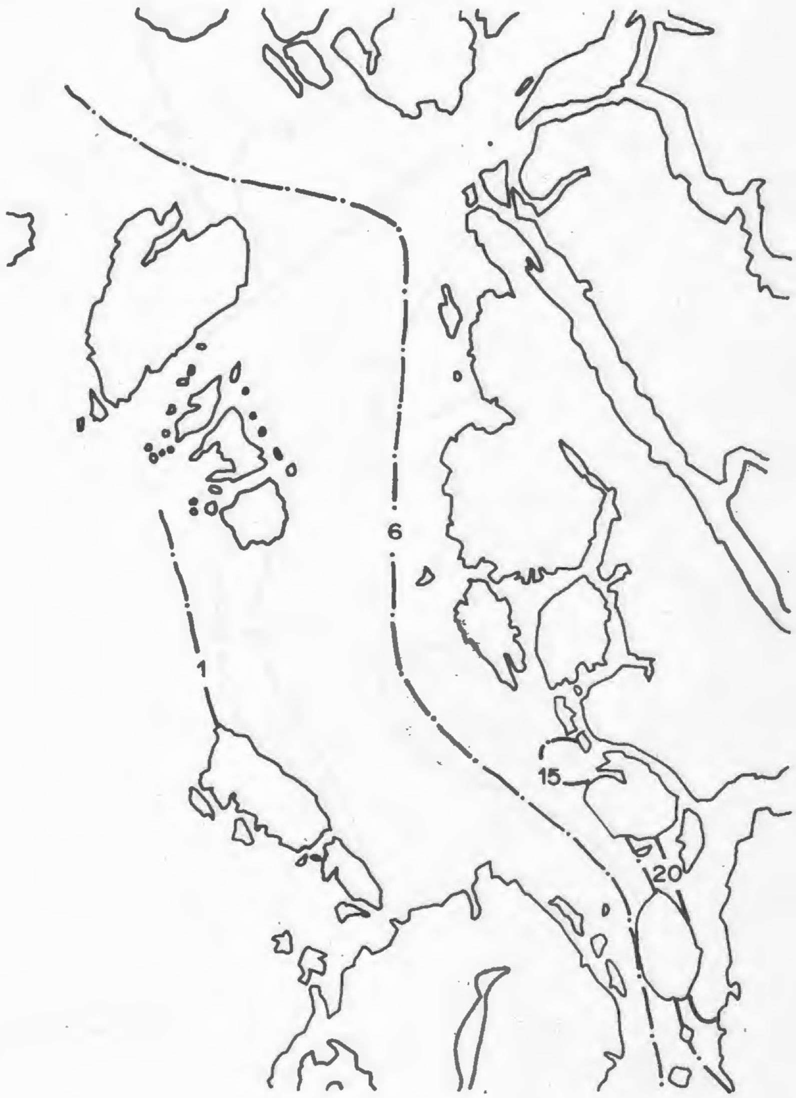
Concentrations of dissolved oxygen measured in October 1974 show that deeper waters of Prince Rupert Harbour are isolated from replenishment at the surface. Oxygen in the bottom waters declined from eight milligrams per litre to less than 6.5 milligrams per litre at the head of the Harbour. Results obtained by *Waldichuk (1968)* showed a similar distribution (see Annex C-3). These distributions appear to result from limited mixing, and may be related to rapid oxygen consumption, stagnation, or sluggish northward circulation at depth. Low levels of dissolved oxygen may also be associated with high turbidity which by shading reduces photosynthesis. The turbid estuarine surface layers also contain dilute organic wastes, and the consequent oxygen consumption by bacteria may significantly affect the isolated deeper layers.

The normal surface water currents in Chatham Sound have been outlined by *Trites (1956)* and *Cameron (1948)*. Under conditions of normal river discharge about 70 per cent of Skeena River water moves northward from the mouth of the river along the west side of Digby Island and the Tsimpsean Peninsula. Thus, the water mass along the west coast of the study area is formed in the Skeena estuary. This water flows northward until it merges with the Nass River effluent from Portland Inlet and flows to the sea north of Dundas Island. During normal conditions at least 70 per cent of the Skeena River discharge reaches the sea through Dundas Passage rather than through the central and southern passages. Current measurements taken on 24 August 1948, at a point in Chatham Sound near the entrance to Prince Rupert Harbour, showed that the average current at all depths was in a direction of 315° T (north-west), and ranged from 0.57 knots at the surface to 0.10 knots at a depth of 20 meters. These conditions are illustrated in Figure 17 based upon the work of *Cameron (1948)* and *Trites (1956)*.

This surface regulation pattern changes considerably during the freshet. The work of *Cameron (1948)* and *Trites (1956)* showed large concentrations of fresh water

Figure 17

FRESHWATER CONCENTRATION IN CHATHAM SOUND NORMAL CONDITIONS*

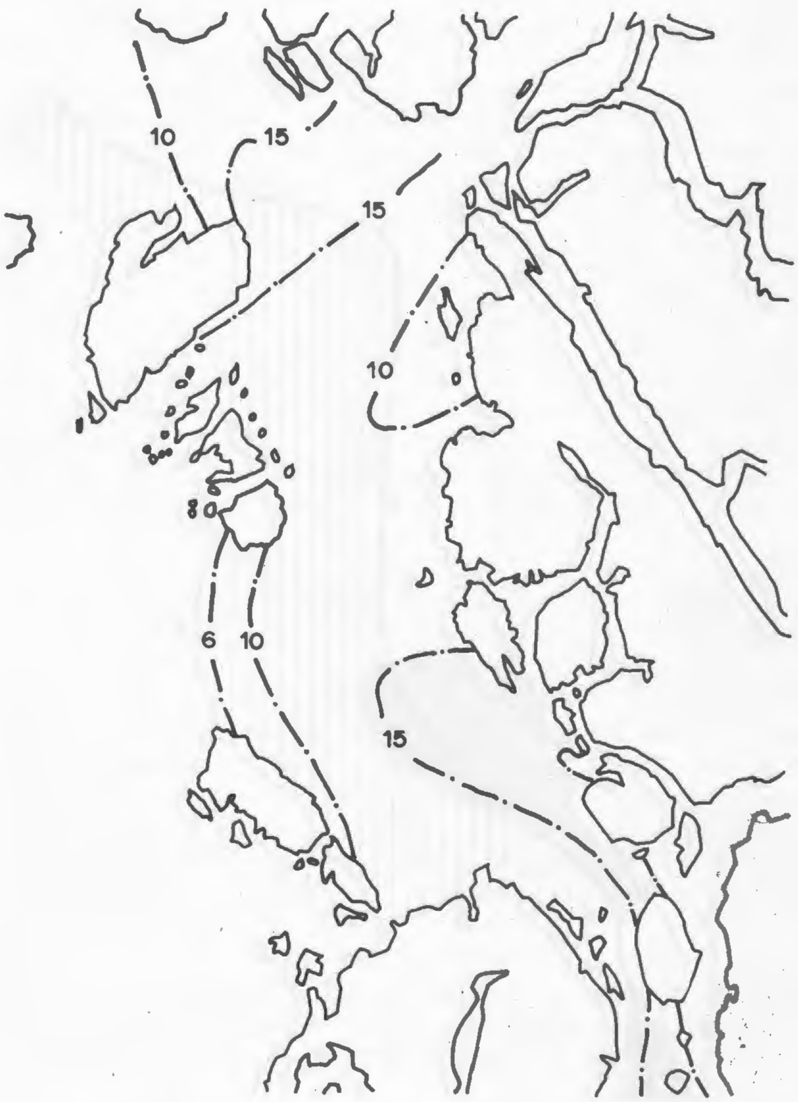


After Cameron (1948) and Trites (1956)

* Percentage freshwater in upper 60 feet

Figure 18

FRESHWATER CONCENTRATION IN CHATHAM SOUND FRESHET CONDITIONS*

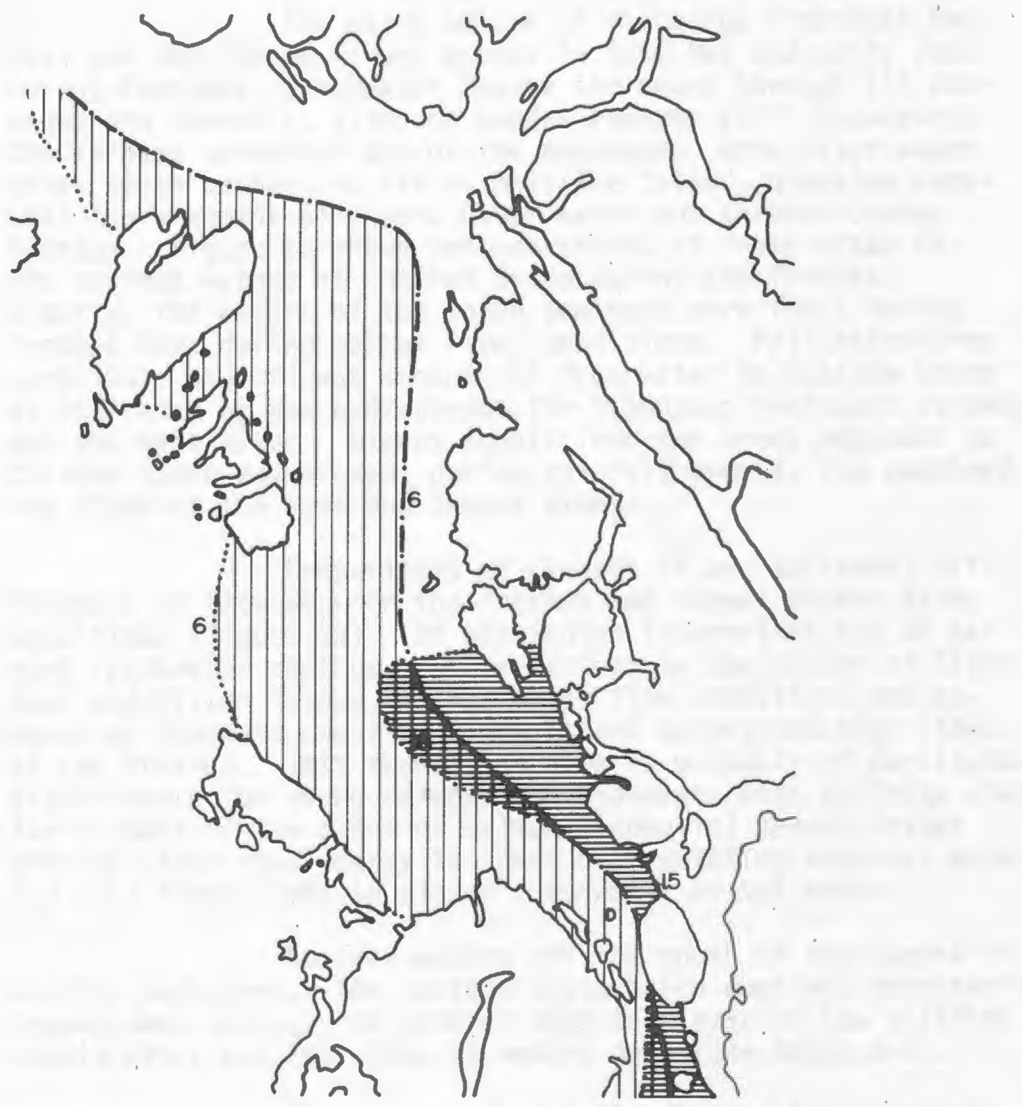


After Cameron (1948) and Trites (1956)

* Percentage freshwater in upper 60 feet

Figure 19

RANGE OF 6% AND 15% FRESHWATER CONCENTRATION CONTOURS



- ——·—— Location of concentration contour at normal flows
- ·········· Location of concentration contour at freshet flows
- (vertical hatching) Normal to freshet variation in 6% freshwater contour
- (horizontal hatching) Normal to freshet variation in 15% freshwater contour

throughout Chatham Sound following the peak discharges of the Nass and Skeena Rivers. Their work was carried out during 1948 when Skeena discharge was the highest on record.

The major volume of discharge from both the Nass and the Skeena Rivers occurs in late May and early June. During freshets, freshwater leaves the sound through all passages and channels, although Dundas Passage still transports the largest amount of any of the passages. Nass River water moves south perhaps as far as Melville Island, blocking somewhat the movement of Skeena River water out through Dundas Passage. Figure 18 shows concentrations of fresh water in the surface waters of Chatham Sound during the freshet. Clearly, the waters of the sound are much more fresh during freshet than during normal river conditions. Fall rainstorms contribute significant amounts of freshwater to Chatham Sound as indicated by the hydrographs for Tsimpsean Peninsula streams and the Nass River. Direct runoff from the areas adjacent to Chatham Sound may exceed, during rainfall events, the combined low flows of the Nass and Skeena Rivers.

Comparisons of Figures 17 and 18 reveal differences in flow between the freshet and normal Skeena River conditions (Figure 19). Of particular interest is the 15 per cent freshwater contour. It is evident in the region of Flora Bank and Kitson Island during normal flow conditions and expands up the west coast of Digby Island during the high flows of the freshet. This transition area is probably of particular significance for young salmon: environments with salinity similar to that of the blood of salmon (isomotic) permit faster growths since less energy is spent on regulating internal water and salt levels than in either freshwater or sea water.

Surface waters off the mouth of the Skeena are visibly turbulent. The surface disturbance does not necessarily induce deep mixing. In October 1974 the layer of low salinity turbid water was less than 15 meters deep (see Annex C-3).

The waters of Port Simpson are less strongly influenced by the Skeena outflows. Average surface salinity on November 6, 1974 was 27.0 parts per thousand at Port Simpson by comparison with 19.1 parts per thousand in Prince Rupert one week earlier. Port Simpson waters were clearer than those of the Prince Rupert area, showing a uniform transmissibility of 48 per cent from the surface to 30 meters and a slight increase below that depth (see Annex C-3).

Currents in the Port Simpson area were weak and highly variable in direction during early November 1974 (see Annex C-3). Velocities were less than one-half of one knot in contrast to the stronger currents observed by *Waldichuk (1968)* in Prince Rupert Harbour. This difference is attributable to the length of Prince Rupert Harbour in relation to the size of the mouth.

Biological Characteristics: The mixing of freshwater inflow from rivers with the saline coastal seawater produces a set of conditions that are unusually rich in nutrients yet lethal to most marine and freshwater organisms. Relatively few organisms are adapted to the wide ranges of salinity found in estuaries, but those that do survive are usually abundant.

Secondary production in estuaries is based more on detritus food chains than on grazing food chains. Most detritus is derived from living vegetation in the estuary, with significant input from plant and animal material carried in by fresh water runoff, and from the death of organisms meeting the hostile physiological environment of the estuary. Bacteria-rich detritus formed in estuaries is a nutritionally better food source for animals than the live plant tissue *(Darnell, 1967)*. Sea water entrained from below the euphotic zone contains unutilized nutrients and undecayed seston, the slowly sinking remains of phytoplankton and zooplankton feces.

Primary production in large estuaries is enhanced by high nutrient levels, but limited by reduced light due to turbidity. As the freshwater layer moves seaward the fines begin to settle out, and become mixed with clear sea water, resulting in increasing clarity (as indicated by transmissibility) and more favourable conditions for phytoplankton and attached plants. The sea contributes the majority of nutrients in the salt wedge countercurrents from below the euphotic zone. Additional nutrients, notably inorganic phosphate, are carried into the estuary in runoff. A biochemical cycle is completed with the return of surface organic wastes to the benthos. Nutrients become trapped, mixed and concentrated. This relatively rapid cycling of biological and chemical resources contributes to an overall high level of productivity.

The following sections outline the pelagic, benthic, subtidal and intertidal flora and fauna of Chatham Sound and the areas of potential port development.

Pelagic Environments: zooplankton: Zooplankton are important to the marine trophic web in two ways. By vertical migrations and the encapsulation of phytoplankton remains into faster-sinking fecal pellets they provide an energy pathway between primary production in surface waters and the benthos. Zooplanktivorous fishes such as herring and some salmon utilize this resource directly.

In this study zooplankton tows were taken at each of the ten deep stations in Prince Rupert Harbour and Port Simpson Harbour. The results are shown in condensed form in Table 4a. The species assemblage is typical of that to be expected in British Columbian neritic marine areas. Copepods dominate the fauna by numbers, but at many stations the larger crustacea, the euphausids, mysids, and amphipods, were dominant by biomass. The large numbers of subadult copepods represent the proportion of the population which will overwinter in an advanced juvenile stage to mature sexually in the spring.

Because the zooplankton are transported horizontally by currents, their distribution can change rapidly with time. More extensive sampling over time would be required to form a statistically valid comparison between sites. However, the euphausid *Euphausia pacifica,* which is a large and important member of this community, appears more abundant toward the head of Prince Rupert Harbour than at the more seaward locations.

Benthic Environments: For the purposes of comparison between sites and convenience of discussion, benthic environments were distinguished from subtidal environments by depth of samples. Benthic samples were taken at depths of about 50 meters in the deepest parts of the two areas studied, except one very deep dample at 128 M.

Benthic organisms are particularly important in nutrient cycles in estuaries. They usually form the bulk of the biomass of estuarine communities, and, more than the free-swimming organisms, the benthos must survive the extreme variations in salinity, temperature and turbidity that occur in estuaries. Plants and animals that have adapted to these conditions constitute a specialized estuarine assemblage, typically low in diversity and high in productivity.

TABLE 4a

SUMMARY OF PLANKTON DENSITIES, OCTOBER-NOVEMBER, 1974,
in numbers per cubic meter

	P0	P1	P2	P3	P4	P5	P7	S1	S2	S3
Copepoda:										
Calanus adult	-	0.9	0.6	-	0.2	-	-	-	0.1	-
subadult	10.1	2.7	0.3	1.6	1.0	2.0	1.7	3.6	1.5	3.0
Metridia adult	1.5	1.4	-	-	-	1.5	-	0.7	-	1.0
subadult	46.2	6.8	2.4	4.2	2.0	5.1	4.3	9.0	2.5	7.4
Pseudocalanus adult	3,8	11.3	6.1	21.2	14.1	27.1	21.3	22.7	15.9	18.2
subadult	23.1	7.7	4.2	12.2	4.0	9.2	10.7	10.4	8.9	10.3
Acartia adult	6.2	6.8	5.5	15.8	21.6	-	29.9	38.5	42.2	27.0
subadult	3.8	6.8	1.5	10.6	6.0	-	10.2	9.0	13.9	7.4
Tortanus adult	0.5	-	-	-	0.5	-	-	-	-	-
subadult	0.5	-	-	-	-	1.5	-	-	-	-
Other species adult	2.4	0.9	0.6	2.6	2.0	4.1	3.9	3.6	-	1.5
subadult	3.8	1.8	0.6	2.6	1.0	2.5	2.1	1.1	3.0	1.0
Euphausiacea:										
Euphausia >1.5 cm	0.4	1.5	0.04	-	-	-	-	-	-	-
<1.5 cm	-	2.0	5.2	1.0	0.5	-	-	0.4	-	-
Mysidacea	0.2	0.1	0.04	-	0.03	-	0.7	-	-	0.1
Amphipoda	0.6	0.3	0.04	-	-	0.1	0.3	0.5	0.1	0.1
Chaetognatha *Sagitta elegans*	1.7	0.6	0.08	0.4	0.2	0.3	0.7	0.7	0.6	0.5
Ctenophora *Pleurobrachia bachei*	1.1	-	-	0.1	0.2	-	0.3	-	0.1	-
Medusae	-	-	-	-	-	-	0.05	-	-	-

Samples were oblique hauls of a 30.75 m diameter net of 333 μ nylon mesh.

The deeper series of samples in this study were taken from ten stations on the floors of Prince Rupert Harbour and Port Simpson Harbour with a 0.052 m^2 Ponar Grab. The samples were taken at depths ranging from 45 to 53 m, with one sample from 128 m. Most sediments were in the Wentworth size class of very fine silt, and were moderately well-sorted. The two exceptions, stations at the seaward end of Prince Rupert Harbour, had coarse, poorly sorted substrates (see Annex C-3). Benthic photography transects were taken across selected deepwater areas. The images are not sufficiently high in contrast or graphic clarity to include in the report but are stored for possible future reference.

The benthic fauna found in the Prince Rupert and Port Simpson areas was typical of the southern British Columbia inlet trough fauna (see *Ellis 1970*). Communities are dominated by bivalve molluscs and errantiate polychaete worms. Table 5 shows that the samples contained between five and 28 species of infauna with total numbers of organisms varying from ten to 91 per grab. The average number of species per sample for Prince Rupert Harbour was 17 while that for Port Simpson was 11. The diversity index (H) is a measure derived from information theory describing the variety of organisms in a community. High diversity within a homogeneous substrate results from stable conditions, while low diversity results from a fluctuating environment, which may be natural or the result of human activities.

The stations in Prince Rupert Harbour which had well-sorted silt substrates had faunal diversities ranging from 0.84 to 0.89. The values for Stations P3 and P4 are divergent. Station P4 had an elevated diversity of 1.12. This result can be related to the fact that the substrate was heterogeneous, and thus offered several microhabitats. The sorting coefficient was high as the result of the presence of gravel and small cobbles along with silt. Bottom photographs revealed that some of the cobbles were exposed, probably as a result of tidal currents, offering a special habitat for sessile species. Station P3 also offered a coarse substrate, but in this case the larger particles were an unconsolidated litter of broken shells. This instability apparently discouraged several species.

Diversity, number of species, and weight of animals were also lower in Port Simpson Harbour relative to Prince Rupert Harbour. A number of species common in Prince Rupert Harbour did not occur at all in the deep samples from

Port Simpson Harbour. The reason for this difference is not apparent from the limited data. It may be related to the delivery of inorganic nutrients, detritus, and dissolved organic matter by the Skeena River to the surface waters of Prince Rupert Harbour.

Subtidal Environments: Subtidal environments are defined for comparative purposes as the shallow bottom areas between the lowest tide line and the deeper benthic troughs. These areas include the deeper mud and sand flats and the steep subtidal shores. Subtidal organisms, as described for the deeper benthos, must be adapated to the physiological stresses imposed by their situation since they are unable to escape unfavourable conditions.

Subtidal environments were sampled with a variety of gear including the Ponar Grab and beach seines. Stations at DeHorsey Bank, Flora Bank, Ridley Island, Melville Cove, Bacon Cove, Osborne Cove, and Stumaun Bay were sampled with Ponar Grabs. These stations were at depths ranging from seven to 13 meters. The results are summarized in Table 5.

In general, the fauna taken at these stations were typical of shallow water marine faunas found in inlets in southern British Columbia *(Ellis 1970)*. Highest diversity of invertebrates was found at Ridley Island which also had the highest number of species. Ridley Island is situated in an area of immediate estuarine influence and the mixing processes and resultant nutrient inflows are expected to have greater effect on species diversity than at other marine locations.

Stumaun Bay had the second highest diversity and abundance of species. This location may be representative of the communities found in eelgrass beds between Venn Passage and Port Simpson; the eelgrass may function as an indicator of the physical habitat in which these diverse communities occur, or may create the habitat itself. The eelgrass provides cover and food for a variety of juvenile fish and crabs.

The DeHorsey Bank and Flora Bank samples were unique in the unusually high abundance of the small bivalve *Transennella tantilla*. This small slam appears to be characteristic of the fauna of the sandy banks and is associated with *Clinocardium californiesense*, a cockle, and the small tellen *Tellina nuculoides* at Flora Bank. Also associated with *Transennella* at DeHorsey Bank is the errant polychaete *Nephtys punctata*.

TABLE 5

SUMMARY OF BENTHIC RESULTS

Approximate Location	Prince Rupert Harbour Inner					Prince Rupert Harbour Outer		Port Simpson			Stumaun Bay
STATION (see Annex C-3)	PO	P1	P2	P3	P4	P5	P7	S1	S2	S3	St
Depth, m	53	47	45	46	47	47	45	128	48	45	7
Number of animals	49	48	58	48	91	27	39	10	44	30	88
Number of species	16	17	19	12	28	14	15	5	12	10	17
Total Weight	22.53	52.38	34.05	14.05	24.59	22.80	9.92	34.09	195.02	186.24	5.11
Weight animals<4 g	4.55	8.26	7.15	9.28	14.70	3.85	5.22	5.99	4.01	3.44	5.11
Diversity (H)	0.859	0.838	0.878	0.805	1.123	0.852	0.889	0.418	0.738	0.712	1.003
Median substrate size mm	0.0061	0.0056	0.0067	0.026	0.012	0.0050	0.0052	0.0078	0.0097	0.019	0.31
Sorting coefficient	9	8	7	69	114	7	9	6	5	9	3

TABLE 5 - Continued

Approximate Location	Dehorsey Bank	Flora Bank	Ridley Island	Melville Arm	Bacon Cove	Osborne Cove
STATION (see Annex C-3)	Ho	Fl	Ri	Me	Ba	Os
Depth	8m	8.5	13m	8.5	?	9
Number of animals	626	737	112	140	74	37
Number of species	12	16	20	11	9	7
Total Weight	7.45	6.45	72.37	3.52	2.19	3.47
Weight of animals < 4 g	7.45	6.45	4.23	3.52	2.19	3.47
Diversity (H)	0.174	0.185	1.056	0.559	0.514	0.469
Median substrate size mm	0.020	0.032	0.011	0.068	0.09	0.10
Sorting coefficient	17	14	12	3	17	6

Samples taken in 0.052 square meter Ponar Grab, October-November, 1974.

At two locations in Prince Rupert Harbour there was evidence of damage to the shallow subtidal fauna from log booming. At Bacon Cove the sample contained wood debris and diversity was low. At Osborne Cove wood debris was very abundant, the sediment smelled strongly of H_2S, and diversity was still lower. The errant polychaete *Ammotrypane aulogaster* appeared to be a biological indicator of this disturbance.

Beach seine samples taken in subtidal areas at four locations indicate that Ridley Island has more abundant and diverse populations of small fish (except herring) than any other site. The greatest weight and greatest number of species were captured at this site, though few of the species in this or any haul are presently fished commercially. Notable at the Ridley site was a very large catch of gammarid amphipods *(Anisogammarus confervicolus)*, which apparently thrives in the receiving waters of pulp mill wastes *(Levings, pers. comm.)*.

Starry flounders *Platichthys stellatus* and staghorn sculpins *Leptocottus armatus* were taken at all beach seining sites (see Annex C-3). Preliminary examination of the stomach contents of these species indicates that the starry flounder consumes mostly errant polychaetes and bivalves, while the staghorn sculpin apparently preys on large numbers of decapods, especially crabs.

At the Pike Island seine site in Venn Passage, a large number (400-500) of juvenile herring were captured. This indicates that this shallow protected area is used by herring as a rearing ground. Additional sampling would be required to verify this suggestion.

The Port Simpson seine haul taken near the proposed port location did not indicate a diverse or abundant fish population. Starry flounder was the second most common species after *Cymatogastris aggregata*, the yellow shiner or shiner sea perch. Eight Dungeness crabs *(Cancer magister)* were also captured. Unfortunately, no beach seining was realized in the eelgrass community in Stumaun Bay.

Intertidal Environment: There are a variety of intertidal environments within the study area ranging from rocky shores through cobbles and sand to mud flats. Rocky shores are characteristic of much of the shoreline of the study area.

TABLE 6

BEACH SEINE HAULS

OCTOBER 29 - NOVEMBER 6, 1974

INVERTEBRATE AND FISH SPECIES	Casey Cove	Pike Island	Port Simpson	Ridley Island
PHYLUM ARTHROPODA				
Order Amphipoda:				
Anisoammarus (confervicolus?)	X			X
Order Isopoda:				
Idothea wosensenski	X			X
Order Decapoda:				
Pandalus danae				
Crago alaskensis	X		X	X
Crago franciscorum	X		X	X
Cancer magister		1	8	4
Order Mysidacea:				
mysid A	X		X	
PHYLUM ANNULATA				
Order Polychaeta:				
Hesperonoe sp.	X			
PHYLUM MOLLUSCA				
Class Gastropoda				
Lacuna marmorata				X
FAMILY CLUPEIDAE (herring)				
Clupea harengus pallasi	15			43
Clupea harengus pallasi (juvenile)		400-500		
FAMILY SALMONOIDEA (salmons)				
Onchrhynchus keta (juvenile) 'chum salmon'				1
Salvelinus malma - 'Dolly Varden"		1		
FAMILY OSMERIDAE (smelts)				
Hypomesus pretiosus pretiosus				1

X = Present

TABLE 6 continued.

FISH SPECIES	Casey Cove	Pike Island	Port Simpson	Ridley Island
FAMILY GADIDAE (cods)				
Gadus macrocephalus			3	
Thragra chalcogramma			1	3
FAMILY PLEURONECTIDAE (flounder)				
Isopsetta ischrya			14	
Parophys vetulus				64
Platichthys stellatus	13	20	18	7
FAMILY EMBIOTOCIDAE (sea perches)				
Cymatogaster aggregata	1		13	25
FAMILY TRICHODONTIDAE (sand fishes)				
Trichodon trichodon		3		
FAMILY COTTIDAE (sculpins)				
Agonis acipenserinus				3
Blepsias cirrhosus				3
Clinocottus acuticeps	1			4
Clinocottus embryum		1		
Enophrys bison			5	15
Leptocottus armatus	26	16	12	28
FAMILY LIPARIDAE (snailfish)				
Careproctus melanurus				17
Liparis fucensis				5
FAMILY GASTEROSTEIDAE (sticklebacks)				
Gasterosteus aculeatus		1		4
FAMILY AULORHYNCHIDAE (tube snouts)				
Aulorhynchus flavidus	36			25

Mixed cobbles and sand were found on Fairview Point, Frederick Point, and parts of Venn Passage. Stumaun Bay also has some of this unstable substrate. Sand flats are found in large areas of Duncan Bay, Big Bay, Venn Passage and Stumaun Bay. Smaller areas of sand flats are found in coves such as Melville Arm, Bacon Cove and Osborne Cove. Small areas of intertidal mud flats are also associated with the sand flats in protected places such as Melville Arm and Venn Passage.

Substrate characteristics, along with salinity regimes and exposure to surf, are the dominant physical parameters that define intertidal habitats and have a determining effect on species diversity. Diversity and biomass were highest on fissured bedrock, and lowest on sand and loose cobbles which provide no secure attachment. The salinity fluctuations and sediment load imposed on the Prince Rupert shore may account for its general poverty relative to Port Simpson.

The intertidal areas of Ridley Island, Flora Bank and the outer coast of Digby Island and the Tsimpsean Peninsula were photographed from the air in colour in September 1974. By reference to this and other available aerial photography, a preliminary distribution map for eelgrass (*Zostera* sp.) beds was produced and is stored for possible future reference.

Intertidal communities in the vicinity of the initial port site alternatives were sampled in October and November of 1974. The intertidal environments were sampled with one square meter quadrats which were placed on a transect up the intertidal zone and organisms within the transect identified and counted. These data are presented in detail in Annex C-3 to this report. Each transect was photographed in colour and catalogued for possible future reference.

A summary of intertidal fauna by sampling site is presented in Table 7 and by tidal zone in Table 9. The sites showing the greatest number of species were Bacon Cove with the most species, followed by Ridley Island and Port Simpson. These sites also had similar substrates--boulders and bedrock.

There are several intertidal areas in the Prince Rupert Area which have been apparently damaged by pollution *(Drinnan, 1974)*. These are, in approximate order of damage, Wainright Basin, Porpoise Harbour, the northern tip of Ridley Island and the foreshore of the city of Prince Rupert. The damaged area on Ridley Island was not included in the site examined in this study.

TABLE 7.

INTERTIDAL FAUNA	OSBORNE COVE (1)	PETHICK POINT	BACON COVE	MELVILLE ARM	FAIRVIEW POINT	FREDERICK POINT (1)	RIDLEY ISLAND	PORT SIMPSON
PHYLUM PORIFERA								
Halichondria sp.(?)	52.5%		+	+			8.0%	
PHYLUM ARTHROPODA								
ORDER THORACIA:								
Balanus spp. (2)	63.0%	25.0%	16.0%	475	10.0%	10.0%	25.0%	9.0%
ORDER ISOPODA:								
Ligia (?)			+	17		46		7
Idothea sp.			+					
Cirolina kinkaidi	20	3	5.5					
ORDER AMPHIPODA:								
Orchestia sp.			3					
Orchestia (?)	30			100	3	219	67	43
ORDER DECAPODA:								
Archaeomysis sp. (?) (mysid)			3					
Hemigrapsis sp.			5	17				10
Pagurus	15	3	9	5	10	33	12	168
Callianassa californiensis			+					
PHYLUM MOLLUSCA								
CLASS AMPHINEURA:								
Katarina tunicata			+				5	3
Tonicella lineata			17				7	3
Mopalia hindsi							7	
CLASS GASTROPODA:								
Acmaea pelta	88				27		10	
Acmaea scutum		60	24	20	3	5	20	18
Acmaea persona				84				7
Acmaea digitalis	15	89	22			56	9	14
Acmaea sp. (juvenile)		120						
Thais lamellosa		3	+				3	
Thais emarginata			+	7		8		3
Thais lamellosa (+ T. emarginata)		227						
Searlsia dira			7					
Littorina spp.	100			34	13	527	137	342
Littorina sitkana	333	77	51		18		53	
Ceratostoma sp.					16			
CLASS PELECYPODA:								
Mytilus edulis	225	90	78	3	150	137	19	61
Mya arenaria			+					
Protothaca staminea			+		+			
Saxidomuis sp.					+			
Clinocardium nikalli			+					
Macoma nasuta			+					
PHYLUM ECHINODERMATA:								
CLASS ASTEROIDEA:								
Pisaster ochraceous			+					
Evasterias troschelli			+				3	
CLASS ECHINOIDEA:								
Strongylocentrotus droebachiensis			3					
PHYLUM ANNELIDA								
CLASS CHAETOPODA								
ORDER POLYCHAETA:								
Terrebellid worm							3	
Sabellida worm							20	
Errant Polychaete			13			5		
PHYLUM NEMERTEA								
Nemertean worm					3			
PHYLUM CHORDATA								
Goby						5		7
NUMBER OF SPECIES	10	10	27	11	12	11	17	14

(1) = figures represent mean of numbers for upper and intermediate tidal zones for this station; lowest intertidal zone not inspected

(2) = % coverage on square meter quadrants.

\+ = presence only recorded.

Data collected October-November 1974

The intertidal fauna is generally similar to the communities found in similar habitats in Georgia Strait. Species found to be characteristic of all sites are indicative of moderate surf exposure and are described as follows: *Balanus* sp. (barnacle), the amphipod *Orchestia* sp., *Pagurus* sp. the hermit crab, the limpets *Acmaea digitalis* and *A. scutum*, the periwinkle, *Littorina* sp. and the mussel, *Mytilus edulis*.

A summary of the flora listed from the intertidal transects is presented in Table 8. The most dense algal cover was encountered at Osborne Cove, followed by Port Simpson. Algae in greatest abundance for all sites were *Ulva* sp., the green sea lettuce, the red algae *Endocladia muricata* and *Gigartina* sp., the brown alga *Fucus gardneri*. Surf grass *(Phyllospadix scouleri)* was encountered in low densities at several protected areas in Prince Rupert Harbour. Eelgrass (*Zostera* sp.) was not found in any intertidal transects; the eelgrass community was sampled with a benthic grab.

The dense algal cover at Ridley Island consists largely of the favoured species for the green sea urchin *(Strongylocentrotus droebachiensis)*, which is absent from the site. The Bacon Cove site contained green sea urchins and much less of the preferred algae. There is some suggestion, therefore, that the sea urchin is intolerant of the conditions at Ridley Island.

The greatest densities of eelgrass (from airphotos) were found on the large sand flats at Duncan Bay, Big Bay, Venn Passage and Stumaun Bay. Eelgrass are of particular significance for salmon and the marine fishes. Herring spawn deposited on eelgrass has a greater survival rate than that deposited on other substrates *(Outram, 1957)*. Juvenile salmon find protective cover and abundant forage in the eelgrass beds. The eelgrass contributes large quantities of exceptionally rich material to the detritus food chain (bacteria - amphipods - salmon).

The relative importance of *Fucus* sp., *Laminaria* spp., *Zostera* and *Phyllospadix* populations in modifying intertidal habitats must be related to the physical conditions in any location, including the height in the intertidal zone, substrate character, and exposure to sun and surf. By modifying the effects of one or more of these parameters, the plant growth provides stability and food for a faunal assemblage much richer than possible without revegetation.

On rocky shores, the *Laminaria* holdfast provides protection for a large number of invertebrate species from both wave shock and predation. Also on rocky shores, *Phyllospadix* plays a smaller role in habitat differentiation, through rhizome growth in crevices.

Grazing and attachment areas are extended by vertical growth of sea grasses (up to 10 feet in depth) and *Laminarian* (to nine feet in length and a foot or more in width).

In habitats of high wave exposure, forests of *Phyllospadix* and *Laminaria* decrease wave shock, while in protected mud-sand bays, *Zostera* cover provides extensive protection from dessication. On mid to high intertidal rocky shores, the effectiveness of *Fucus* cover in preventing dessication is limited.

Of all four groups, *Zostera* probably plays the most important role in habitat modification by consolidating sand and mud into a stable substrate through extensive rhizome growth.

TABLE 8.

INTERTIDAL FLORA	OSBORNE COVE		BACON COVE		FAIRVIEW POINT		RIDLEY ISLAND		PETHICK POINT	MELVILLE ARM	FREDERICK POINT	PORT SIMPSON
ANTHOPHYTA:												
Phyllospadix scouleri			+									
CHLOROPHYCEAE:												
Enteromorpha compressa						*						
Enteromorpha intestinalis v. Clindracea						*						
Nostroma fuscum		*										
Spongomorpha coalita		*			8%							
Spongomorpha saratilis						*						
Ulva fenestrata				*		*						
Ulva rigida								*				
Ulva scagelii				*		*						
Ulva (Monostroma?)			3%		3%					2%		2%
Green slime alga											+	
Fresh water Chlorophyta												3%
RHODOPHYCEAE:												
Callithamnion bisporum or C. biseriatum		*										
Cryptosiphonia woodii		*							3%			
Dilsea californica		*						*				
Endocladia muricata									15%	10%	5%	20%
Gelidium sp.												4%
Gigartina sp.			17%		8%		7%			13%	5%	3%
Gigartina papillata		*		*				*				
Iridaea cordata			+									
Lithothamnion sp.			2%				30%					9%
Nicrocladia borealis								*				
Odonthalia floccosa		*						*				
Polysiphonia hendryi		*										
Polysiphonia pacifica						*						
Porphura miniata				*								
Prionitis lanceolata									3%			
Pterosiphonia bipinnata		*										
Ptilota tenuis								*				
Ralfsia sp.			+						+	6%	6%	8%
Rhodoglossum affine						*		*				
Rhodoglossum rossum		*						*				
Rhodomela larix								*				
Rhodymenia palmata		*										
Rhycodrye setchellii								*				
PHAEOPHYCEAE:												
Alaria sp.						*	17%					
Alaria margineta		*		*		*		*				
Fucus distichus		*		*		*		*				
Fucus gardneri	84%		20%		8%		15%		8%	18%	20%	21%
Halosaccion glandiforme												3%
Laminaria sp.			+				17%					
Laminaria groelandica								*				
Laminaria saccharina		*										
MISCELLANEOUS:												
Algae C (unidentified)					27%							
Moss												3%
Phyllospadix scouleri (eel grass)			+									
Verrucaria sp. (lichen)					3%		15%					
Lichen (unknown)										+		
Terrestrial grass												7%
NUMBER OF SPECIES	1	14	8	6	6	10	6	13	4	7	5	11

\+ (= presence of species), percent substrate covered, and density per square meter along transects in October and November, 1974.

* = presence of species recorded by Drinnan, summer of 1974.

NEAT

TABLE 9

OCCURRENCE BY TOTAL NUMBERS FROM ALL SITES IN THREE TIDAL ZONES	LOWER	INTERMEDIATE	UPPER
PHYLUM PORIFERA			
Halichondria sp. (?)	*	*	
PHYLUM ARTHROPODA			
ORDER THORACIA:			
Balanus spp.	*	*	*
ORDER ISOPODA:			
Ligia (?)	4	11	16
Idothea sp.		+	
Cirolina kinkaidi	1	5	4
ORDER AMPHIPODA:			
Orchestia sp.	3		
Orchestia (?)	82	40	102
ORDER DECAPODA:			
Archaeomysis sp. (?) (mysid)	1		
Hemigrapsis sp.	2	4	5
Pagurus	96	109	21
Callianassa californiensis	+		
PHYLUM MOLLUSCA			
CLASS AMPHINEURA:			
Katarina tunicata	1	3	
Tonicella lineata	15	3	
Mopalia hindsi	1	1	
CLASS GASTROPODA:			
Acmaea pelta		74	62
Acmaea scutum	11	70	22
Acmaea persona		7	91
Acmaea digitalis	1	53	119
Acmaea sp. (juvenile)	30	6	
Thais lamellosa	+		1
Thais emarginata	2	6	
Thais lamellosa (+ T. emarginata)	67	1	
Searlsia dira	2	1	
Littorina spp.	96	1235	837
Littorina sitkana		22	318
Ceratostoma sp.	5		

NEAT

	LOWER	INTERMEDIATE	UPPER
LASS PELECYPODA:			
Mytilus edulis		356	138
Mya arenaria	+		
Protothaca staminea	+		
Saxidomuis sp.	+		
Clinocardium nikalli	+		
Macoma nasuta	+		
LUM ECHINODERMA			
LASS ASTEROIDEA:			
Pisaster ochraceous	+		
Evasterias troschelli	+		
LASS ECHINOIDEA:			
Strongylocentrotus droebachiensis	1		
LUM ANNULATA			
LASS CHAETOPODA			
ORDER POLYCHAETA:			
Terrebellid worm		1	
Sabellida worm		6	
Errant Polychaete	4	1	
LUM NEMERTEA			
Nemertean worm	1		
LUM CHORDATA			
Goby		2	1

+ indicates occurrence only

* very frequent; given as % cover in transect data

Data collected October-November 1974

CHAPTER C-3

C3.0 THE SITES

C3.1 Port Simpson

C3.1.1 Freshwater Environments

Locating the bulk facility at Port Simpson will result in direct effects on more watersheds than any of the ten sites considered in the Phase I study. The port site itself will be adjacent to Neaxtoalk Lake, and both road and rail access will cross the short outlet stream. Road access to this site will involve the Stumaun Creek, Georgetown Lake and Pearl Harbour Creek systems and possibly the McNichol Creek drainage. Rail access to the Port Simpson site will run through the Neaxtoalk Lake drainage, cross a number of small streams along Work Channel, and parallel the Lachmach River, crossing it several times.

Neaxtoalk Lake: In the immediate vicinity of the port site, the Neaxtoalk Lake drainage contains a diverse biological community, resulting from an unusual hydrological situation. The 'normal' lake surface elevation is at or just below the highest tide level. The outlet stream runs through a narrow canyon for approximately 200 feet to the beach. Very high tides, and high rates of precipitation and runoff, acting singly or in combination, result in periodic short-term rises in water level. Fluctuations indicated by recent drift and the edge of the cedar-hemlock forest amount to three to four feet.

Water level fluctuation apparently inhibits muskeg formation. Instead, accumulated organic material, much of which may be swept into the lake from Port Simpson Bay during storms at high tides, becomes compacted. Approximately 95 per cent of the lake shoreline consists of this compacted organic material. The west end has rugged bedrock shores on each side of the outlet.

Substrates in the two tributary streams are mainly organic, peat and wood accumulation from beaver activity, with small amounts of sand and gravel. Both tributaries have banks approximately twice as high as the streams are wide, composed of water-deposited organic materials in natural levees.

The growth of the levees is accelerated by beavers damming the stream mouths to a level above that of the lake's highest levels. This kills segments of the surrounding forest and promotes muskeg growth in the areas 'stabilized' at a high water level by the dams. This in turn increases the amount of organic material being carried into the lake and being deposited on the organic levees and beaches.

The 200 foot long outlet stream runs through bedrock in an incised ravine. The substrate consists of flat slabs of soft shaly rock covered with thick periphyton growth, interspersed with sills of bedrock. There is no gravel in the outlet, and the intertidal stream is quite steep and short. The channel is braided between stable grassy banks and large boulders.

Neaxtoalk Lake had a pH of 4.5 in October 1974, a rather acid concentration (see Table 3). At the time of the survey, following record rainfalls, organic content was 22.1 parts per million. Total hardness was 14.4 ppm., and total dissolved solids concentration was 108 ppm. The presence of widgeon grass near the outlet indicates at least periodic brackish water conditions.

Plant communities in Neaxtoalk Lake are unlike any others in the Tsimpsean Peninsula. Submergent vegetation is abundant, heavily grazed by migrating waterfowl and muskrats, and occurs over a wide littoral zone. Emergent aquatics include bullrush on shoals in the lake center, and several species of (freshwater) marsh grasses on a wide beach which gradually flattens out away from shore, fading into muskeg 100 to 300 feet from the lake.

Due to the small drainage basin and the organic/bedrock surrounding terrain, Neaxtoalk Lake appears to have a limited capacity for fish production. In many ways the lake resembles an inland 'pothole' lake. A population of trout is reported there. Since this population has no apparent spawning grounds in the system, recruitment may come via Port Simpson Bay from Stumaun Creek or coastal streams elsewhere. Should access be constructed and recreation encouraged, Neaxtoalk Lake would likely be suitable for fish planting or a put-and-take fishery.

Stumaun Creek: Stumaun Creek would be used as a water supply for a Port Simpson bulk loading facility, and would have road access constructed through the drainage.

Stumaun Creek branches at the high tide line. The main fork is steeper and drains an entirely mountainous area, originating in a small lake system. The west fork drains a less mountainous area of rolling terrain, and has more shallow gradients. Estimated monthly mean flows and calculated flood hydrographs are shown for Stumaun Creek main fork in Figure 10, and for the west fork in Figure 11. The main fork shows larger spring snow melt floods due to the higher drainage elevation; both forks show peak flows in the fall due to rainfall.

Minimum flows in the main fork are estimated to be as low as 2 cfs, and in the west fork 1 cfs (Annex C-2). Water removal for a port facility has been projected as approximately 100,000 gallons per day, equivalent to a flow of 0.185 cfs or 9.2 per cent of the estimated minimum for the main fork.

The stream contains four main types of substrate and habitat: gravel pool and riffle, boulder rapids, rubble bar and pool, and intertidal gravel pool and riffle. The two branches of Stumaun Creek differ widely in the lower reaches: the main stem has a gradient of five to ten per cent, and the west tributary a gradient of about two per cent.

The main stem has approximately one mile of pool and riffle in the upper reaches, a gravel substrate with a pool/riffle ratio of about two, and a gradient of about two per cent. Below this is a long section of almost continuous rapids. Here the boulder substrate is broken by occasional log jams and associated rubble bars with a pool/riffle ratio of about 0.2. Immediately above the high tide line and the confluence with the west branch is a rubble bar and log jam, probably positioned by the effect of tides on the stream velocity. As discussed above, the substrate is derived from layered metasedimentary bedrock which results in an extremely rough surface on the rubble bars.

The creek is susceptible to extreme fluctuations in discharge. Following the period of heavy rains during fall 1974, high water marks were evident five to six feet above the 'normal' level, indicating flows possibly in excess of 300 cubic feet per second. Discharge at the time of survey was approximately ten cfs. At this level most of the stream trickled among boulders except in deeper pools. There was insufficient gravel in the main stem to take a shovel-sample for analysis.

The west branch of Stumaun Creek, which joins the main stem close to the high tide line, has abundant gravel substrate and occasional log jams. The log jams tend to re-direct the channel which has a pool/riffle ratio close to one.

Two gravel samples were taken in the west branch to give an indication of suitability for fish and invertebrate life. At a station immediately above the mouth and the highest tide line, an 0.79 litre sample contained 6.3 per cent fines (particles less than 0.4 millimeters in diameter) and 58.2 per cent material between 4 millimeters and 25 centimeters in diameter. At a second station about one-half mile above the mouth, where evidence of recent spawning activity was noted, a .76 litre sample contained 3.3 per cent fines (under 0.4 millimeters) and 52.0 per cent between 4 millimeters and about 12 centimeters in diameter. By comparison, a 1.165 litre sample taken from McNichol Creek contained a number of live salmon eggs, 13 per cent fines and 42 per cent over 4 millimeters diameter. All samples were sorted by wet-seiving, and proportions determined volumetrically.

The intertidal portion of Stumaun Creek has abundant areas of gravel of a size suitable for salmon spawning. Within the narrow upper reaches of the estuary the intertidal stream bed is three to four times the width of the stream above tidal influence, and has long pools ten to 20 centimeters in depth at low tide. This section has more than 500 square meters of apparently ideal spawning habitat for pink and chum salmon (the more salinity tolerant species) mostly in long pools. Where the estuary widens out onto Stumaun Bay, the gradient increases and the stream becomes braided in small ephemeral distributaries, mostly in riffles.

Water samples collected in the west fork of Stumaun Creek in October 1974 showed low dissolved solids. Values ranged from 14 to 34 ppm. TDS, total hardness was 12 ppm. Organic content was 8.1 to 9.8 ppm., and pH ranged between 5.3 and 6.2. Water quality data are shown in Table 3.

Invertebrate samples were collected from the main fork of Stumaun Creek in the first riffle above the high tide line. The most abundant taxonomic group was *Plecoptera* (stonefly) nymphs, *Chironomid* (midge) larvae and adults, and *Nematoda* (roundworms). Invertebrate data are shown in Table 4. Diversity of aquatic fauna, by the *Cairns (1971)* method, was moderate, averaging 4.56 for the five samples taken. Invertebrate density was low, however at 90.8 organisms per square meter, probably due to the peak flows prior to sampling.

Fish populations now known in Stumaun Creek include pink and coho salmon, sea-run cutthroat trout, Dolly Varden and steelhead. Only the pink salmon run is considered significant to the regional commercial or recreational fisheries at the present time due to limitations of access. The cutthroat and steelhead might support a modest local recreational fishery if access were provided.

Pearl Harbour (Lahon) Creek: Pearl Harbour or Lahon Creek occupies the drainage adjacent to Stumaun Creek. Over half of the drainage area is occupied by muskeg, with a portion draining the western slopes of Mount Ben and Leading Peak.

Estimated mean monthly flows, and flood flows, are presented for Lahon Creek in Figure 12. Lahon Creek was not investigated on the ground in this study. From aerial reconnaissance and topographic maps it was estimated that there are 1.5 miles of stream with a gradient in the 0.5 to 3 per cent range. In these reaches the stream is likely to contain a pool to riffle ratio and gravel substrates suitable for salmonid spawning and invertebrate production. The average gradient of the whole stream is about 2 per cent.

No information has been obtained on water quality or invertebrate populations of Lahon Creek. Water draining the more mountainous parts of the drainage would be similar to that of Stumaun Creek. Seepage from the muskeg terrain in the lower part of the drainage could contribute acidity and organic content similar to Neaxtoalk Lake. Invertebrate populations could reflect these differences in water chemistry through differences in relative abundance of species.

Minor runs of pink, chum and coho salmon are reported in Pearl Harbour Creek *(W. McKenzie, Fisheries Officer, pers. comm.)*, and good runs of steelhead and cutthroat are recorded *(A. Ackerman, Former Conservation Officer, pers. comm.)*.

Georgetown Creek: Road access to the Port Simpson site would probably be constructed along the east side of Georgetown Lake. This drainage is one of the larger ones in the Tsimpsean Peninsula.

Estimated mean monthly flows and flood flows are shown in Figure 13 for the main stem of Georgetown Creek above its mouth on Georgetown Lake. Draining a high elevation area between Tuck Inlet and Work Channel, Georgetown Creek shows a snowmelt in May and June of similar size to the fall rainfall freshet. This stream has over five miles of streambed with a gradient suitable for salmon habitat (ranging from 0.3 to 3 per cent), and an average gradient of about 2 per cent.

The western half of the drainage area for Georgetown Lake is muskeg covered. Much of the northwestern end of the lake has a muskeg shore.

There is no information available on water quality or invertebrate populations in the Georgetown system. The upper portions would be expected to resemble Stumaun Creek. The lake and downstream portions would be similar in water and faunal characteristics to Neaxtoalk Lake.

An old mill dam imposes a barrier to the use of the system by anadromous fish. However, the system appears to have potential for sockeye production, with relatively large areas of spawning stream, lake and estuarine habitats. The lake contains cutthroat trout populations, and once supported coho and steelhead runs *(A. Ackerman, Former Conservation Officer, pers. comm.)*.

Lachmach River: The Lachmach River flows northwest to the southeast end of Work Channel across the isthmus of the Tsimpsean Peninsula. Preliminary railway route drawings show six stream crossings and about 1.5 miles of coincidence with the stream bed along the Lachmach River. The stream would be parallelled for its entire length regardless of refinements in route location.

The Lachmach is a mountain river with some lake control. A major portion of the drainage is above tree-line. This has the effect of delaying the major snowmelt freshet until several weeks after that of the Tsimpsean Peninsula. The peak flow probably occurs most often during the month of June. Estimated mean monthly flows and calculated peak flows are shown in Figure 16.

The main stem has a gradient of less than one per cent for its entire length. Lachmach Lake lies in a tributary valley, has a length of 1.3 miles, and the outlet gradient is over ten per cent. The Lachmach was not inspected on the ground in this study. However, the substrates are likely to consist of sandy gravel with patches of boulders and silty clays. The Lachmach Lake outlet probably has boulder and bedrock substrates.

There is no information available on water quality or invertebrate populations of the Lachmach.

Pink and chum salmon use the Lachmach system in runs of some commercial significance. Sport fish known include sea-run cutthroat, coho salmon, probably Dolly Varden and possibly steelhead. No steelhead were reported caught in the Lachmach in the 1973-74 season, according to B.C. Fish and Wildlife Branch Steelhead Harvest questionnaires, after an estimated 12 angler days of fishing effort.

Work Channel Streams: The preliminary railroad access plans for the Port Simpson site include a route along the west shore of Work Channel. Approximately 28 streams large enough to appear on a 1:50,000 scale topographic map would be crossed at or near the mouth by the proposed route.

The hydrology of these streams is of fundamental importance to engineering and design of the railroad, but of less significance to the aquatic environment. Estimation of hydrographs for monthly and peak flows, as well as estimation of minimum flows, would provide a positive basis for further consideration of the biological importance of these streams; this should precede the engineering design phase.

None of the streams flowing directly into Work Channel are large, and none are considered significant fish producers *(McKenzie, Fisheries Officer, pers. comm.)*. Five of these have over one mile of stream order 2 or higher (the length of stream below the confluence of the highest two tributaries), and two of them over three miles of order 2 stream. Two systems contain significant lake habitats, and the mouths of many could provide minimal estuarine habitats for the inlet. None have been surveyed or evaluated in detail.

Major tributaries to Work Channel not directly affected by the proposed port facility include the Ensheshe, Toon, Thulme and Leverson Rivers. Hydrological data is available for the Thulme, and has been used in the precipitation-runoff analysis for the study area. All of these rivers are major salmon producers *(McKenzie, Fisheries Officer, pers. comm.)*.

C3.1.2 Estuarine/Marine Environments

The site proposed for port development has a steep shore composed mostly of boulders and cobbles over shelving bedrock with cracks. Exposure is moderate. Salinity is higher and less fluctuating than at the sites nearer the Skeena. Stumaun Bay has large areas of sand and mud flats overlying fluvial gravels.

Water quality analyses conducted in October 1974 indicated that the water column in Port Simpson Harbour was stabilized by a surface layer of low salinity though this effect was much more pronounced in Prince Rupert Harbour. Dissolved oxygen decreased with depth in a way which can be considered normal for the area and time of year.

The algal community of the Port Simpson intertidal zone is diverse and healthy in appearance, and contains several species not seen, or seen only occasionally, in Prince Rupert Harbour. The common brown alga *Fucus* dominated the flora, in association with the red algae *Endocladia muricata* and *Gigartina papillata*. *Lithothamnion*, a coraline red alga, encrusted significant areas of the lower zones, and terrestrial grasses and freshwater Chlorophyta were abundant in the uppermost intertidal zone.

The faunal assemblage of the intertidal zone is typical of that to be found along the northern British Columbian shore. It differs only in minor ways from that commonly found on rocky shores in the Strait of Georgia. In the Port Simpson transect the hermit crab, *Pagarus*, dominated the lower intertidal. Littorinid snails (*Littornia* sp.) characterized the mid inter-tidal in association with the barnacle *(Balanus)* which reached a maximum cover of 17.1 per cent there.

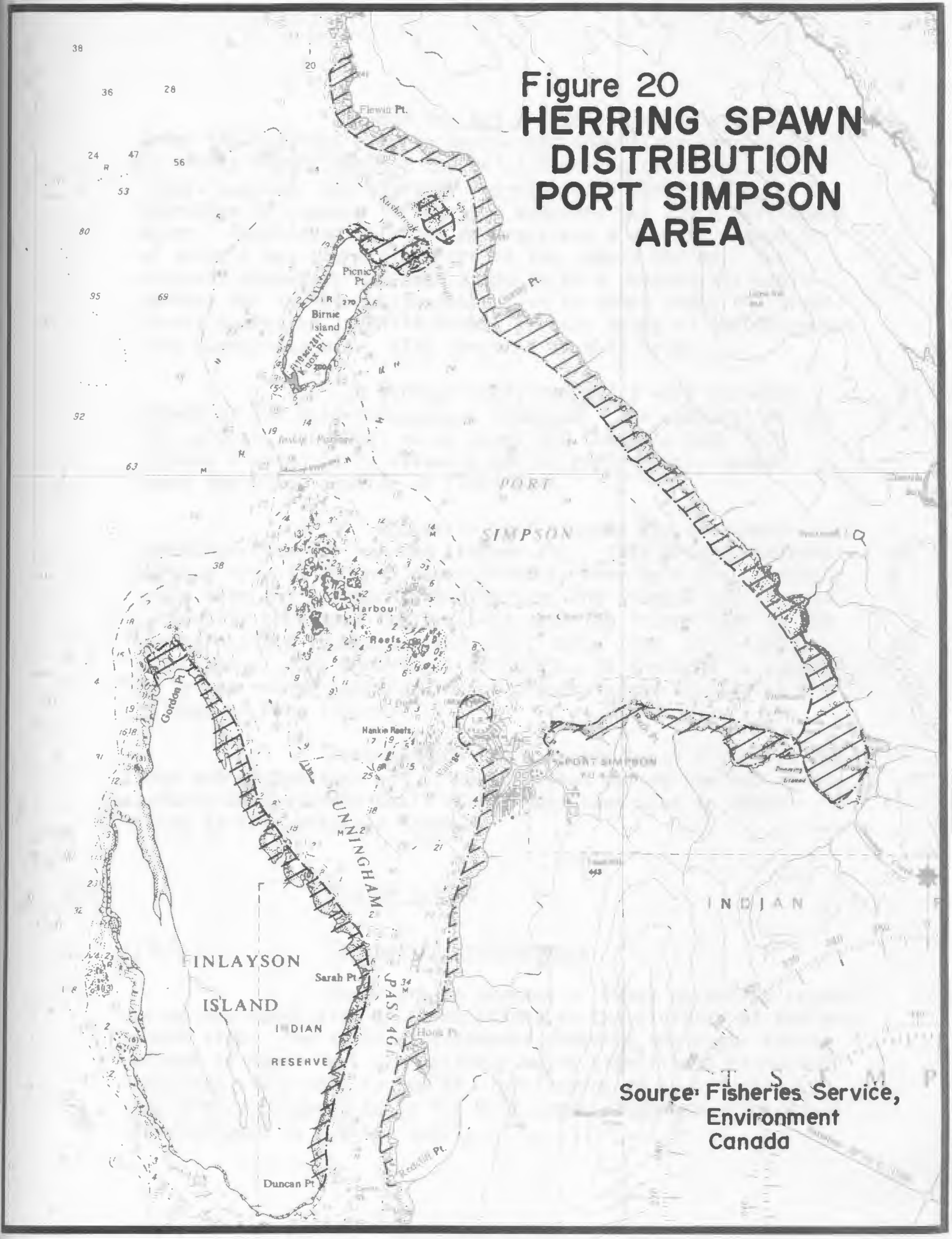


Figure 20
HERRING SPAWN
DISTRIBUTION
PORT SIMPSON
AREA
Flewin Pt.
Picnic Pt.
Birnie Island
PORT
SIMPSON
Harbour
Reefs
Hankin Reefs
PORT SIMPSON
Gordon Pt.
CUNNINGHAM
PASSAGE
FINLAYSON
ISLAND
INDIAN
RESERVE
Sarah Pt.
Duncan Pt.
INDIAN
Source: Fisheries Service,
Environment
Canada

Stumaun Bay was the only sampled site at which the eelgrass *Zostera marina* was found (see Annex C-3). In Prince Rupert Harbour the related marine plant *Phyllospadix scouleri* was sparsely represented. The average abundance of *Zostera* in two grab samples, was 265 g per square meter. Associated with the eelgrass was a diverse community of animals not found elsewhere in the sample series. The eelgrass community has been found to be a uniquely valuable nursery for larval and juvenile fish in other areas. A significant number of juvenile crabs, perhaps young of the Dungeness crab *Cancer magister,* also occurred in this area.

The harbour reefs support a very abundant growth of the kelp *Nereocystis lutkeana.* The combination of the eelgrass, abundant *Fucus* cover and the kelp make Port Simpson a potentially valuable marine environment, second among the sites studied to Flora Bank.

All shores of Port Simpson Bay are known spawning sites for herring (Figure 20). This area (Fisheries Service Area 3) in some years produces over half the herring spawn from the northern sub-district, and Stumaun Bay has occasionally contained the greatest spawning intensities on the northern coast *(Humphreys and Webb, 1970, 1971, 1972, 1973; Webb, 1974)*. The importance of herring to the area is suggested by the recent construction of processing facilities at the village of Port Simpson.

Port Simpson Bay supports local fisheries for crab and groundfish, and salmon trolling during periods of uncertain weather when small vessel operators wish to remain close to the protected harbour.

C3.2 Ridley Island

C3.2.1 Freshwater Environments

There are no streams or lakes on Ridley Island or on the south side of Kaien Island in the vicinity of the proposed site. The small watercourses draining the south facing slopes of Mount Hays are unlikely to be significant biological habitats. The only system of significance to be affected by the Ridley Island site is the Wolf Creek watershed which would be developed as a water supply.

The Wolf Creek drainage has elevations to 2,000 feet and large areas of muskeg with small headwater lakes. The annual precipitation ranges from 90 to 120 inches. Estimated mean monthly flows and flow hydrographs for Wolf Creek are shown in Figure 15.

Water withdrawal for port facility requirements has been projected as approximately 100,000 gallons per day, equivalent to a flow of 0.185 cfs; minimum daily flows for Wolf Creek have been estimated at 4 cfs (see Annex C-2).

Gradients of Wolf Creek range from about one to 15 per cent with an average of approximately four per cent. The substrate in the lower 1/4 mile, which has a steep gradient, is entirely boulders. Since discharge peaks are at least partially moderated by the headwater lakes, the bank vegetation encroaches to the margins of low flow levels.

The estuary of Wolf Creek has been severely disrupted by previous construction and industrial activity. The highway has been constructed on a fill across the upper intertidal zone, isolating a small tidal lagoon from Wainright Basin with five large culverts. These culverts would not impose more than a short-term delay on upstream fish movement. The substrate in the lagoon, and over the entire area between Watson Island and the mainland north of Port Edward, is covered with thick layers of pulp fibre in peat-like mats.

Biological communities in Wolf Creek have not been investigated in the field. Above the highest tide line invertebrate populations would probably be similar to those of other streams in the Peninsula. Life in the intertidal zone has been reported to be reduced to a few species tolerant of pulp mill wastes, such as amphipods, as well as the bacteria which break down the accummulated pulp wastes. Fish populations in Wolf Creek are reported to have included a fair-sized sea-run cutthroat population at one time. The headwaters still contain small cutthroat, and children from the area occasionally fish there.

3.2.2 Estuarine/Marine Environment

In the vicinity of the proposed Ridley Island port facility, the intertidal substrate is rather steep fissured bedrock with large boulders. Exposure is moderate with several wide sectors of the horizon open to Chatham Sound.

Both flora and fauna were abundant and diverse; detailed species lists are presented in Annex C-3. The animal species list for the intertidal zone is the second longest of the study areas; algal cover was high. The Ridley Island harvest showed littornid snails (*Littorina* sp.) to be an abundant invertebrate in the lower intertidal. A sponge covered about 12 per cent of the area, and amphipods were also abundant. *Laminaria,* the kelp, was the most abundant alga. The barnacle *Balanus* covered an average of 25 per cent of the mid-intertidal where the limpet *Acmaea scutum* was also found in moderate abundance. Major invertebrate cover in the upper intertidal was the barnacle *Balanus* and mussels, *Mytilus edulis*. *Fucus* is the dominant alga in the upper intertidal, followed by *Gigartina*. The richness of the fauna continued subtidally, where diversity was as high as that found for Stumaun Bay, and much higher than at any of the other shallow-water stations. A beach seine set in a small sandy cove 0.2 mile south of the intertidal sampling location yielded a generous catch of fish, a few decapod crustacea, mysids, and very many of the amphipod *Anisogammarus confervicolus*. This was a night haul and all the other beach seine sets were made during the day on a rising tide. It is uncertain whether the large numbers of amphipods was the result of their abundance at this site or of a diurnal rhythm of activity.

The site studied was on the western shore of this island, about 0.5 mile south of the small cove which *Drinnan (1974)* found to be seriously affected by the red liquor outfall from the pulp mill on Watson Island.

This area is one in which *Higgins and Shouwenberg (1973)* found very few juvenile salmon during the summer months. Our present knowledge of the physical and biological environments of the area is not detailed enough to understand why this area is not utilized by juvenile salmonids.

C3.3 Kitson Island

C3.3.1 Freshwater Environments

Port development at Kitson Island, involving a rock-fill causeway across Flora Bank, will have direct effects on two freshwater systems: Wolf Creek and the Skeena River. Wolf Creek, as for the Ridley Island site, would be developed for water supply and is described above.

The biology of the Skeena River is reviewed in Chapter C2. The influence of the Skeena on the Kitson Island-Flora Bank area is reviewed briefly below.

The Skeena is the second largest river entering the ocean on the British Columbia coast. The hydrology of the Skeena has been discussed in Chapter C2 of this appendix. Figures 3 and 4 show daily flows for two years representing high and average runoff years. The 1948 peak flows, the largest on record, exceeded 300,000 cubic feet per second. Minimum flows are in the vicinity of 3,000 cubic feet per second. Fluctuations in the discharge of fresh water produce inverse fluctuations in salinity on Flora Bank, as shown in Figures 17, 18 and 19.

The large freshwater discharge and sediment transport are the major influences of the Skeena on the physical environment of the Flora Bank area. The temperature of Skeena discharges produces comparatively more extreme regimes on Flora Bank than in other coastal areas. Sediment transported from the interior is sorted along the Skeena Channel. Gravels are deposited some distance upstream from the coast, and sands compose the stream bed around the mouth. Flora Bank is in the plume from Inverness Passage, receiving much of the fine sediments in the Skeena wash load. The continual contribution of mineral nutrients, rejuvenation of bottom muds, and entrainment of sea water result in high production in certain estuarine communities.

3.3.2 Estuarine/Marine Environments

Flora Bank is unique among the sites studied. It is composed of sand in the higher portions and sandy silt on the associated submerged portions of DeHorsey and Agnew Banks.

Extensive eelgrass *(Zostera marina)* beds are known to exist on Flora Bank *(Higgins and Schouwenberg, 1973)*. The present study found sparse beds of the related *Phyllospadix scouleri* in the protected sandy coves of inner Prince Rupert Harbour, but the Flora Bank beds are likely most important in the area. Subtidal and benthic samples showed a very low diversity assemblage on both DeHorsey and Agnew Banks, dominated by dense populations of the small bivalve *Transenella tantilla;* data are presented in Annex C4 (see Table 5). The low diversity results from a hostile environment characterized by substrate movements and salinity fluctuations. *Transenella* is apparently sufficiently robust to survive these stresses and exploit the detritus-rich inner estuary. The substrate itself results in quite different types of fauna than are found in other subtidal environments in the study region.

This is the area in which *Higgins and Shouwenberg (1973)* found the highest numbers of juvenile salmon during an intensive investigation between May and July 1972. The Ridley Island shore, in contrast, produced relatively fewer captures. *Higgins and Shouwenberg* relate this distribution to the availability of amphipods, which they found only in the vicinity of Flora Bank. *Kaczynski et al (1973)* have shown that for pink and chum salmon *(Onchorhynchus gorbuscha* and *O. keta)* in Puget Sound an onshore stage of development can be described in which both species feed mainly on epibenthic harpacticoid copepods and gammarid amphipods. *Goodman and Vroom (1972)* have reported similar findings. Preliminary results reported by *Higgins and Shouwenberg (1973)* indicate that sockeye, coho and chinook salmon consume amphipods and insect remains in the Flora Bank area. Chinook and sockeye also take copepods.

It is difficult to relate the presence of juvenile salmon in this area to the food available, partly because standard sampling methods do not catch epibenthic animals efficiently, and partly because it is not proven that the location of juvenile salmon is governed by food alone. The sampling in this study shows that amphipods are available in other areas, both intertidally and subtidally.

The major interest in the biota of Flora Bank is in reference to the multi-million dollar salmon and steelhead fisheries. Juvenile salmon and steelhead apparently depend on this area for two functions: acclimation to salt water, during which they must become accustomed to progressively higher salinities over a period of several days; and feeding on plankton and benthos, which must permit fast enough growth to minimize mortality from predation.

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ANNEX C-1

FRESHWATER ENVIRONMENTS

DETAILED METHODS

by

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January 1975

NEAT

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1.0 ANALYSIS OF AVAILABLE INFORMATION

Most existing information on freshwater environments of the study area is in the form of published maps, government manuscript reports and the accumulated personal knowledge of present and former fisheries officers and conservation officers. There is, in addition, a wealth of published literature on salmon and steelhead in the Skeena system.

Watershed areas, stream lengths and approximate stream gradients were obtained from 1:50,000 scale topographic maps. A summary of watershed areas and stream lengths for the Tsimpsean Peninsula is presented in Table C-1-1. Air photos were of little use for defining stream habitats due to the dense forest cover, in most cases obscuring the precise location of the stream.

Most information on freshwater fish populations in Tsimpsean Peninsula streams and lakes was obtained from the two fisheries officers for the area, Pat Harvey and Willy Mackenzie, and two former conservation officers, Andy Ackerman and Gerry Paul. Fish and Wildlife Branch lake surveys, conducted in 1952 and 1972 on the Cancel reservoir system, provided background on water quality and lake biota. The significance of Tsimpsean Peninsula streams and the Nass and Skeena River systems to be commercial fisheries of the north Pacific is indicated by *Aro and Shepard (1967)*, and to the sports fisheries of northern British Columbia by *Reid (1974)*. Two streams in the study area appear in the B.C. Fish and Wildlife Branch annual Steelhead Harvest Analysis, the Kloiya and Lachmach Rivers. Previous consultant reports on the area have not addressed freshwater biology in any detail. Information obtained from these sources has been included in the main body of Appendix C.

Information on the major river systems influencing the study area is much more abundant, and largely concerns the commercially important Skeena River salmon runs. *Scott and Crossman (1973)* show 31 fish species with ranges including the Skeena system, and 27 species ranging into the Nass River drainage; these are listed in Table C-1-2. Although 15 of these species are known to be anadromous, only the Pacific salmon, steelhead, cutthroat, Dolly Varden and eulachon are of economic importance.

TABLE C-1-1

WATERSHED AREAS AND STREAM LENGTHS IN THE STUDY AREA

DRAINAGE	LAKE ON STREAM	STREAM LENGTH(1)	DRAINAGE AREA
NEAXTOALK LAKE	+	0.1 miles	0.8 sq. miles
STUMAUN CREEK		2.5 miles	5.9 sq. miles
PEARL HARBOUR (LAHON) CREEK		6.8 miles	6.8 sq. miles
GEORGETOWN CREEK	+	7.2 miles	22.0 sq. miles
(SALMON BIGHT) CREEK		4.4 miles	7.4 sq. miles
McNICHOL CREEK		4.4 miles	9.2 sq. miles
SILVER CREEK		3.4 miles	7.9 sq. miles
SCISSORS CREEK		0.2 miles	1.4 sq. miles
SHAWATLAN CREEK	+	2.2 miles	18.8 sq. miles
WOODWORTH LAKE	+	---	9.9 sq. miles
(BUTZE RAPIDS) CREEK		2.6 miles	5.7 sq. miles
DENISE CREEK		1.8 miles	9.0 sq. miles
KLOIYA RIVER	+	2.0 miles	32.2 sq. miles
DIANA CREEK	+	4.0 miles	13.9 sq. miles
WOLF CREEK	+	2.8 miles	6.3 sq. miles
BONEYARD CREEK (RAINBOW LAKE)	+	0.5 miles	14.9 sq. miles
LACHMACH RIVER	+	3.6 miles	16.3 sq. miles
McNEIL RIVER	+	4.9 miles	16.6 sq. miles
TSUM TSADAI INLET		---	5.0 sq. miles
BREMNER LAKE	+	0.9 miles	3.1 sq. miles
HUMPBACK CREEK		1.4 miles	5.6 sq. miles

(1) Length of stream of order 2 and higher on main stem.

2.0 FIELD AND LABORATORY METHODS

Selection of sampling sites was based on a comparison of the most recent list of potential port sites and expected ancillary developments with an overview appraisal of streams as habitats for salmon and trout. Stumaun and McNichol Creeks were selected as the most representative of streams of the Tsimpsean Peninsula. Fiscal and temporal priorities precluded sampling at more remote areas, such as the Lachmach system, and conducting systematic sampling programs for fish populations and lake biology.

2.1 Water Quality

Water samples were collected by dipping a small glass bottle beneath the surface of the water body being sampled. Analyses were conducted by a commercial analytical and geochemical laboratory in Vancouver. Tests included pH, dissolved solids, total hardness and total organics determinations. No tests for dissolved oxygen were attempted in the field, since no polluted areas were to be sampled; low readings would be most unlikely following the major October freshets, and of little significance without continued monitoring. Water quality information obtained in this study is shown in Table 3 in the main body of Appendix C, and sample sites are shown in Figure C-1-1.

2.2 Substrate Analyses

The lower portions of Stumaun Creek's two forks, McNichol Creek and the outlet of Neaxtoalk Lake were walked in late October 1974, and distribution of gravel and fish habitats noted (see Chapter 2, Section C). Gravels were sampled using a spade and two standard sieves, to arrive at a rough estimate of the proportion of fines in the substrate.

Following removal of the gravel from the stream bed, the outer, stream-washed portions of the spade load were scraped away, leaving approximately one litre of undisturbed gravel. This sample was wet-sieved, using 4.75 and 0.4 mm mesh openings, and proportions of each size category determined volumetrically.

The number of samples taken was insufficient for determining any but the most outstanding differences in particle size distribution, and none were detected between the stations sampled. Sample sites are shown on Figure C-1-1.

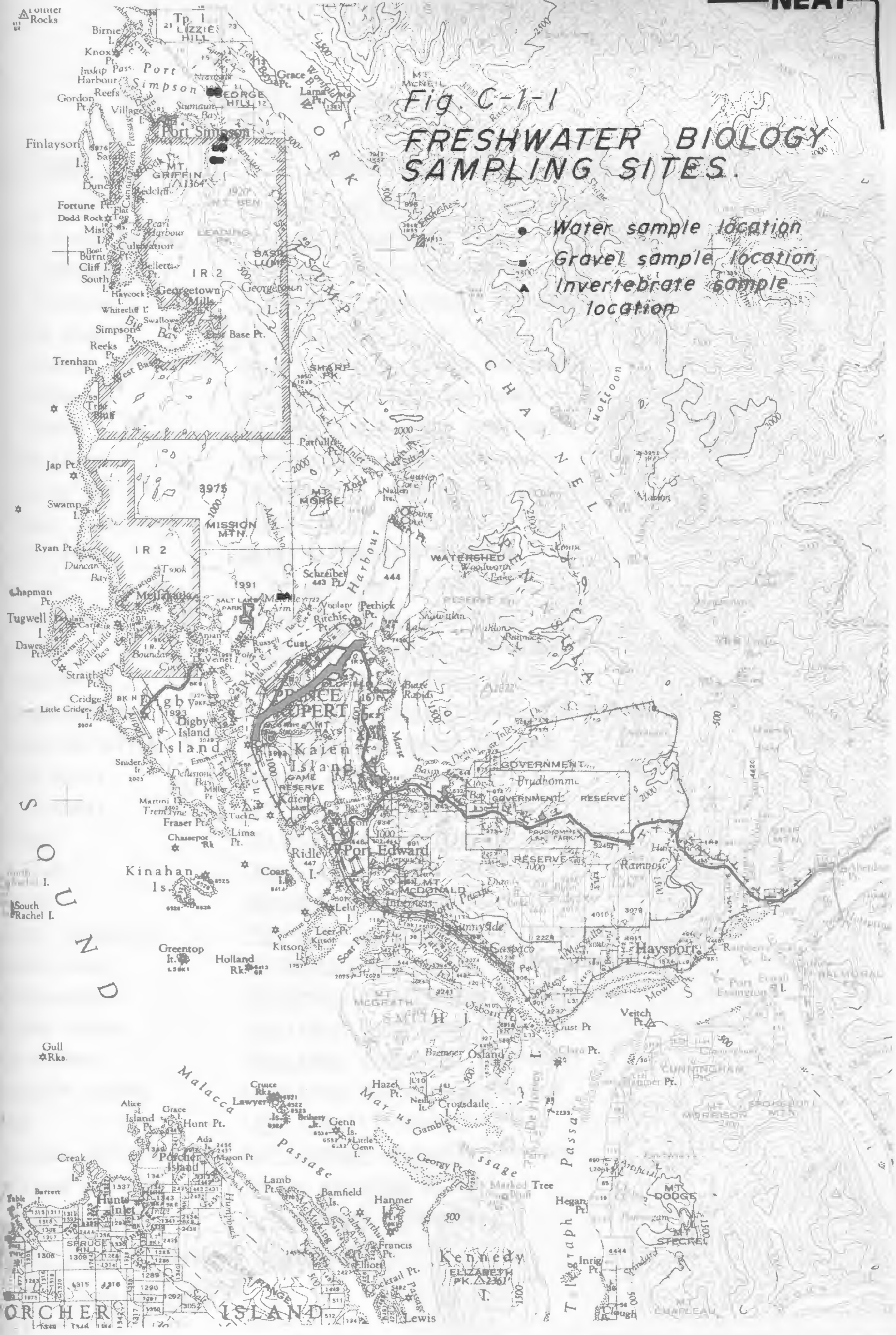

Fig. C-1-1 FRESHWATER BIOLOGY SAMPLING SITES.

TABLE C-1-2

FISH SPECIES IN THE SKEENA AND NASS RIVER SYSTEMS

NAME	SCIENTIFIC NAME	DRAINAGES NASS	SKEENA
Pacific lamprey	Entosphenous tridentatus (Gairdner)	+	+
Western brook lamprey	Lampreta richardsoni Vladykov & Follett		+
Green sturgeon	Acipenser medirostris Ayres	+	+
White sturgeon	Acipenser transmontanus Richardson	+	+
American shad	Alosa sapidissima (Wilson)	+	+
Pink salmon	Oncorhynchus gorbuscha (Walbaum)	+	+
Chum salmon	Oncorhynchus keta (Walbaum)	+	+
Coho salmon	Oncorhynchus kisutch (Walbaum)	+	+
Sockeye salmon	Oncorhynchus nerka (Walbaum)	+	+
Chinook salmon	Oncorhynchus tshawytscha (Walbaum)	+	+
Cutthroat trout	Salmo clarki Richardson	+	+
Rainbow trout	Salmo gairdneri Richardson	+	+
Steelhead	Salmo gairdneri Richardson	+	+
Dolly Varden	Salvelinus malma (Walbaum)	+	+
Lake trout	Salvelinus namaycush (Walbaum)		+
Lake whitefish	Coregonus clupeaformis (Mitchill)	+	+
Pygmy whitefish	Prosopium coulteri (Eigenmenn & Eigenmenn)		+
Mountain whitefish	Prosopium williamsoni (Girard)	+	+
Rainbow smelt	Osmerus mordax (Mitchill)	+	
Longfin smelt	Spirinchus thaleichthys (Ayres)	+	+
Eulachon	Thaleichthys pacificus (Richardson)	+	+
Lake chub	Couesius plumbeus (Agassiz)	+	+
Peamouth	Mylocheilus caurinus (Richardson)	+	+
Northern squawfish	Ptychocheilus oregonensis (Richardson)	+	+
Longnose dace	Rhinichthys cataractae (Valenciennes)		+
Redside shiner	Richardsonius balteatus (Richardson)	+	+
Longnose sucker	Catostomus catostomus (Forster)	+	+
White sucker	Catostomus commersoni (Lacépède)		+
Largescale sucker	Catostomus macrocheilus Girard	+	+
Burbot	Lota lota (Linnaeus)	+	+
Threespine stickleback	Gasterosteus aculeatus Linnaeus	+	+
Coastrange sculpin	Cottus aleuticus Gilbert	+	+
Prickly sculpin	Cottus asper Richardson	+	+

SOURCE: Scott & Crossman, (1973)

2.3 Invertebrate Samples

A series of five Surber sampler collections were made near the mouths of each of Stumaun and McNichol Creeks. Each series was collected moving upstream from the top of a riffle into or through a pool; there was no gravel at the Stumaun Creek station, and the distribution of small rubble extended above and below a small pool just above the high tide line.

Each sample jar was examined in the lab, sorted and indexed according to the *Sequential Comparison Index* for faunal diversity *(Cairns et al, 1971)*. This method, briefly, involves randomizing the specimens in a lined pan, then comparing, in sequence, adjacent organisms and recording by an X and O tally whether each pair examined was apparently the same or different. One or more of the same organism is a run; the total number of runs divided by the total number of organisms is then multiplied by the number of apparently different types of organisms. The resulting index (DI_t) ranges from near 1 for communities of low diversity to 10 or more in more diverse associations. In addition to the DI_t, mean faunal density and major taxonomic groups represented are shown in Table 4 in the main body of Appendix C. Invertebrate sample sites are shown in Figure C-1-1.

ANNEX C-2

PRECIPITATION-RUNOFF ANALYSIS

DETAILED METHODS

by

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ANNEX C-2

PRECIPITATION-RUNOFF ANALYSIS

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1.0 AVERAGE PRECIPITATION

Because of the absence of steam gauging records, both average and peak flows were estimated from precipitation data. This is generally an unsatisfactory procedure but was necessary in this case. Discharge and precipitation data utilized are shown in Tables C-2-1 and C-2-2 respectively.

The average precipitation data was analyzed in an attempt to produce an isoheytal map of the area. Since much of the precipitation data is short term, the first portion of the analysis was to relate overlapping precipitation data in an attempt to extend the short records.

There is insufficient overlapping data to directly evaluate the difference between the long term Prince Rupert station and the newer Prince Rupert Airport, Montreal Circle and Roosevelt Park stations. Double mass plots of precipitation using Falls River as a base were used to estimate long term average precipitations. Results were as follows:

Prince Rupert	96 inches
Prince Rupert - Airport	97 inches
Prince Rupert - Montreal Circle	115 inches
Prince Rupert - Roosevelt Park	112 inches
Falls River	145 inches

Average Port Simpson precipitation based on the 1886 to 1910 records is 92 inches; however, as this period does not overlap with the long term Prince Rupert station, it was not possible to directly verify this period as being typical. Records at Nass Harbour overlap Port Simpson and Prince Rupert by ten years and 18 years respectively. Using Nass Harbour as a base for a double mass plot, an average annual precipitation of 73 inches at Port Simpson was obtained. This precipitation appears low, however, Nass Harbour shows a similar average annual precipitation and Mill Bay only slightly higher at 84 inches per year. In the absence of additional data, it should be assumed that the derived average annual precipitation for Port Simpson is correct.

There is insufficient data to estimate the effects of elevation, aspect, exposure or orientation on precipitation. A recent study *(Shaefer & Nikleva, 1973)* of the North Vancouver area indicated that the two most important factors were the mountain slopes, which provide a mechanism for lifting air and thereby increasing precipitation, and the valleys that open to the general air flow and thereby provide a funnelling effect.

TABLE C-2-1

AVAILABLE DISCHARGE DATA

Water Survey Gauge Number	Stream	Location	Drainage Area sq. mi.	Records
08EF001	Skeena at Usk	54°37'50" 128°25'40"	16,300	1928-31 1936-date
08EG013	Boneyard Creek	54°11'55" 130°04'50"	12.6	1964-65
08EG004	Thulme River	54°29'30" 129°59'45"	28.4	1928-31
08DB002	Union Creek	54°39'45" 130°15'45"	23.3	1928, 1929-31
08DB001	Nass above Shumal Creek	55°12'50" 129°08'20"	7,410	1929-49 1956-date

TABLE C-2-2

PRECIPITATION DATA

Name	Location	Elevation (feet)	Records
Prince Rupert	54^{o} 17' 130^{o} 23'	170	Aug 1908-Dec 1962
Prince Rupert- Airport	54^{o} 18' 130^{o} 26'	110	May 1962-date
Prince Rupert- Montreal Circle	54^{o} 19' 130^{o} 17'	280	Aug 1959-date
Prince Rupert- Roosevelt Park	54^{o} 18' 130^{o} 20	298	July 1966-date
Port Simpson	54^{o} 30' 130^{o} 36'	26	Aug 1886-June 1910
Naas Harbour	54^{o} 56' 129^{o} 56'	20	Feb 1900-Aug 1929
Falls River	53^{o} 56' 129^{o} 44'	50	Nov 1931-date
Kloiya Dam*			1952-59
Rainbow Lodge*			1960-62 1966-71 1973

*Data collected by Canadian Cellulose, several months missing.

Figure C-2-1 shows the available average annual precipitation data plotted with respect to elevation. The applicable elevation chosen was not necessarily the elevation of the station itself, but that of the surrounding ground level that mainly influences the station. A good example of this is Falls River which receives a high precipitation by virtue of the 3000 plus foot high mountains to the west. The Rainbow station shows higher precipitation than its elevation indicates; this is a result of the valley effect as air masses move into the area from the south and west.

From the topography of the area and the available data, isoheytals for the study area were estimated as shown on Figure C-2-2.

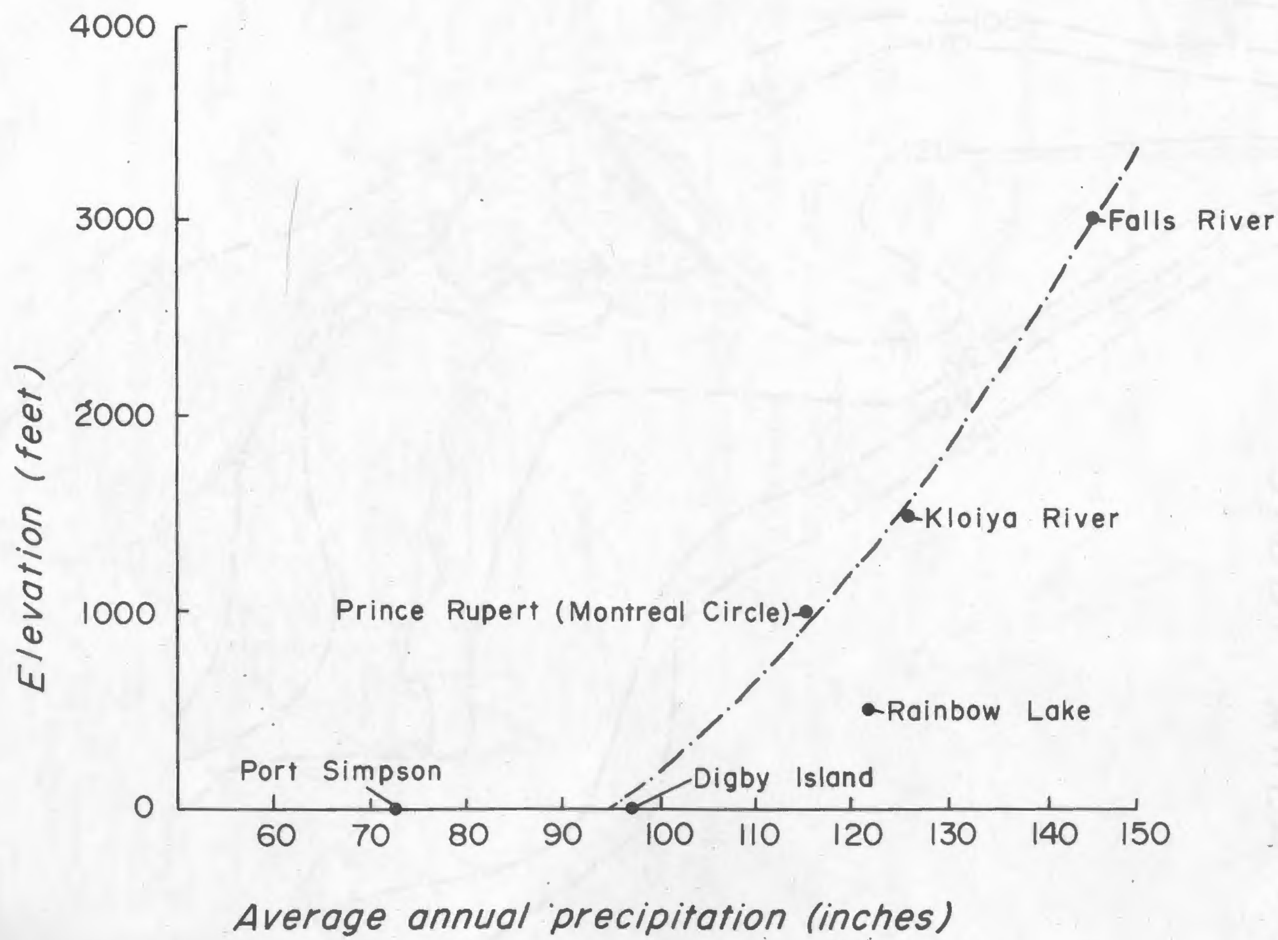
In an attempt to verify the isoheytals, Boneyard Creek discharge data for 1964-65 was compared to the total precipitation data for the same period. Monthly comparisons were not made so the effects of snow and storage in Rainbow Lake could be ignored. Unfortunately, Rainbow precipitation data does not exist for these years so the Prince Rupert data was transposed by the ratio of the isoheytal values.

Runoff and precipitation were related by the simplified water budget equation of mean precipitation equals mean runoff plus mean evapotranspiration.

Available data *(Ferguson, O'Neill & Cork, 1970)* indicates a mean lake evaporation of about 20 inches in the Prince Rupert area. The study of North Vancouver *(Schaefer & Nikleva, 1973)* concluded that mean evapotranspiration is less than mean lake evaporation by about 30 per cent. This is because most lake evaporation takes place in the relatively dry summer and although in a lake actual evaporation can equal potential evaporation, there are limitations to the water available for evaporation on the land. In addition, higher levels have less potential evapotranspiration than lake data collected at lower levels. Consequently, mean evapotranspiration of 15 inches per year was selected. This corresponds to 20 inches assumed for a study in neighbouring Alaska *(U.S. Department of Agriculture, Alaska)*.

The final comparison showed an annual precipitation over the Boneyard Basin of 117 inches and an equivalent runoff of 110 inches, indicating that the isoheytals show slightly low precipitation. Because of the potential errors in the above procedures, the isoheytals were not modified.

Fig. C-2-1 - ELEVATION vs. PRECIPITATION



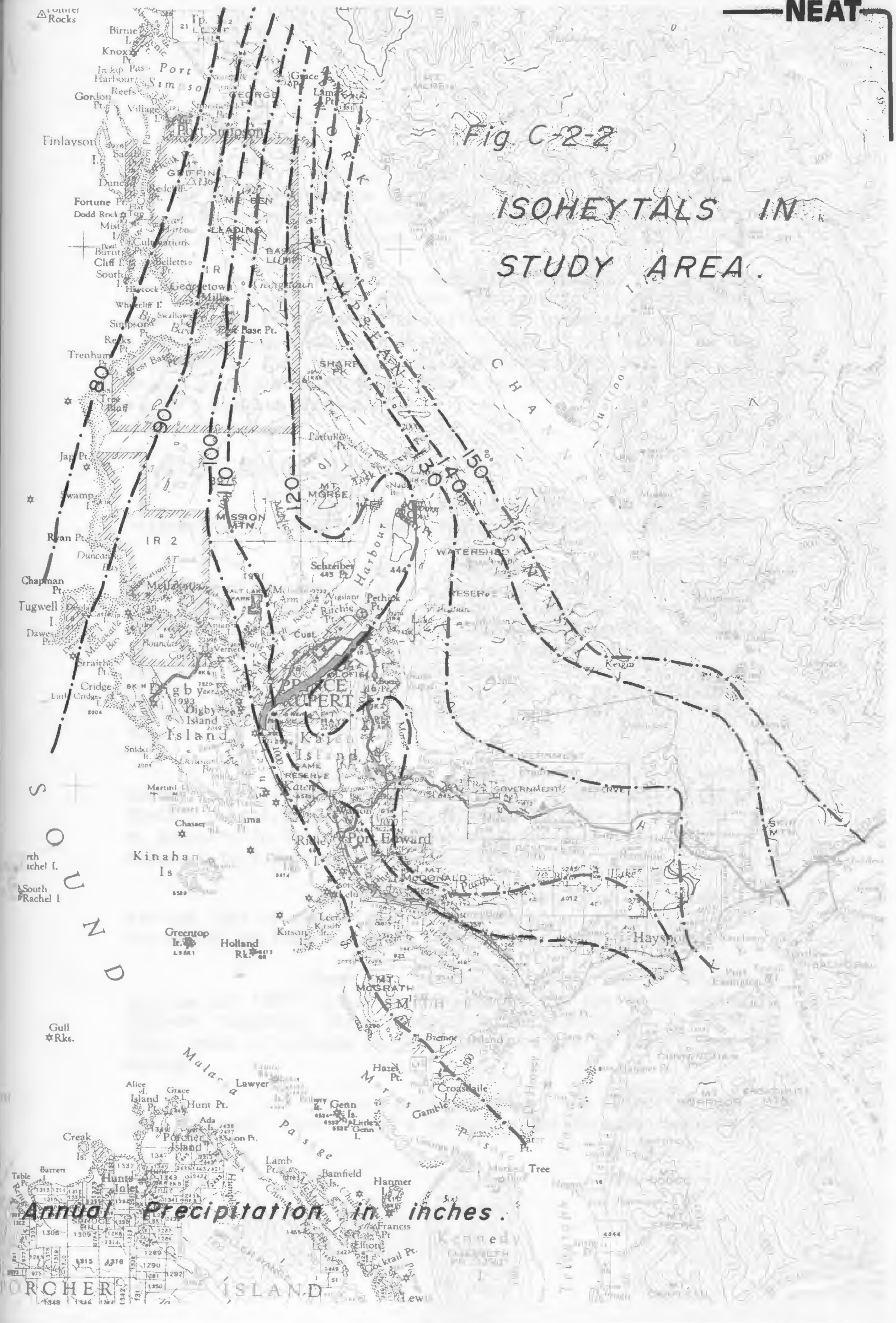


Fig. C-2-2

ISOHEYTALS IN STUDY AREA.

Annual Precipitation in inches.

Similar runoff comparisons indicated an average precipitation on the Thulme basin of 185 inches and on the Union basin of 170 inches. These appear very high and should be used with caution.

It must be emphasized that the isoheytals were drawn using only a few low level precipitation stations, some limited knowledge of the effect of topography on precipitation and about one year of runoff data at one site. If development of the area proceeds, additional precipitation gauges at higher elevations should be installed and the station at Port Simpson reinstated.

2.0 AVERAGE MONTHLY FLOWS

Average monthly flows in the streams of interest were estimated from available precipitation data.

Mean monthly precipitation patterns at Prince Rupert and Port Simpson were found to be nearly identical, (see Figure C-2-3), so the monthly distribution from Prince Rupert was applied throughout the study area. Mean monthly precipitation over any particular basin was estimated from the mean monthly precipitation at Prince Rupert multiplied by the ratio of the average annual precipitation over the basin (from the isoheytal map) to the average annual precipitation at Prince Rupert.

Mean monthly runoff was estimated as mean monthly precipitation minus mean monthly evapotranspiration. Monthly evapotranspiration was assumed to have the same pattern as measured in Vancouver *(Ferguson, O'Neill & Cork, 1970)* adjusted to a yearly total of 15 inches.

The runoff-precipitation relation assumed that average loss of precipitation to groundwater is negligible over any month and that temporary water storage can be ignored.

Over most of the area, bed rock is relatively shallow and infiltration to groundwater can easily be neglected. However, temporary water storage can be significant. The three major means of storage in the study area are in lakes, snow and muskeg.

In this overview study, the effect of lakes has been ignored. This is not a serious simplification because for

Fig. C-2-3- PRECIPITATION PATTERN, Prince Rupert & Port Simpson.

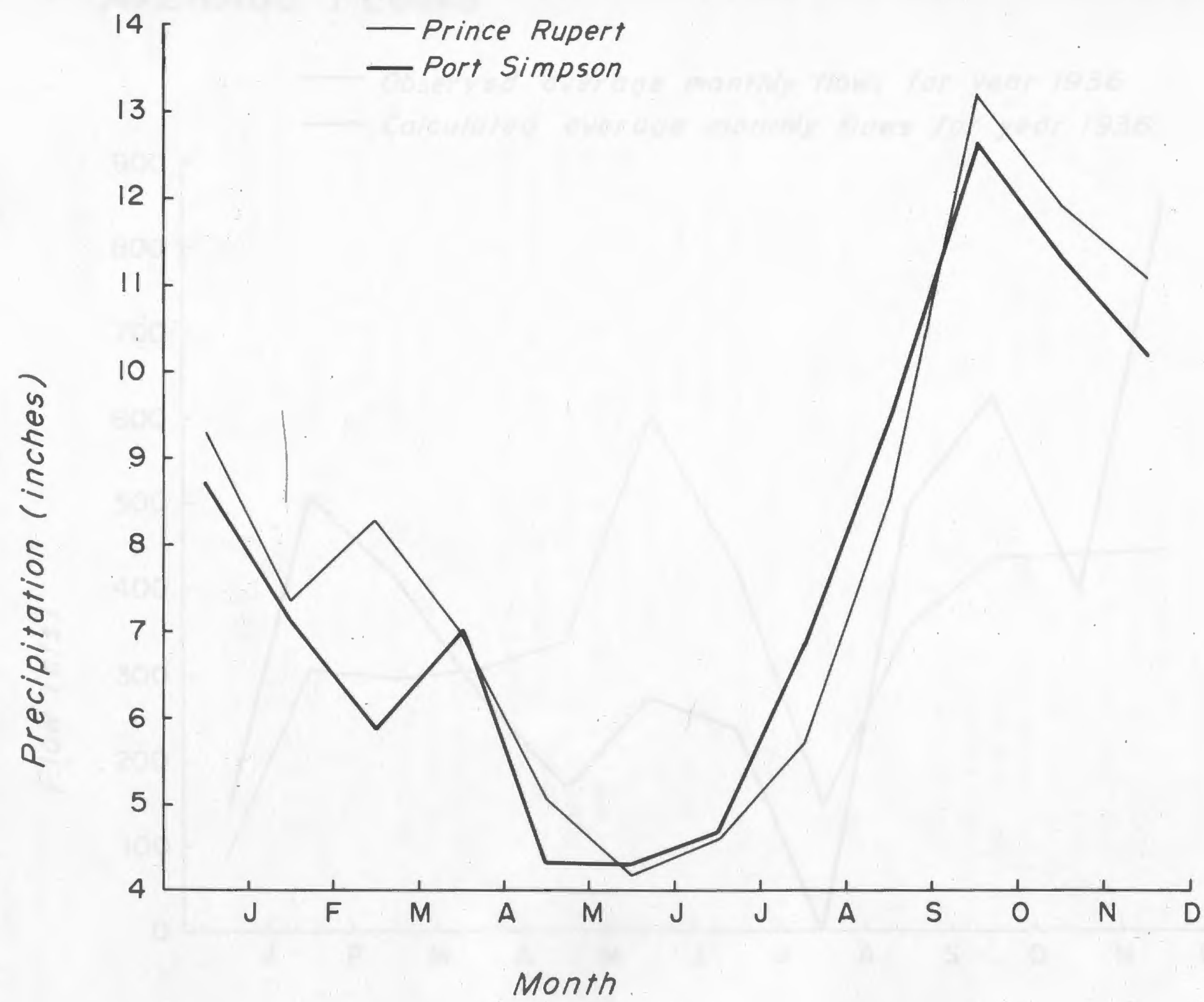
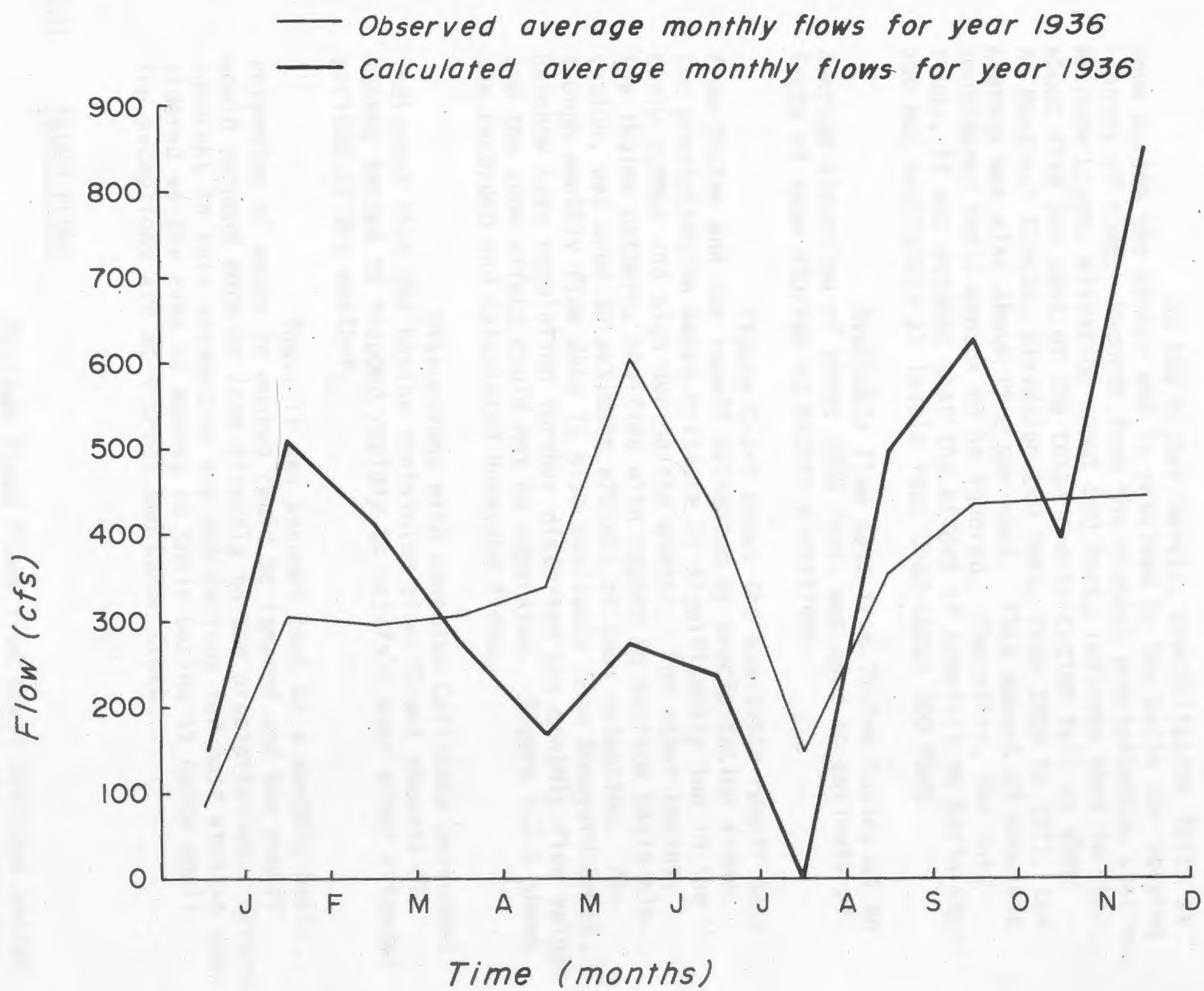


Fig. C-2-4- THULME RIVER-OBSERVED AND CALCULATED AVERAGE FLOWS



most of the streams under consideration the percentage of lake area to total drainage basin area is quite small.

On the higher levels, precipitation falls as snow during the winter and is retained in the basin for varying lengths of time. Records from the highest precipitation station, Rainbow Lodge, elevation about 500 feet, indicate that in 1962, about five per cent of the total precipitation fell as snow. At Montreal Circle, elevation 280 feet, from 1959 to 1973, the average was also about five per cent. This amount of snow was considered small enough to be ignored. Therefore, for this study, it was assumed that the effect of snowfall on basin storage was negligible at levels less than about 500 feet.

Available flow data from Thulme Basin, at an average elevation of about 2000 feet, was used to estimate effects of snow storage at higher elevations.

Figure C-2-4 shows the available runoff data from Thulme and the runoff estimated by precipitation alone. The precipitation based estimate is significantly low in the early summer and high during the winter. For other basins, the Thulme pattern, modified with regard to average basin elevation, was used to estimate effects of snow retention. Although monthly flow data is also available from Boneyard Creek, Rainbow Lake regulation further distorted the monthly flow values and the snow effect could not be separated. Figure C-2-5 shows the recorded and calculated Boneyard flows.

Discussions with Canadian Cellulose personnel indicated that the basins containing significant amounts of muskeg tended to respond rapidly to rainfall even after extended periods of dry weather.

Thus, it was assumed that on a monthly basis, retention of water in muskeg could be ignored and the runoff would respond more or less directly to the precipitation. Errors inherent in this assumption are not serious for most streams considered as the area of muskeg in their basins is quite small. The exceptions are Wolf Creek and Lahon Creek.

3.0 FLOOD FLOWS

Maximum flood flows from small drainage basins in coastal areas occur due to rainfall either in the summer or fall. Flood hydrographs from snow melt have consequently not been considered in this study.

Fig. C-2-5-BONEYARD CREEK-OBSERVED AND CALCULATED AVERAGE FLOWS

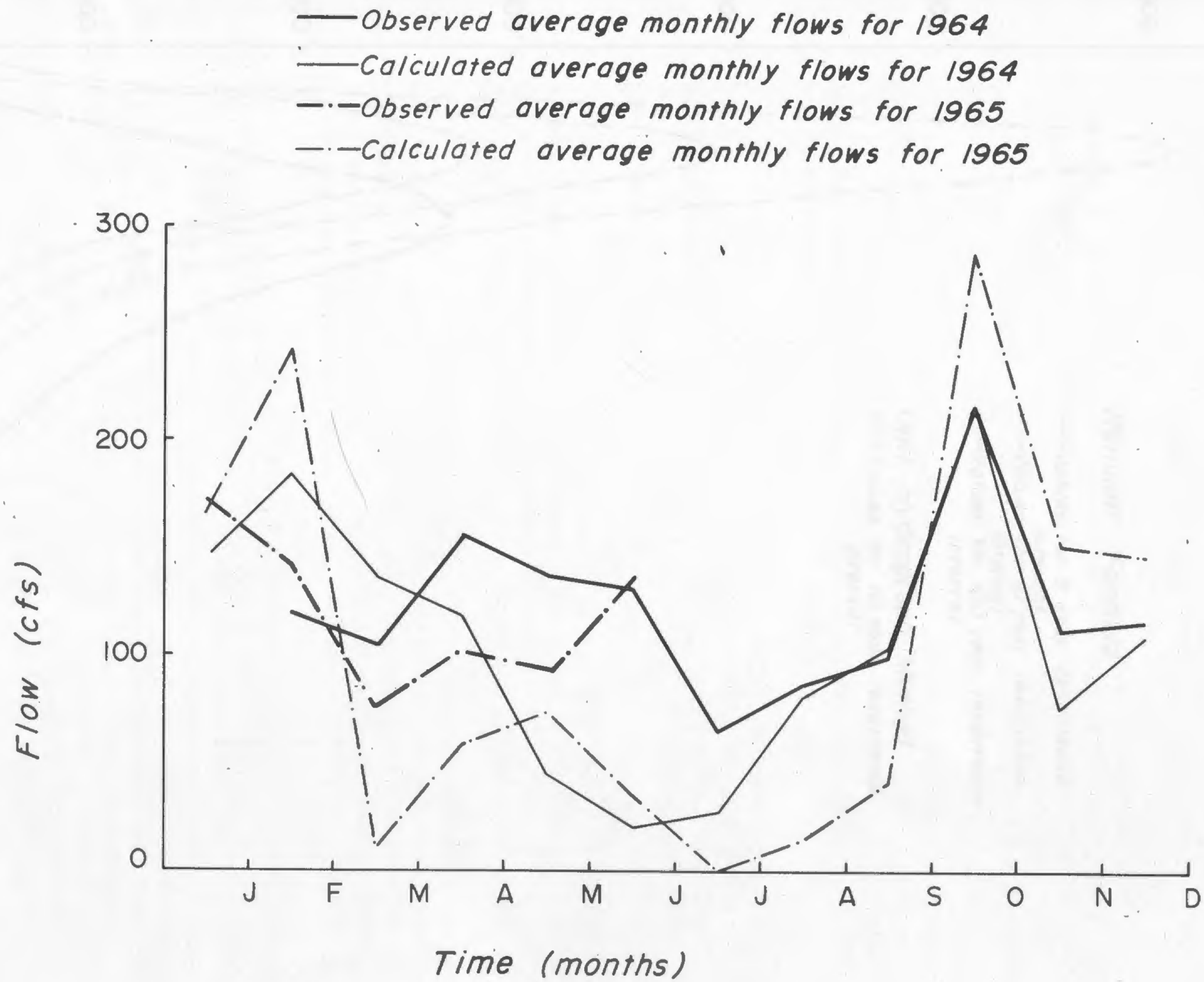
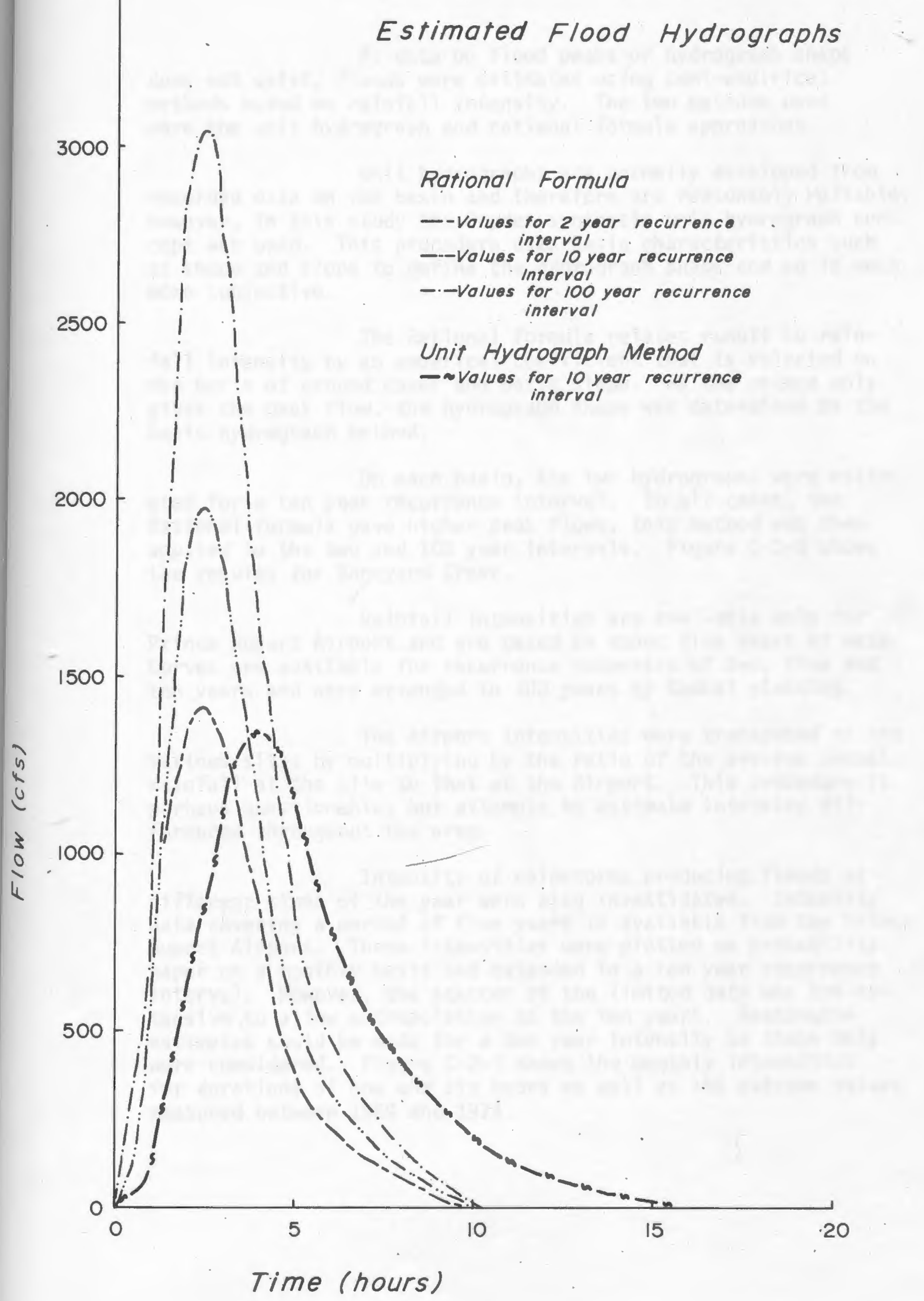


Fig. C-2-6 - BONEYARD CREEK



As data on flood peaks or hydrograph shape does not exist, floods were estimated using semi-empirical methods based on rainfall intensity. The two methods used were the unit hydrograph and rational formula approaches.

Unit hydrographs are normally developed from recorded data on the basin and therefore are reasonably reliable; however, in this study the Snyder synthetic unit hydrograph concept was used. This procedure uses basin characteristics such as shape and slope to define the hydrograph shape and so is much more subjective.

The Rational formula relates runoff to rainfall intensity by an emperical coefficient that is selected on the basis of ground cover and basin slope. As the method only gives the peak flow, the hydrograph shape was determined by the basic hydrograph method.

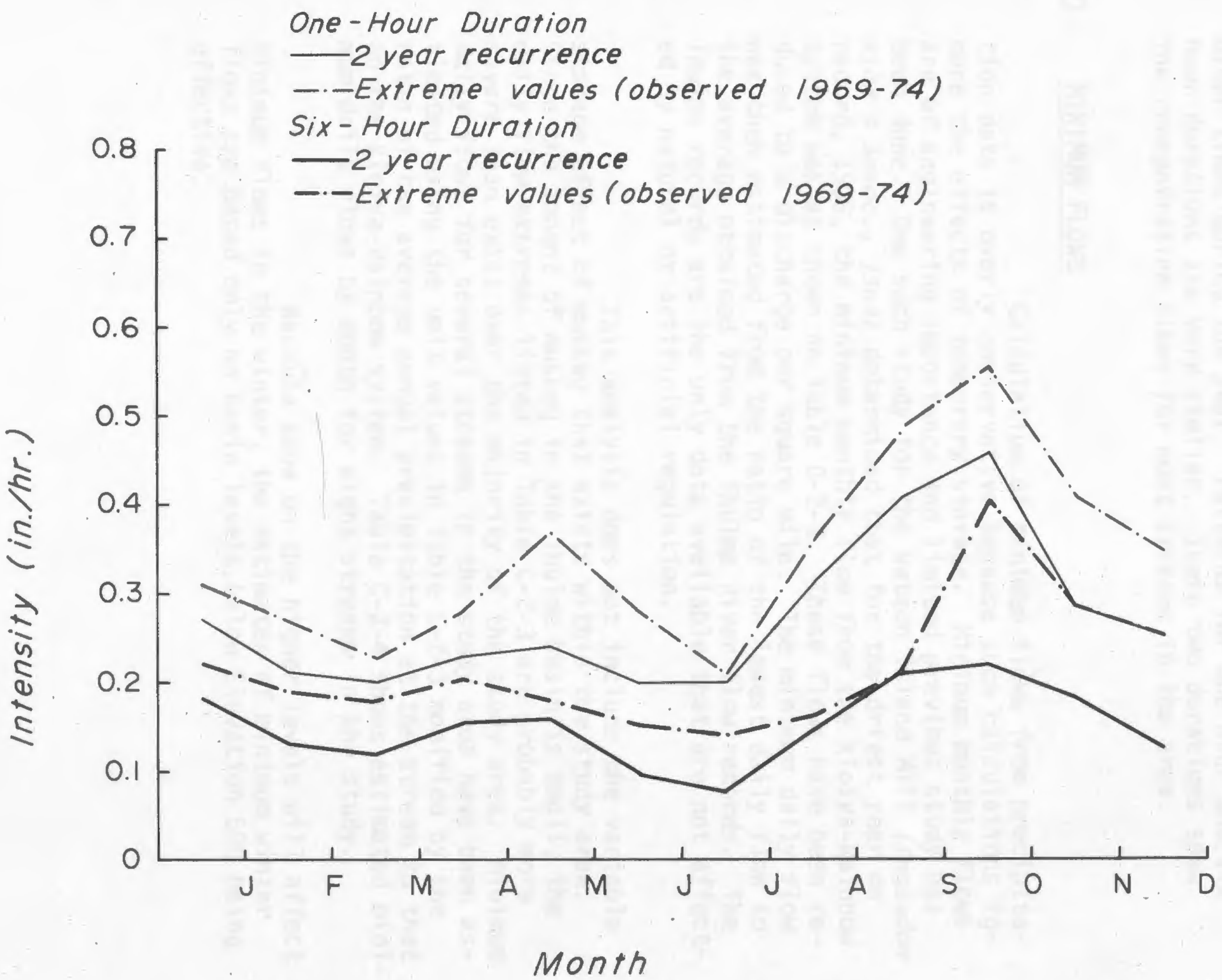
On each basin, the two hydrographs were estimated for a ten year recurrence interval. In all cases, the Rational formula gave higher peak flows; this method was then applied to the two and 100 year intervals. Figure C-2-6 shows the results for Boneyard Creek.

Rainfall intensities are available only for Prince Rupert Airport and are based on about five years of data. Curves are available for recurrence intervals of two, five and ten years and were extended to 100 years by Gumbel plotting.

The Airport intensities were transposed to the various sites by multiplying by the ratio of the average annual rainfall at the site to that at the Airport. This procedure is perhaps questionable, but attempts to estimate intensity differences throughout the area.

Intensity of rainstorms producing floods at different times of the year were also investigated. Intensity data covering a period of five years is available from the Prince Rupert Airport. These intensities were plotted on probability paper on a monthly basis and extended to a ten year recurrence interval. However, the scatter of the limited data was too extensive to allow extrapolation to the ten years. Reasonable estimates could be made for a two year intensity so these only were considered. Figure C-2-7 shows the monthly intensities for durations of one and six hours as well as the extreme values measured between 1969 and 1974.

Fig. C-2-7 - RAINFALL INTENSITY - DURATION CURVES, PRINCE RUPERT



In general terms the fall and early winter months experience significantly more intense rainfall than at other times during the year. Patterns for one hour and six hour durations are very similar. These two durations span the concentration times for most streams in the area.

4.0 MINIMUM FLOWS

Calculation of minimum flows from precipitation data is overly conservative because such calculations ignore the effects of temporary storage. Minimum monthly flows are of engineering importance and limited previous study has been done. One such study for the Watson Island Mill *(Ingledow Kidd & Assoc., 1964)* determined that for the driest year on record, 1935, the minimum monthly flow from the Kloiya-Rainbow system was as shown on Table C-2-3. These flows have been reduced to a discharge per square mile. The minimum daily flow was then estimated from the ratio of the lowest daily flow to the average obtained from the Thulme River flow records. The Thulme records are the only data available that are not affected by natural or artificial regulation.

This analysis does not include the variable storage effect of muskeg that exists within the study area. Since the amount of muskeg in the Thulme basin is small, the daily flow extremes listed in Table C-2-3 are probably more severe than exist over the majority of the study area. Minimum daily flows for several streams in the study area have been estimated using the unit values in Table C-2-3 modified by the ratio of the average annual precipitation at the stream to that on the Kloiya-Rainbow system. Table C-2-4 shows estimated minimum daily flows by month for eight streams in the study.

Because snow on the higher levels will affect minimum flows in the winter, the estimates of minimum winter flows are based only on basin levels below Elevation 500 being effective.

TABLE C-2-3

DERIVED MONTHLY FLOWS - 1935

KLOIYA - DIANA - RAINBOW

Month	Min. Ave. Monthly Discharge* Cfs.	Unit Ave. Monthly Discharge Cfs/sq. mi.	Est. Ratio Min. Daily Flow to** Ave. Monthly Flow	Est. Min. Daily Flow Cfs/sq. mi.
January	95	2.27	.3	.68
February	168	4.02	.25	1.00
March	119	2.85	.25	.71
April	56	1.34	.4	.54
May	61	1.46	.4	.58
June	104	2.49	.5	1.25
July	67	1.60	.5	.80
August	144	3.44	.5	1.72
September	182	4.35	.2	.87
October	250	5.98	.1	.60
November	357	8.54	.2	1.71
December	294	7.03	.3	2.11

* Ref. 1964, Ingledow Kidd report.

**Based on 1930-31 Thulme River data.

TABLE C-2-4

MINIMUM DAILY FLOWS

NTH	ESTIMATED MINIMUM DAILY FLOW (CFS)							
	Boneyard Creek	Stumaun Creek (Main Fork)	Stumaun Creek (West Fork)	Georgetown Creek	McNichol Creek	Wolf Creek	Lachmach River	Lahon (Pearl Harbour) Creek
N.	19	3	2	9	7	5	12	4
B.	28	4	2	14	10	7	17	6
R.	20	3	2	10	7	5	12	5
R.	15	2	1	8	6	4	9	3
Y	17	2	1	8	5	4	10	4
NE	35	5	3	17	12	9	22	8
LY	23	3	2	11	8	6	14	5
G.	49	6	4	24	17	12	30	11
P.	25	3	2	12	8	6	15	6
T.	17	2	1	8	6	4	10	4
V.	49	6	4	24	17	12	30	11
C.	60	8	5	30	20	14	37	14

ANNEX C-3

ESTUARINE AND MARINE CHARACTERISTICS

OF THE

STUDY AREA AND

PORT SITES

by

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Victoria, B.C.

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1. METHODS

General

The N.E.A.T. survey of the marine biology and oceanography of the Prince Rupert and Port Simpson areas was conducted by Dobrocky SEATECH Limited. The field work was performed between October 20 and November 8, 1974. Three investigators, E. Anderson, J. Dempsey and B. Lea worked from the 40 foot oceanographic vessel *SEATECH II* using a variety of instruments. A fourth investigator, J. Goddard, joined the field team during the census of intertidal biota. The form of the survey was adjusted to satisfy two purposes: first to investigate sites suggested for port development so that the value and vulnerability of their resident communities might be compared; second to provide a statistically useful baseline against which future changes might be measured.

Physical Oceanography

Temperature, salinity, and oxygen concentration were determined using a Hydrolab "Surveyor" model 6D *in situ* water quality analyzer. Water clarify was measured with a Hydroproducts Model 612 transmissometer. The reported values are per cent transmission of light from an incandescent source over a 1 m path. Currents were measured with a Helle Model 4100 current meter from an anchored vessel.

The manufacturers stated accuracies are as follows:

Parameter	Accuracy	Standardization
Temperature	$\pm$ 0.2 ^{o}C	Internal
Salinity	$\pm$ 0.15 ^{o}/oo	Internal
Oxygen	$\pm$ 0.2 mg x 1^{-1}	Winkler titration *(Strickland and Parsons, 1968)*
pH	$\pm$ 0.1 pH unit	Reference buffer
Transmissibilty	$\pm$ 2%	Internal
Current	$\pm$ 0.1 kn	Internal

Positions were determined by radar to $\pm$ 0.02 mile.

Plankton

Plankton samples were collected with a 3/4 m diameter opening and closing conical plankton net of 333 μ mesh apertures. The net was lowered to within 1 m of the bottom, opened, and towed at about 2.5 kn while hauling obliquely to the surface. Tows lasted about 5 minutes. The towing time, speed, depth of tow, and geometry of the net were used to calculate the theoretical volume sampled.

Benthos

Soft bottoms were sampled with a 0.052 m^2 Ponar Grab. The samples were seived through a 2 mm screen and the animals picked out and stored in buffered formalin. In the laboratory, the specimens were counted, identified, and weighed by G. O'Connell. Identifications were carried only so far as readily available keys and descriptions would allow with reasonable certainty, and effort was concentrated on the more common species. Some duplicate samples and reference specimens are retained by SEATECH.

The diversity index used here is H defined as $\Sigma p_i \log p_i$ where p_i is the proportion which the i^{th} species composes of the entire population. *Pielou (1969)* has shown that the calculation for finite samples should be performed according to the formula:

$$H = \frac{1}{N} \log \frac{N!}{N_1! \, N_2! \, N_3! \, \ldots \, N_s!} .$$

The base of the logarithm is not standard; 10 has been chosen here for convenience. To convert from $\log_{10}$ to $\log_2$, multiply by 3.322.

A series of submarine photographs was taken with a Benthos Model 371 Deep Sea Utility Camera to document the condition of the bottom. These are available at SEATECH.

Mechanical Analysis of Sediment Samples

Sub-samples from each grab sample and several beach sites were taken from particle size analysis. The method used was that adapted by *Coon and Ellis (1973)* from a method of the American Society of Engineers. Basically, the particles are dispersed in a detergent solution, the larger classes separated by seiving and weighed, and the smaller classes graded by hydrometry. The hydrometry procedure is based on the fact that larger particles fall faster.

The sorting coefficient is calculated as the ratio $S = \frac{03}{Q_1}$ where Q_3 and Q_1 are the first and third quartile diameters respectively. A marine sediment whose S is greater than 4.5 is considered poorly sorted.

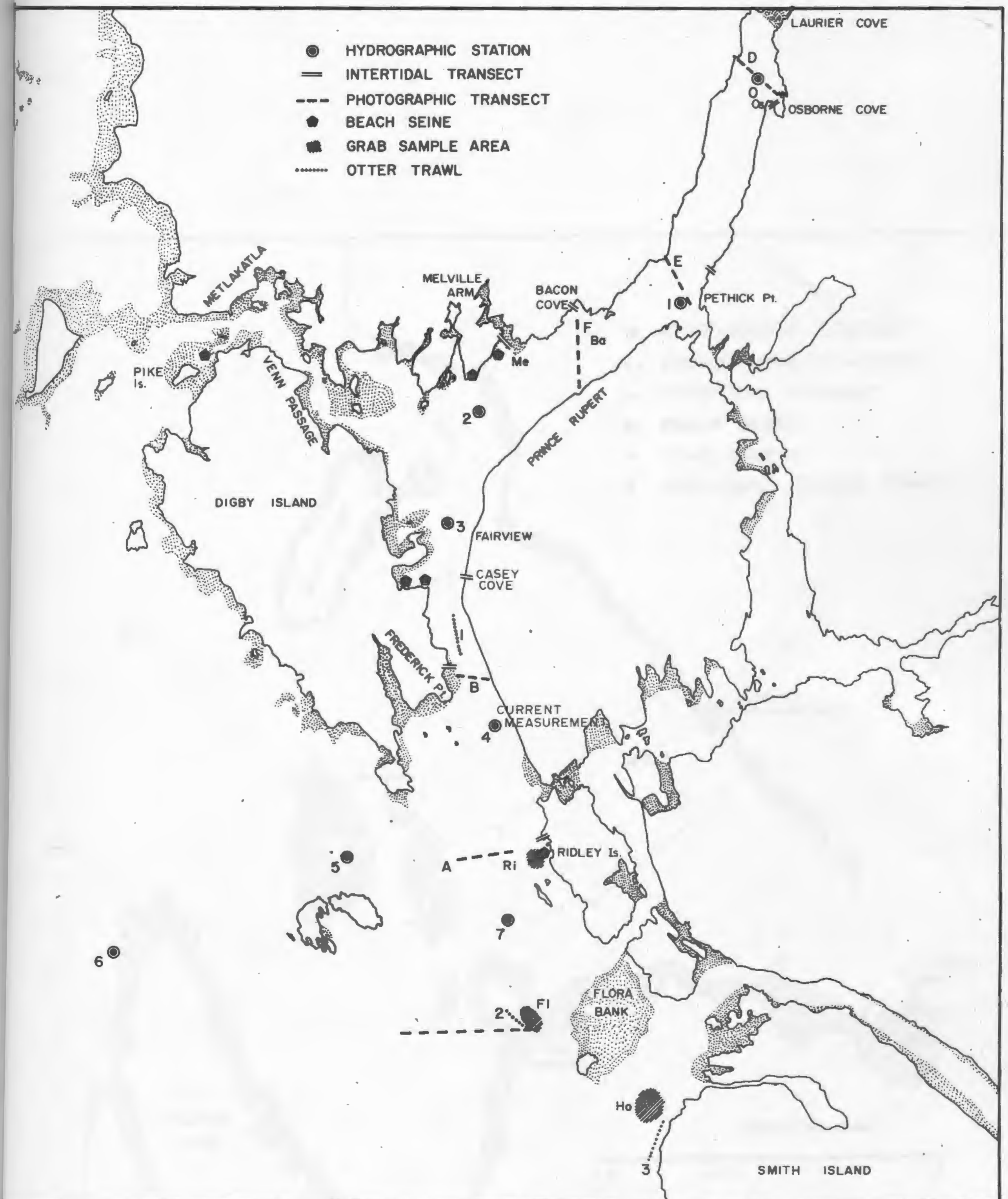
Beach Seining

The beach seine was 120 m long with mesh sizes approximately 5 cm (stretched) in the wings and approximately 0.8 cm in the pocket. All of the larger fish captured were measured. Most were released and a sub-sample kept for determination of their gut contents. Specimens of the smaller fish and invertebrates were preserved for identification in the laboratory.

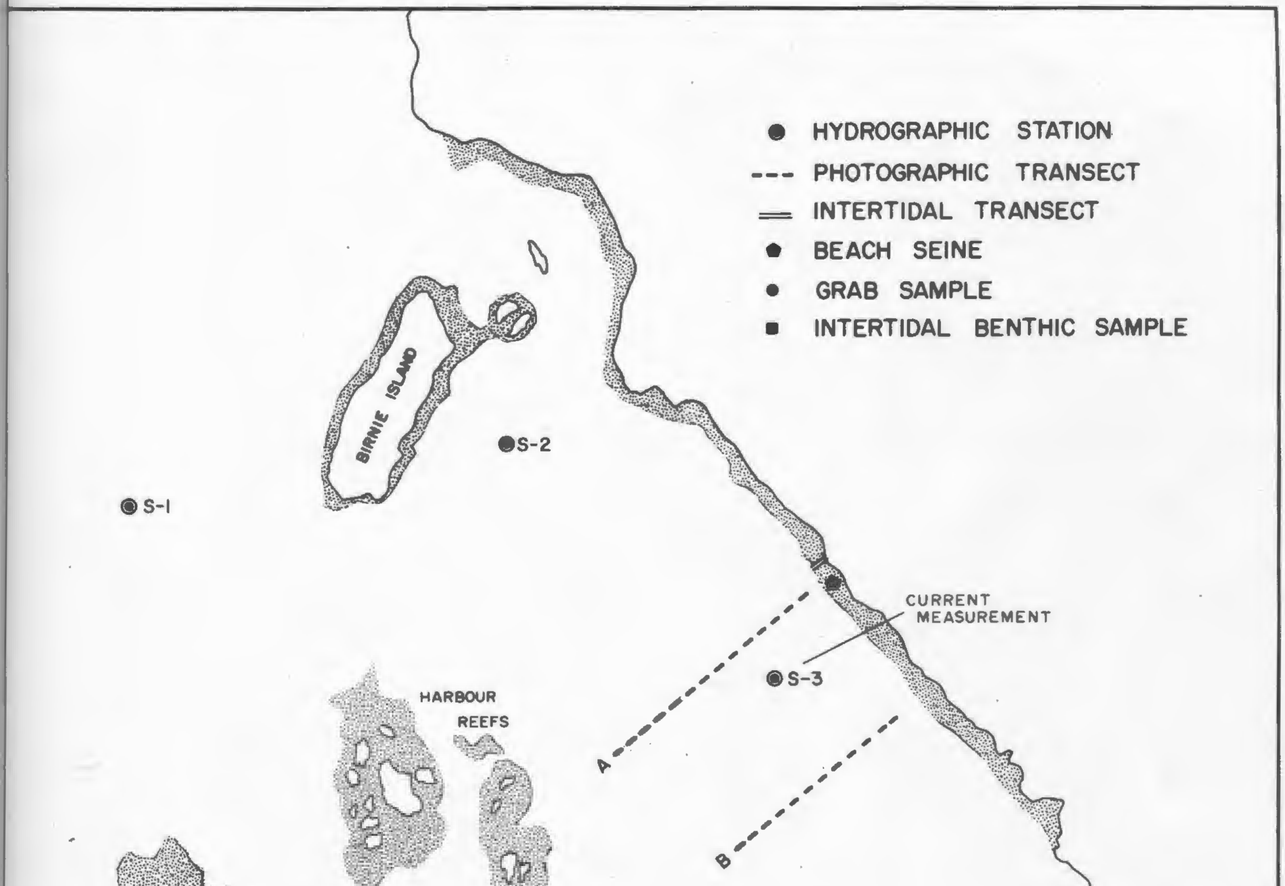
Intertidal Biota

Transects were laid out perpendicular to the shore from a conspicuous object above the high-water mark to the low water level, using a marked nylon line. At intervals along this line of 1 m, 2 m, or 4 m, depending on the slope of the shore, a 0.1 m^2 quadrat frame was placed over the line. One observer counted all the animals greater than 3 mm long which could be seen within the quadrat without excavation while the other recorded the data. Then the second observer estimated the per cent cover of macroscopic algae while the first recorded. Unfamiliar specimens were preserved for later identification. Two such transects were censused at each site. A colour photographic record of the sites is on file at SEATECH.

C-3-1



PRINCE RUPERT (reference Hydrographic Chart No. 3735)

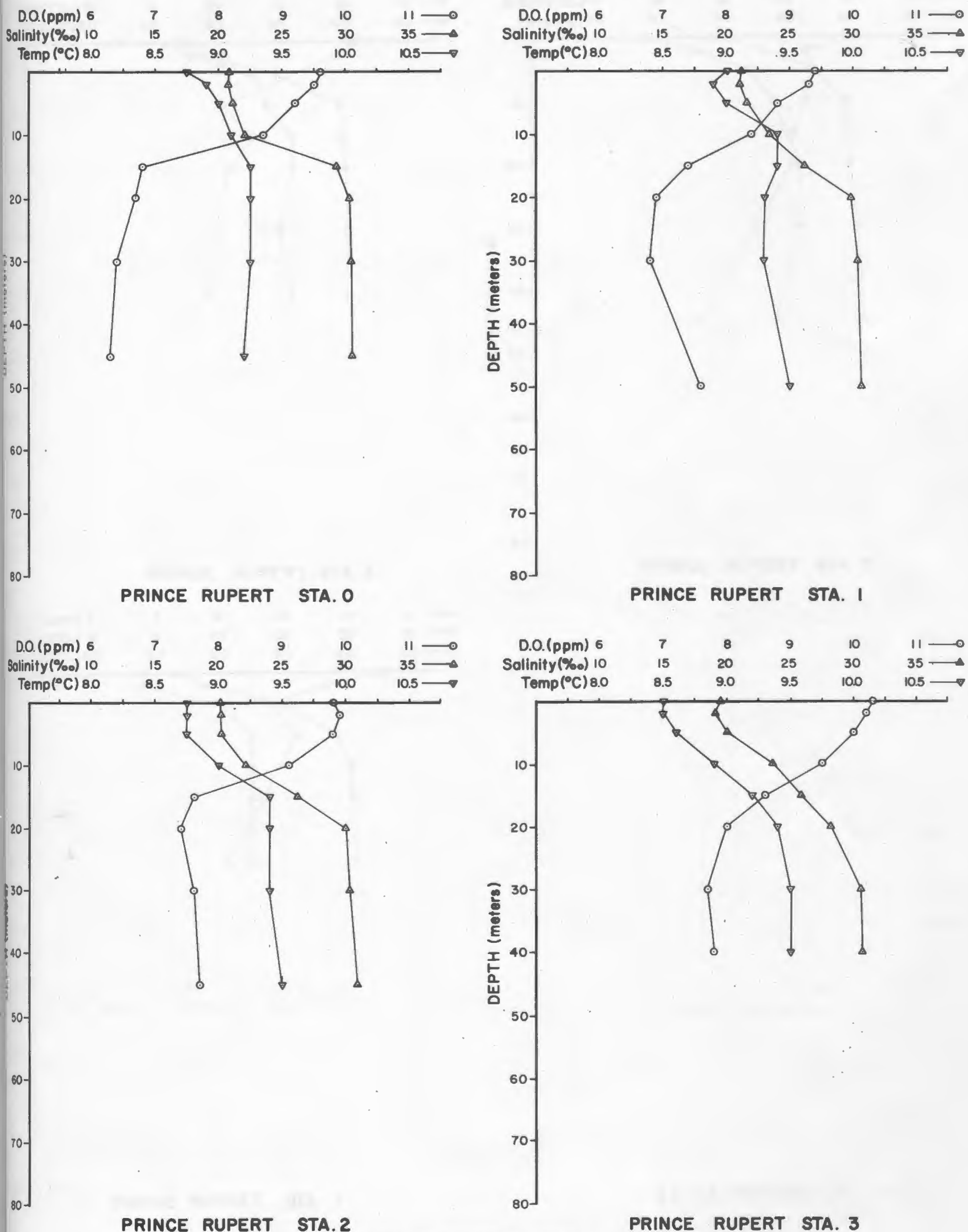


PORT SIMPSON (reference Hydrographic Chart No. 3982.)

NEAT

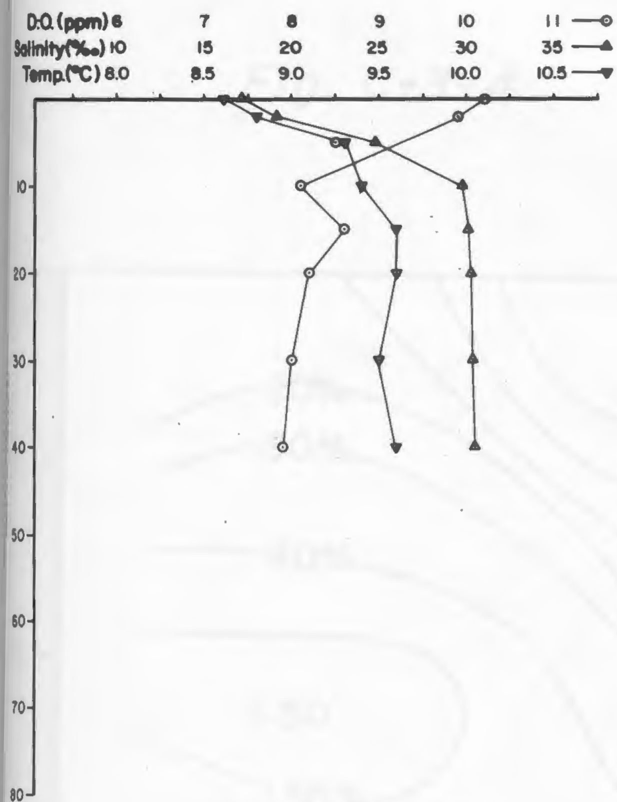
2. SUMMARY OF PHYSICAL AND CHEMICAL OCEANOGRAPHIC DATA FOR THE STUDY AREA.

Fig. C-3-3a- DISSOLVED OXYGEN CONCENTRATION, SALINITY and TEMPERATURE PROFILES

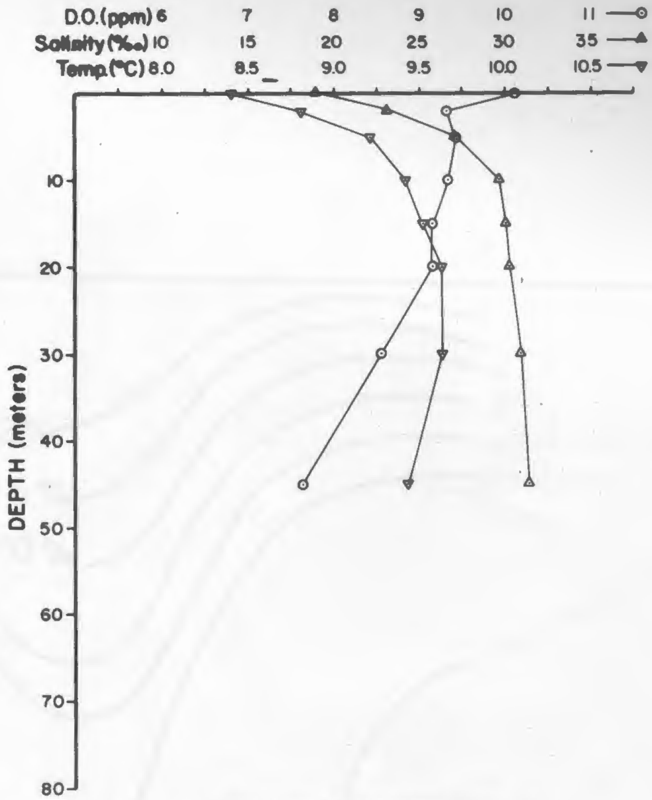


22-23 OCTOBER 1974

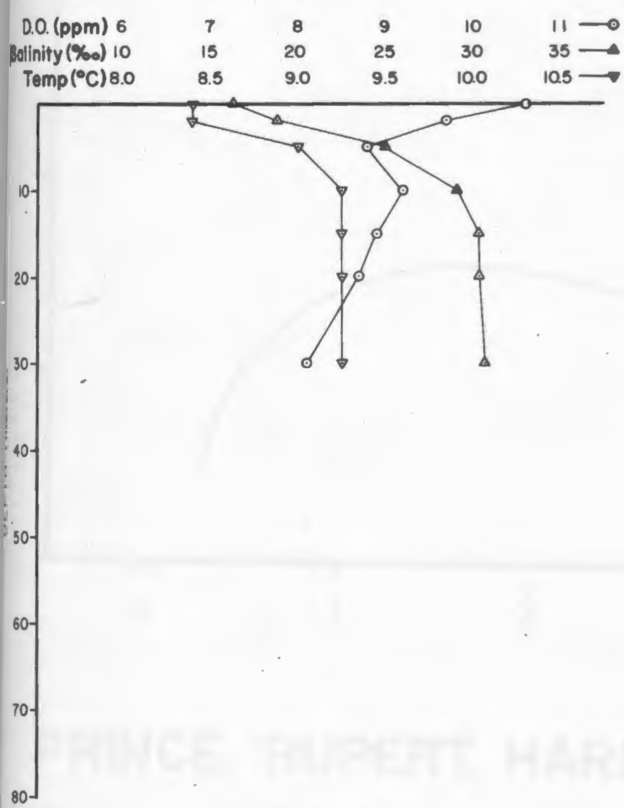
Fig. C-3-3b - DISSOLVED OXYGEN CONCENTRATION, SALINITY and TEMPERATURE PROFILES



PRINCE RUPERT STA. 4



PRINCE RUPERT STA. 5

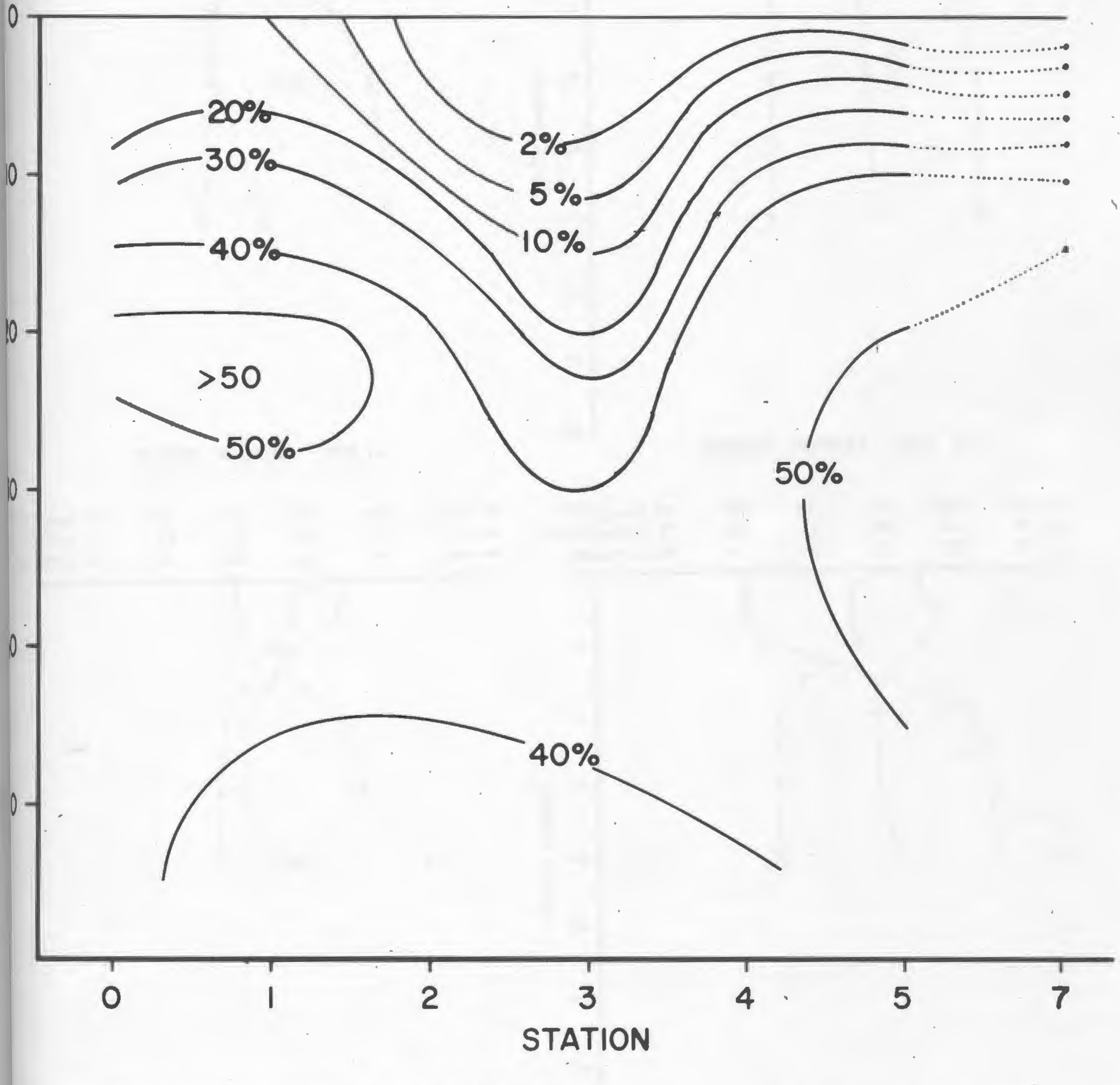


PRINCE RUPERT STA. 7

22-23 OCTOBER, 1974

NEAT

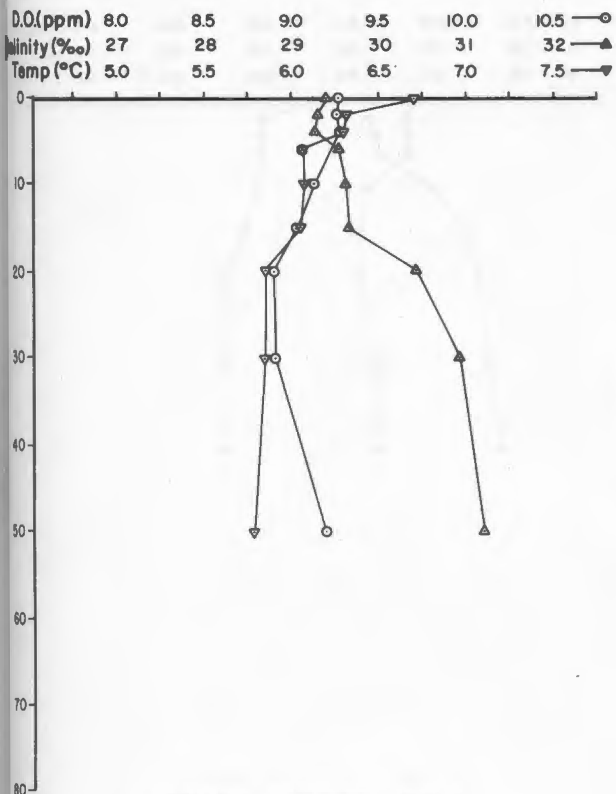
Fig. C-3-4



PRINCE RUPERT HARBOUR OCT. 22-23, 1974

% TRANSMISSIBILITY

C-3-5a- DISSOLVED OXYGEN CONCENTRATION, SALINITY and TEMPERATURE PROFILES



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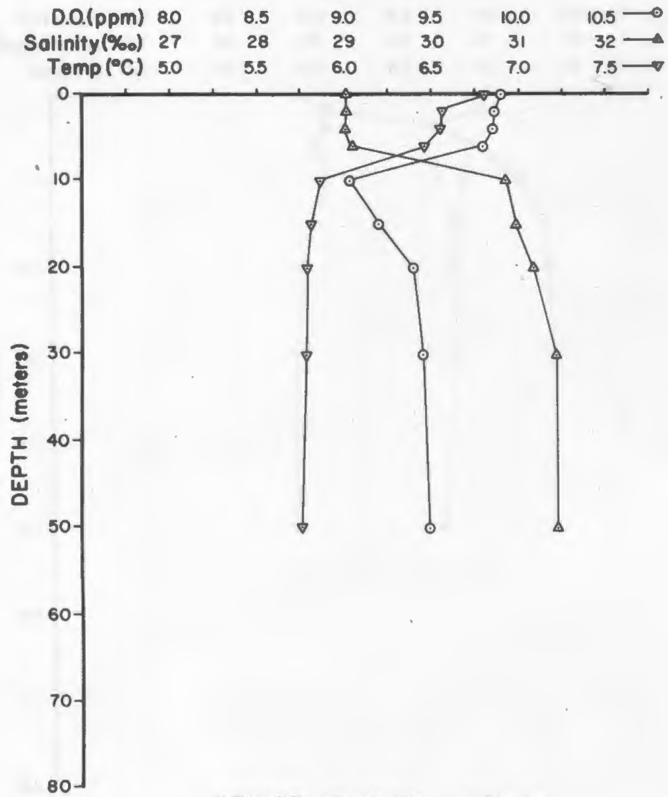
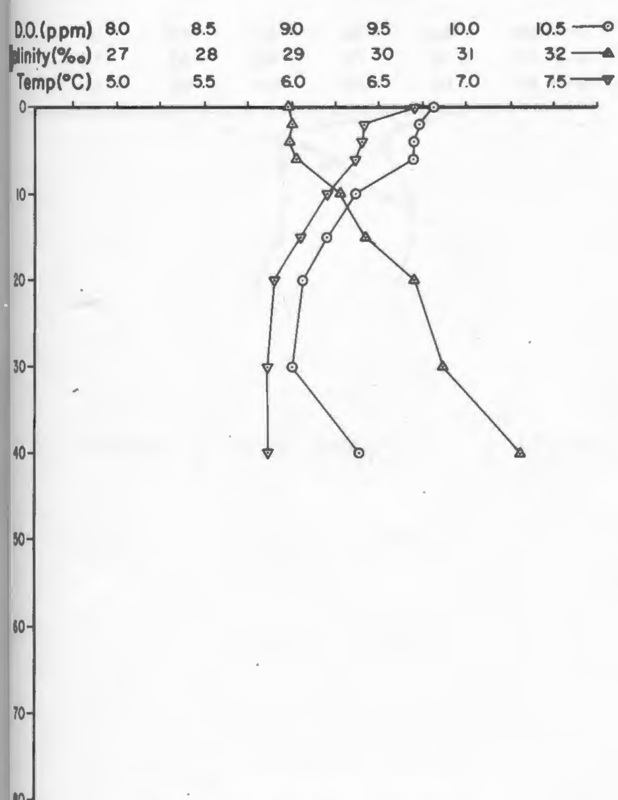


PRINCE RUPERT STA. 2



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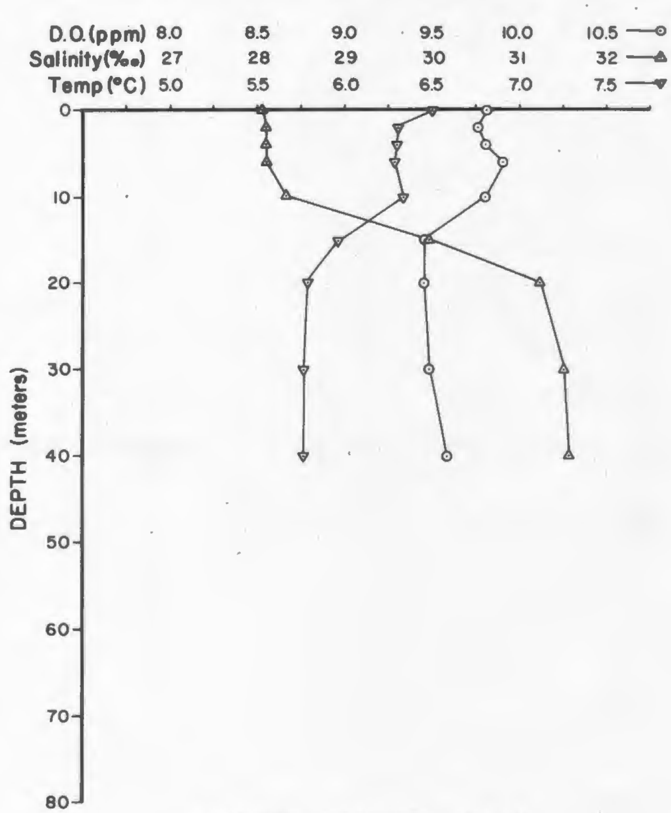
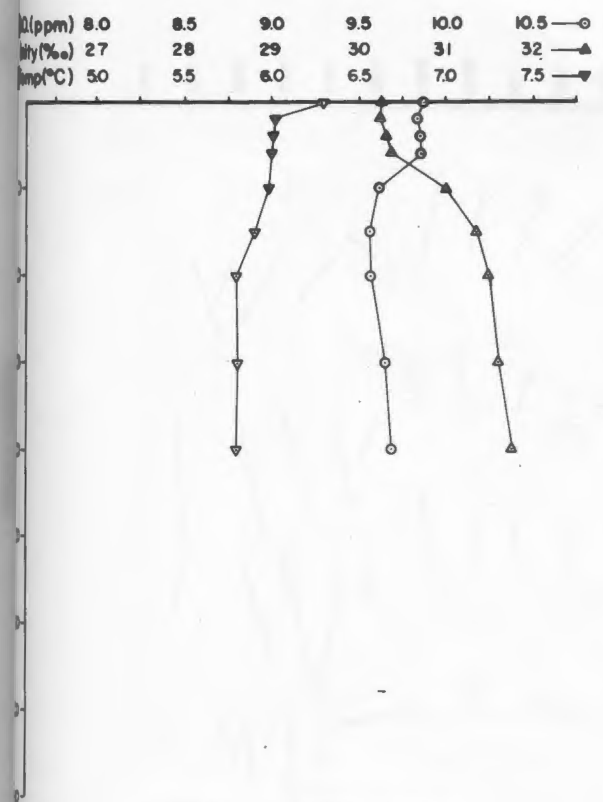


PRINCE RUPERT STA. 4

15–18 APRIL, 1961

NEAT

ig. C-3-5b - *DISSOLVED OXYGEN CONCENTRATION, SALINITY and TEMPERATURE PROFILE*



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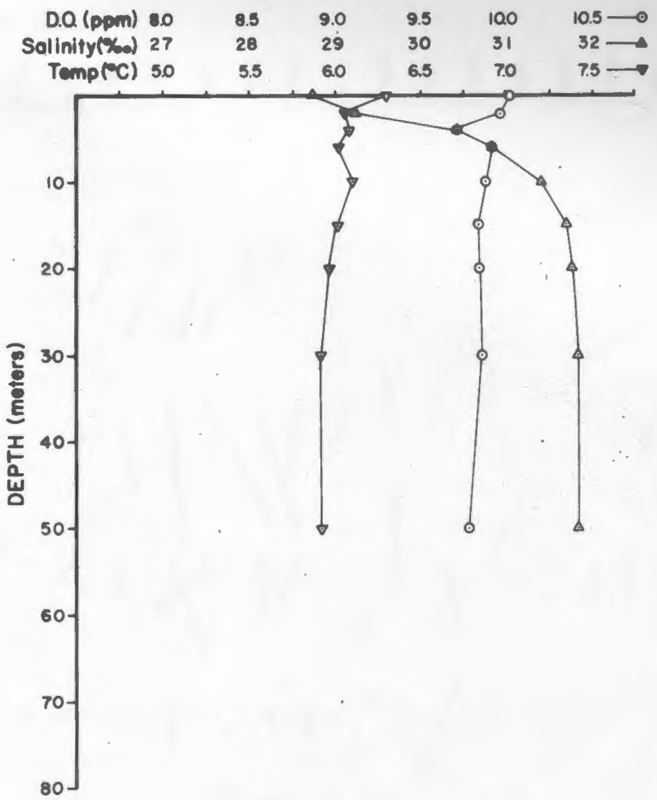

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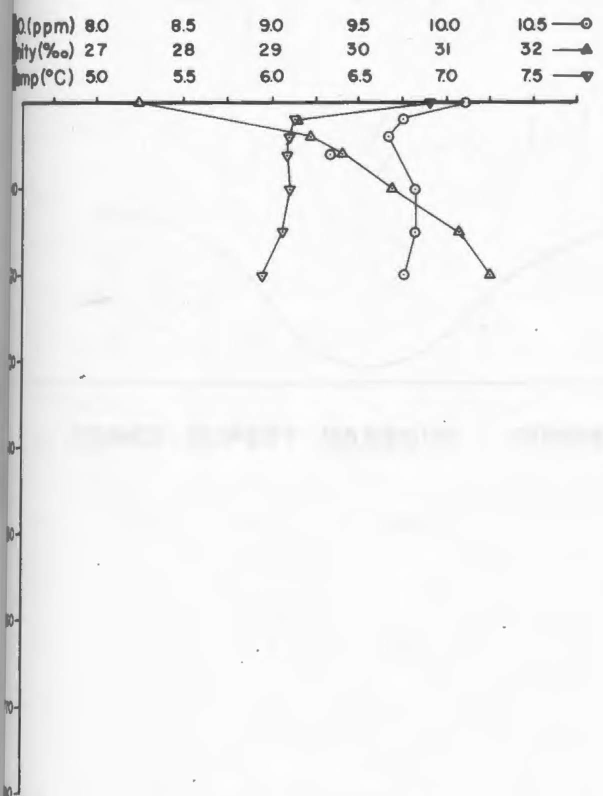
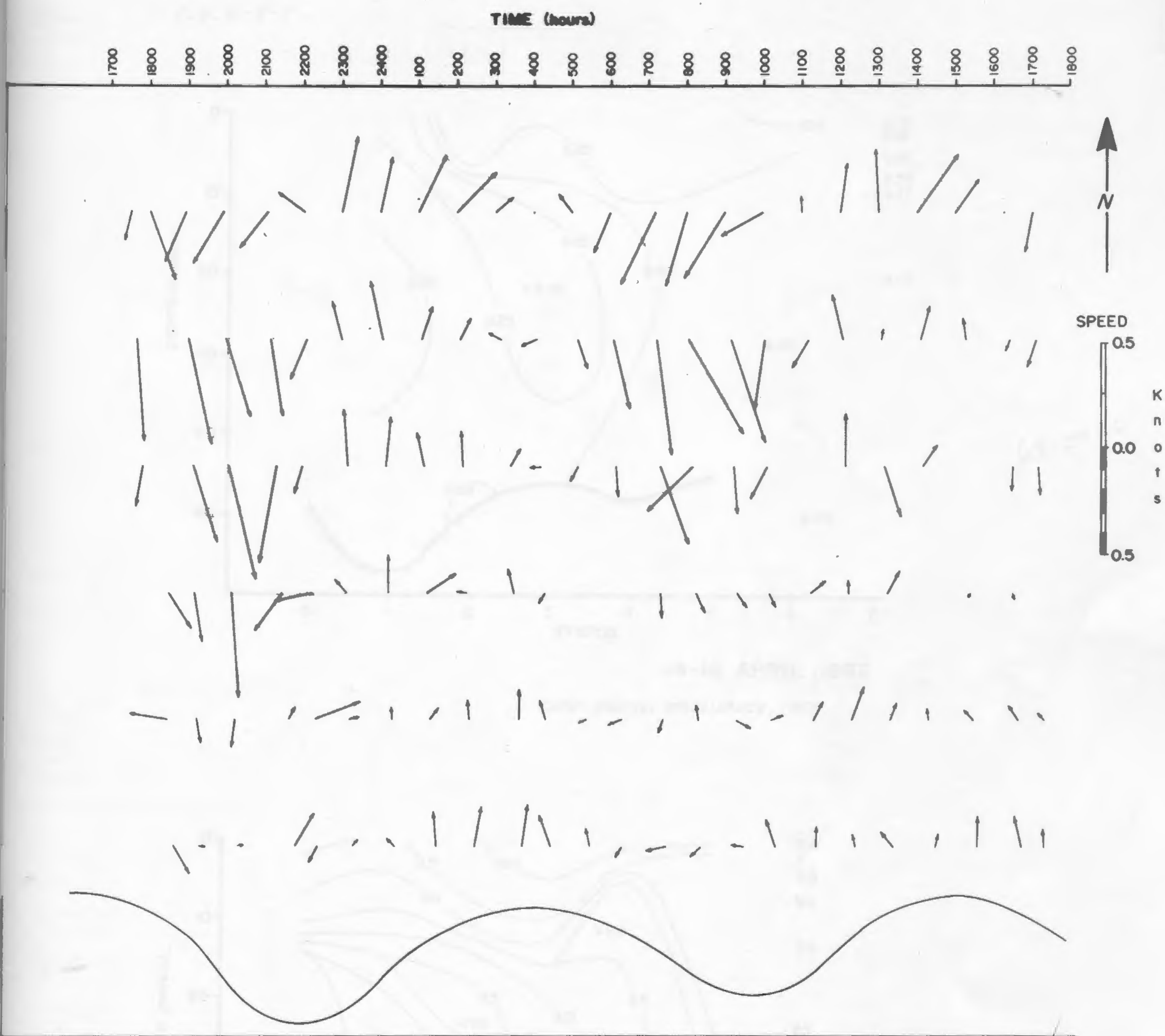


PRINCE RUPERT STA. 7

15-18 APRIL, 1961

Source: Waldichuck, et al. 1968.

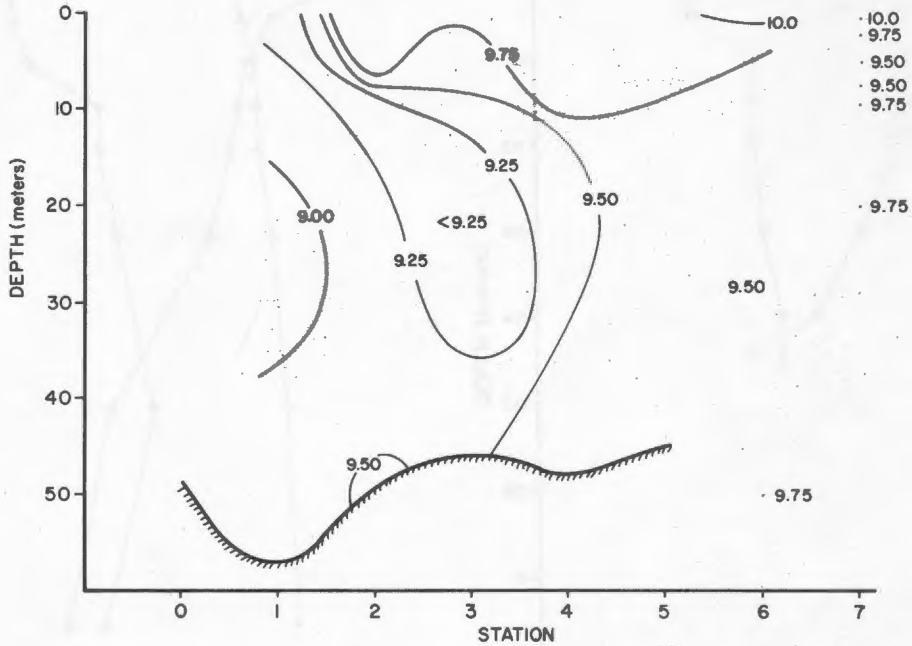


PRINCE RUPERT HARBOUR CURRENT MEASUREMENT 24-25 OCTOBER, 1964

Data source: Waldichuk, 1968.

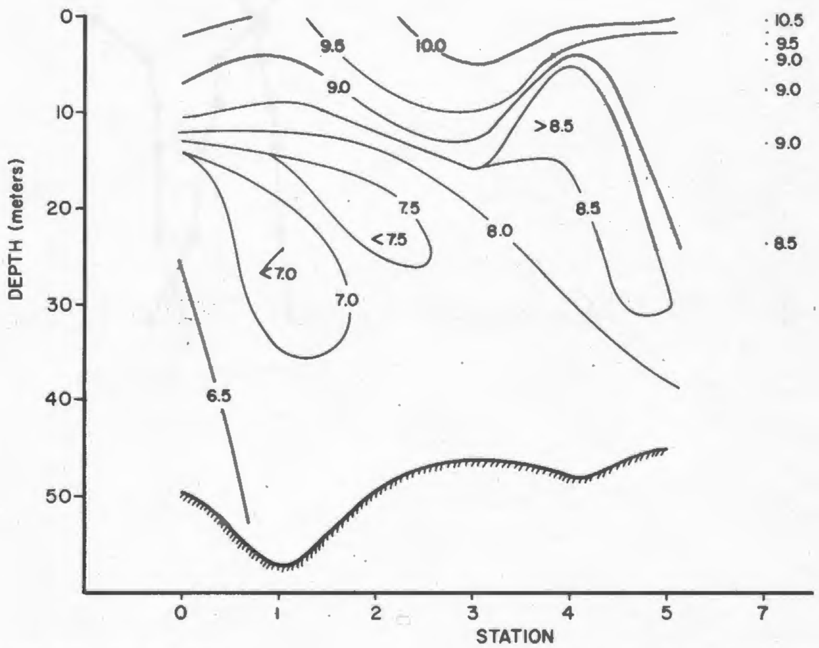
64-0012

Fig. C-3-7



14-18 APRIL ,1962

Data Source: Waldichuck, 1968.

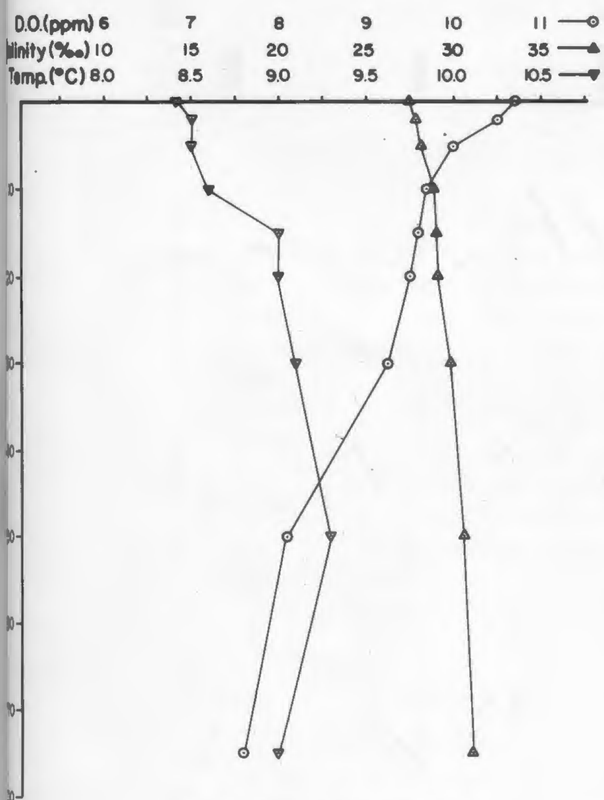


PRINCE RUPERT 22-23 OCTOBER,1974

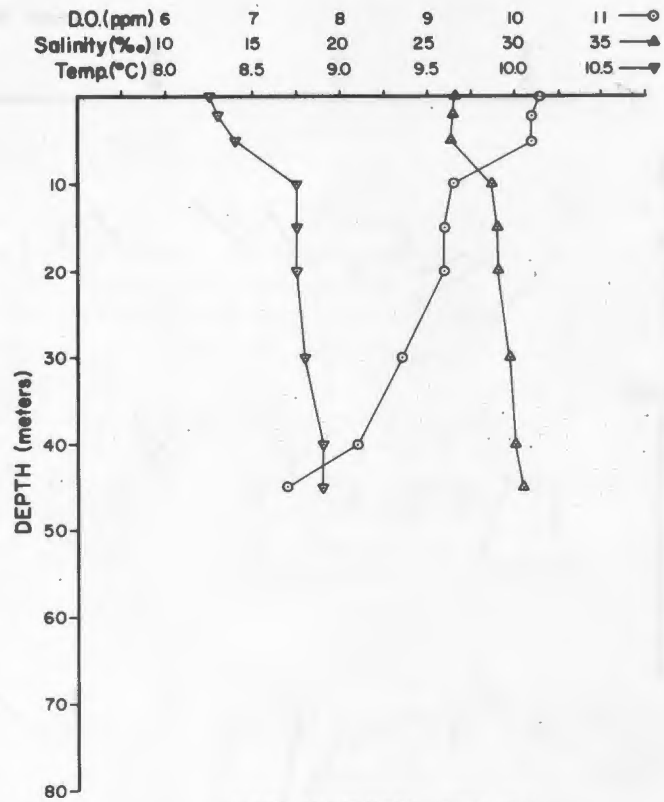
OXYGEN CONCENTRATIONS, mg/l

62-0020

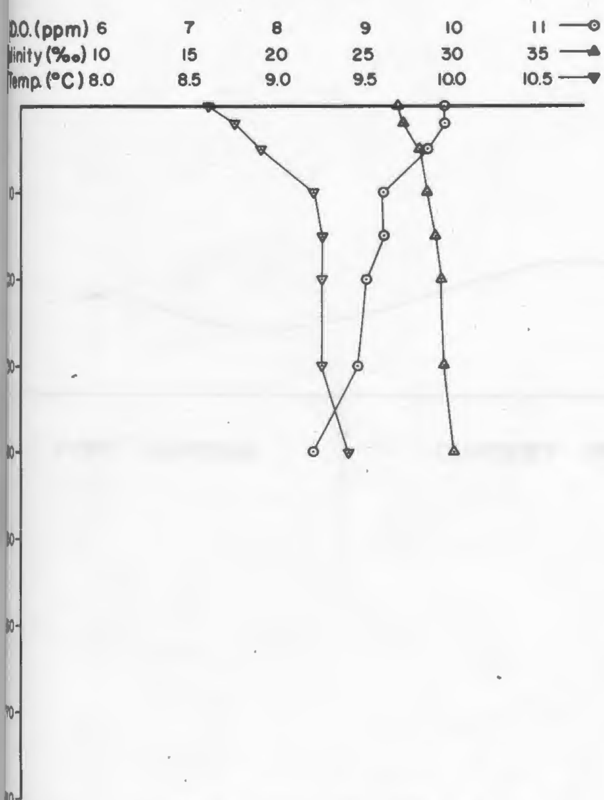
Fig. C-3-8- DISSOLVED OXYGEN CONCENTRATION, SALINITY and TEMPERATURE PROFILES



PORT SIMPSON STA. S1



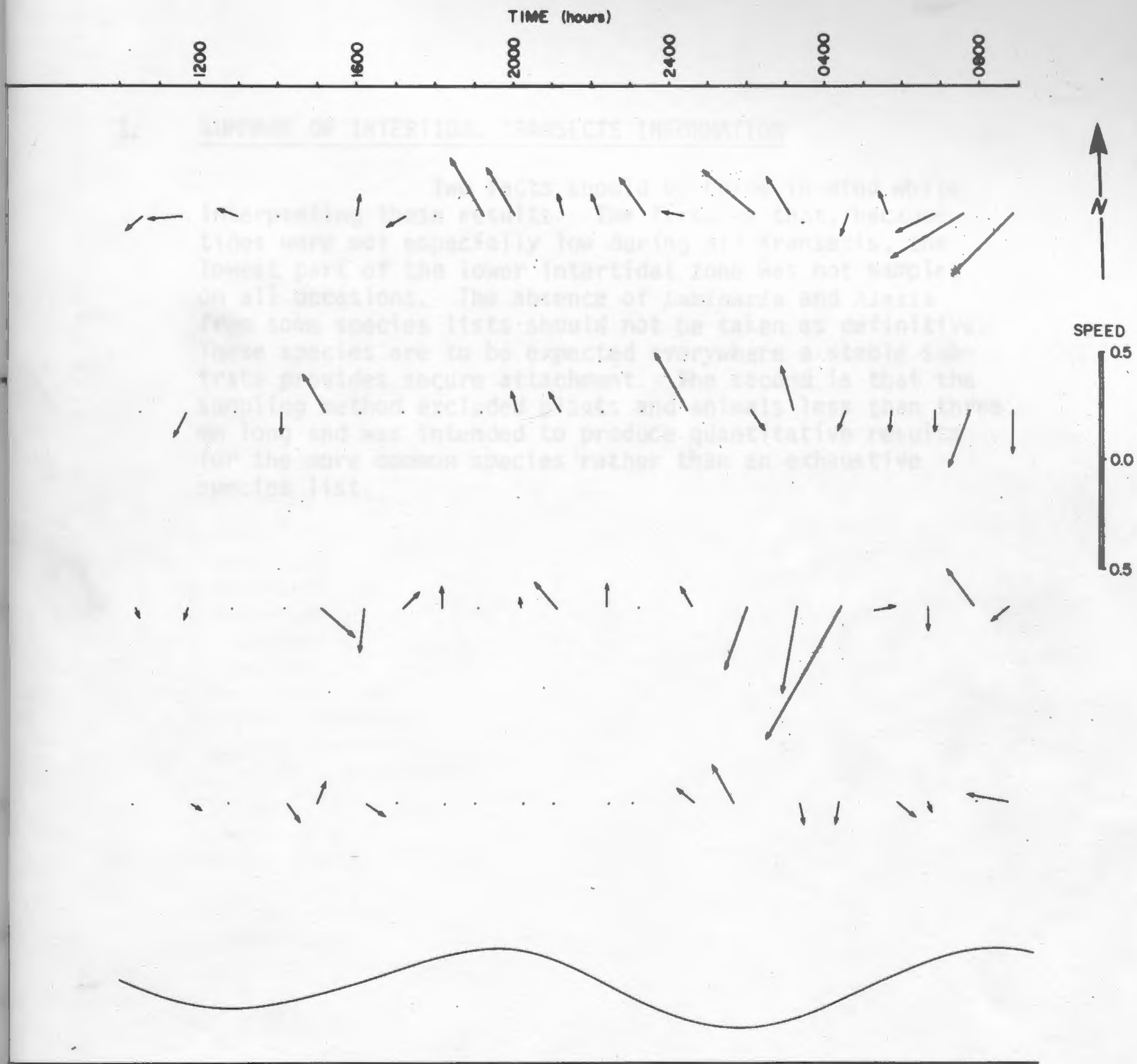
PORT SIMPSON STA. S2



PORT SIMPSON STA. S3

6 NOVEMBER, 1974

3-9



PORT SIMPSON CURRENT MEASUREMENT 7-8 NOVEMBER ,1974

3. SUMMARY OF INTERTIDAL TRANSECTS INFORMATION

Two facts should be borne in mind while interpreting these results. The first is that, because tides were not especially low during all transects, the lowest part of the lower intertidal zone was not sampled on all occasions. The absence of *Laminaria* and *Alaria* from some species lists should not be taken as definitive. These species are to be expected everywhere a stable substrate provides secure attachment. The second is that the sampling method excluded plants and animals less than three mm long and was intended to produce quantitative results for the more common species rather than an exhaustive species list.

Ridley Island (2 transects taken) DATE STUDIED: October 31, 1974

	Species	Total animals	No. quadrats with animal	Animals /m^2
r	*Littorina* sp.	80	2	160.0
w 2 m)	*Pagurus* sp.	3	2	6.0
	Tonicella lineata	2	2	4.0
	Mopalia hindsii	1	1	2.0
quadrats	*Acmaea scutum*	1	1	2.0
ied	Amphipods (gammarid - *Orchestria* sp?)	20	1	40.0
	Sponge (*Halichondria*?)		2	12%avg cover
mediate	*Tonicella lineata*	1	1	1.3
- 4 m)	*Littorina* sp.	1	1	1.3
	Pagurus sp.	2	1	2.5
	Mytilus edulis	1	1	1.3
	Balanus spp.		6	25%avg cover
	A. scutum	4	8	5.0
quadrats	*A. pelta*	1	1	1.3
ied	*Thais lamellosa*	1	1	1.3
	Katarina tunicata	3	2	3.8
	Mopalia hindsii	1	1	1.3
	Evasterias troschelli	2	2	2.5
	Terrebellid worm	1	1	1.3
	Sabellida worm	6	1	1.3
	Sponge (*Halichondria*?)		4	14%
r	*Mytilus edulis*	14	3	12.7
ve 4 m)	*Balanus* spp.		7	49.3%
	Littorina sitkana	78	3	70.9
n quadrats	*A. pelta*	10	5	9.1
ied	*A. digitalis*	8	3	7.3

tidal substrate data

	Zone	Comments
ey	Lower	Boulders.
nd	Intermediate	Boulders and bedrock.
	Upper	Large boulders and bedrock.

: Ridley Island (2 transects taken) DATE STUDIED: October 31, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
r ow 2 m)	*Laminaria* sp.	2	15%
quadrats	*Alaria* sp.	2	10%
ied	*Lithothamnion* sp.	2	7%
mediate	*Fucus gardneri*	3	5.3%
- 4 m)	*Gigartina* sp.	1	0.69%
quadrats ied	*Lithothamnion* sp.	4	9.4%
	Verrucaria sp.	3	3.3%
r	*Fucus*	10	69.0%
ve 4 m)	*Gigartina*	4	6.9%
en quadrats	*Verrucaria* sp.	5	12.7%
ied	*Lithothamnion*	2	8.2%

Frederick Point (2 transects taken) DATE STUDIED: November 2, 1974

	Species	Total animals	No. quadrats with animal	Animals /m²
ediate	*Acmaea digitalis*	46	9	41.8
4 m)	*A. scutum*	1	1	.9
	Mytilus edulis	209	10	190.0
	Thais emarginata	5	3	4.5
	Balanus sp.		10	15%avg cover
	Pagurus sp.	2	2	1.8
quadrats	*Littorina* spp.	320	9	290.9
d	Goby	1	1	.9
	Errant polychaete	1	1	.9
	Isopod (pillbox - *Ligia*?)	10	2	9.1
	Amphipod (gammarid - *Orchestria*?)	20	1	18.2
	Littorina spp.	210	3	210.0
4 m)	*Balanus* spp.		8	5.6%avg cover
	Acmaea digitalis	48	8	48.0
	Pagurus sp.	11	2	11.0
	Mytilus edulis	20	3	20.0
adrats	Isopods (pillbox - *Ligia*?)	14	3	14.0
d	Amphipods (gammand - *Orchestria*?)	95	4	95.0

idal substrate data

	Zone	Comments
rick	Lower	Sandy with some boulders.
t	Intermediate	Sandy with cobbles and some gravel.
	Upper	Large smooth cobbles, evidence of freshwater runoff.

: Frederick Point (2 transects taken) DATE STUDIED: November 2, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
rmediate	*Fucus gardneri*	4	8.6%
- 4 m)	*Ralfsia* sp.	6	4.6%
	Endocladia muricata	4	1.6%
en quadrats	*Gigartina* sp.	1	0.5%
ied	Green slime alga	4	x
r	*Fucus gardneri*	4	4.0%
ve 4 m)	*Ralfsia* sp.	2	1.0%
	Gigartina sp.	1	0.5%
uadrats	*Endocladia muricata*	1	0.5%
ied	Green slime alga	3	x

Fairview (2 transcects taken) DATE STUDIED: November 1, 1974

	Species	Total animals	No. quadrats with animal	Animals /m²
	Acmaea scutum	1	1	2.5
w 2 m)	*Pagurus* sp.	4	2	10.0
	Nemertean worm	1	1	2.5
uadrats	*Ceratostoma* sp.	5	1	12.5
led	Also seen in this zone:			
	Protothaca staminea			
	Saxidomuis sp.			
mediate	*Littorina* sp.	8	2	11.4
- 4 m)	*Balanus* spp.		6	15.7%avg cover
	A. pelta	5	3	7.1
	Mytilus edulis	6	2	8.6
quadrats	*Pagurus* sp.	2	2	2.8
led	Amphipods (*Orchestria*?)	Many	1	≈30
	Balanus sp.		6	15.7%avg cover
e 4 m)	*Mytilus edulis*	84	2	140.0
	A. pelta	32	5	53.3
uadrats	*Littorina sitkana*	22	4	36.7
led				

idal substrate data

	Zone	Comments
iew	Lower	Cobbles and sand.
	Intermediate	Boulders and cobbles.
	Upper	Gently sloping bedrock with some cobbles and gravel.

Fairview (2 transects taken) DATE STUDIED: November 1, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
	Ulva (Monostroma?)	2	2.5%
w 2 m)	*Gigartina* sp.	2	1.5%
	Alga C (unidentified)	1	1.3%
quadrats			
ed			
mediate	*Fucus gardneri*	3	5.1%
- 4 m)	*Gigartina* sp.	5	5.1%
	Ulva (Monostroma?)	3	1.7%
quadrats	*Verrucaria* sp.	1	0.7%
ed			
	Fucus gardneri	4	24.2%
e 4 m)	*Gigartina* sp.	4	7.5%
	Spongomorpha coalita	1	4.2%
uadrats	*Verrucaria* sp.	1	0.8%
ed	Alga C (unidentified)	1	12.5%

Melville Cove (2 transects taken) DATE STUDIED: October 29, 1974

	Species	Total animals	No. quadrats with animal	Animals /m²
	Acmaea scutum	3	1	7.5
2 m)	*Balanus* spp.	26	2	65.0
	Pagurus sp.	5	3	12.5
uadrats	*Thais emarginata*	2	1	5.0
d	Isopod (*Ligia*?)	3	1	7.5
	Amphipod (*Orchestria*?)	60	2	150.0
	Sponge (*Halichondria*?)		2	x
diate	*Balanus* spp.	465	4	930.0
4 m)	*A. scutum*	6	2	12.0
	Sponge (*Halichondria*?)		1	x
uadrats	*A. persona*	5	1	10.0
d	*Mytilus edulis*	1	1	2.0
	Littorina spp.	31	3	51.7
4 m)	*Balanus* spp.	680	5	1133.0
	A. persona	61	3	101.7
adrats	Isopod (*Ligia*?)	2	1	3.3
d	*Hemigrapsis* sp.	5	1	8.3

al substrate data

	Zone	Comments
le	Lower	Sand.
	Intermediate	Boulders, some sand and bedrock.
	Upper	Bedrock with large boulders.

Melville Cove (2 transects taken) DATE STUDIED: October 29, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
	Gigartina sp.	3	5.0%
2 m	*Fucus gardneri*	3	3.8%
uadrats ed	*Ralfsia* sp.	3	5.0%
ediate 4 m)	*Gigartina* sp.	4	16%
	Fucus gardneri	5	29%
	Ralfsia sp.	3	3%
uadrats ed	*Endocladia muricata*	3	7%
	Ulva (*Monostroma*?)	3	2.2%
	Gigartina sp.	4	6.7%
4 m)	*Fucus gardneri*	4	10.8%
	Ralfsia sp.	3	2.5%
adrats ed	*Endocladia muricata*	2	1.7%
	Lichen	1	x

: Bacon Cove   DATE STUDIED: October 30, 1974

	Species	Total animals	No. quadrats with animal	Animals /m²
:	*Seralsia dira*	2	2	6.6
pw 2 m)	*Orchestia* sp.	3	3	10.0
	Archaeomysis sp?(mysid)	1	1	3.3
	Tonicella lineata	12	3	40.0
	Acmaea digitalis	1	1	3.3
	Pagurus sp.	2	2	6.6
	Errant polychaete	4	1	13.3
quadrats	*Strongylocentrotus droebachiensis*	1	1	3.3
ied	Also seen:			
	Thais lamellosa (with eggs)			
	T. emargunata			
	Katarina tunicata			
	Pisaster ochraceous			
	Macoma nasuta			
	Clinocardium nikalli			
	Protothaca staminea			
	Venerupsis terierrima			
	Mya arenaria			
	Evasterias troschellii			
	Callianassa californiensis			
mediate	*Tonicella lineata*	2	2	5.0
- 4 m)	*Acmaea scutum*	21	4	52.5
	A. digitalis	8	4	20.0
	Pagurus sp.	7	4	17.7
	Seralsia dira	1	1	2.5
	Hemigrapsis sp.	3	2	7.5
	Balanus spp.		3	20%avg cover
	Cirolina kinkaidi	5	3	12.5
quadrats	*Mytilus edulis*	4	3	13.3
ed	*Littorina sitkana*	19	3	47.5
	Idotea sp.	x	1	
	Sponge (*Halichondria*?)	x	1	
	Pillbox isopod (*Ligia*?)	x	1	
r	*Mytilus edulis*	22	1	44.0
e 4 m)	*Littorina sitkana*	18	2	36.0
	Acmaea scutum	4	2	8.0
	A. digitalis	15	4	30.0
quadrats	*Balanus* spp.		2	30%avg cover
ed				

tidal substrate data

	Zone	Comments
Cove	Lower	Sandy with some broken rock and boulders.
	Intermediate	Broken rock and boulders.
	Upper	Bedrock, many projections and cracks.

Bacon Cove DATE STUDIED: October 30, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
	Ulva (*Monostroma*?)	2	3.3%
2 m)	*Gigartina* sp.	2	3.3%
	Also seen:		
	Laminaria sp.		
quadrats	*Phyllospadix scouleri*		
led	*Iridea cordata*		
mediate	*Ulva* (*Monostroma*?)	1	1.3%
- 4 m)	*Gigartina* sp.	4	30.0%
	Lithothamnion	1	1.3%
uadrats	*Fucus gardneri*	1	1.3%
led	*Ralfsia* sp.	3	16.3
	Fucus gardneri	3	33.0%
4 m)	*Gigartina* sp.	1	4.0%
	Ralfsia sp.	2	2.0%
uadrats			
led			

Also seen: lots of unattached *Fucus* at high water mark at head of bay.

: Port Simpson (2 transects taken)   DATE STUDIED: November 5, 1974

	Species	Total animals	No. quadrats with animal	Animals /m²
er	*Balanus* spp.	73	3	146.0
low 2 m)	*Katarina tunicata*	1	1	2.0
	Acmaea scutum	6	3	12.0
quadrats	*Pagurus* sp.	82	3	164.0
lied	*Tonicella lineata*	1	1	2.0
	Hemigrapsis sp.	2	1	4.0
	Isopod (*Ligia*?)	1	1	2.0
	Littorina spp.	16	2	32.0
	Amphipods (*Orchestia* sp?)	2	1	4.0
rmediate	*A. scutum*	14	4	14.0
- 4 m)	*Balanus* spp.		7	17.1%avg cover
	Littorina spp.	786	9	786.0
	Pagurus sp.	97	6	97.0
	Amphipods (*Orchestia* sp?)	20	2	20.0
uadrats	*Mytilus edulis*	86	6	86.0
lied	*A. digitalis*	21	5	21.0
	Goby	1	1	1.0
	Hemigrapsis sp.	1	1	1.0
	Thais emarginata	1	1	1.0
	A. persona	2	1	2.0
	Isopod (*Ligia*?)	1	1	1.0
er	*A. persona*	30	8	30.0
ve 4 m)	*Littorina* spp.	596	8	596.0
	Balanus spp.		9	5%
	Pagurus sp.	7	1	7.0
uadrats	*Mytilus edulis*	4	1	4.0
lied	Goby	1	1	1.0
	Amphipods (*Orchestia* sp?)	1	1	1.0

rtidal substrate data

	Zone	Comments
	Lower	Shelving bedrock with cracks.
pson	Intermediate	Shelving bedrock with boulders.
	Upper	Boulders and cobbles.

Port Simpson (2 transects taken) DATE STUDIED: November 5, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
	Fucus gardneri	5	9%
w 2 m)	*Lithothamnion*	3	9%
	Halosaccion glandiforme	1	4%
	Ralfsia sp.	3	3%
uadrats led	*Ulva (Monostroma?)*	1	1%
	Endocladia muricata	2	2%
	Gigartina sp.	3	4%
ediate	*Fucus gardneri*	7	25.0%
4 m)	*Ralfsia* sp.	5	7.5%
	Gigartina sp.	5	2.5%
adrats	*Endocladia muricata*	1	5.0%
led	*Lithothamnion* sp.	3	1.5%
	Fucus gardneri	5	7.0%
4 m)	*Ralfsia*	2	1.0%
	Endocladia muricata	3	1.5%
adrats	Terrestrial grasses	4	8.0%
ed	F.W. Chlorophyta	2	2.0%
	Moss	3	2.5%

: Pethick Point DATE STUDIED: October 30, 1974

	Species	Total animals	No. quadrats with animal	Animals $/m^2$
r ow 2m)	*Acmaea* sp. (juvenile)	30	1	150.0
	Cirolina kinkaidi	1	1	5.0
quadrats	*Balanus* sp.		1	30%avg cover
ied	*Thais lamellosa*(+*T. emarginata*)	67	1	335.0
mediate	*Acmaea* sp. (juvenile)	6	1	30.0
m)	*A. digitalis*	22	2	110.0
	A. scutum	24	2	120.0
	Balanus sp.		2	5% avg cover
quadrats	*Pagurus* sp.	1	1	5.0
ied	*Littorina sitkana*	3	1	15.0
r	*A digitalis*	47	3	156.0
ve 4 m)	*A. scutum*	18	3	60.0
	T. lamellosa	1	1	3.3
e quadrats	*L. sitkana*	Many	3	$>200/m^2$
ied	*Balanus* sp.		3	35%avg cover
	Mytilus edulis	27	1	90.0

rtidal substrate data

	Zone	Comments
ick nt	All	Steeply sloping bedrock with cracks.

Pethick Point DATE STUDIED: October 30, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
	Endocladia muricata	1	15.0%
2 m)	*Fucus gardneri*	1	5.0%
	Cryptosiphonia woodii	1	2.5%
adrats	*Ralfsia* sp.	1	x
ed	*Prionitis lanceolata*	1	5.0%
ediate	*Endocladia muricata*	2	10%
4 m)	*Cryptosiphonia woodii*	2	5%
	Fucus gardneri	1	2.5%
adrats	*Ralfsia* sp.	1	x
ed			
	Fucus gardneri	1	3.3%
4 m)	*Endocladia muricata*	1	1.7%
uadrats			
ed			

A: Osborne Cove DATE STUDIED: November 1, 1974

e	Species	Total animals	No. quadrats with animal	Animals /m^2
rmediate	*Balanus* spp.		2	53%avg cover
m - 4 m)	*Mytilus edulis*	55	2	280.0
	Acmaea pelta	22	2	110.0
quadrats	*A. digitalis*	2	1	10.0
died	*Littorina* sp.	40	2	200.0
	Sponge (*Halichondria*?)		1	<5%avg cover
er	*Balanus* spp.		3	72%avg cover
ove 4 m)	*Mytilus edulis*	51	3	170.0
	Littorina sitkana	200	3	666.0
	A. pelta	20	3	67.0
ee quadrats	*Pagurus* sp.	3	1	10.0
died	*A. digitalis*	1	1	3.3
	Cirolara kincaidi	4	1	13.3
	Amphipods (*Orchestria*?)	6	1	20.0

rtidal substrate data

a	Zone	Comments
orne	Intermediate	Sandy gravel and broken rock between bedrock outcrops
ve	Upper	Shelving bedrock.

Osborne Cove DATE STUDIED: November 1, 1974

	Species	No. of quadrats alga found in	Avg. % coverage of alga
ediate - 4 m) adrats led	*Fucus gardneri*	2	80%
e 4 m) uadrats led	*Fucus gardneri*	3	88%

4. SUMMARY OF BEACH SEINE RESULTS

EY COVE October 30, 1974

FISH

Platichthys stellatus	13	31.3cm 21.9cm 30.4cm 31.3cm 26.4cm 35.4cm 28.4cm 7.4cm 27.0cm 22.2cm 11.0cm 27.2cm 26.7cm
Aulorhynchus flavidus	36	
Clupea harengus pallasi	1	
Leptocottus armatus	26	28.0cm 24.5cm 22.2cm 19.0cm 10.5cm 13.3cm
Cymatogaster aggregata	1	
Clinocottus acuticeps	1	
Clupea harengus pallasi	14	average approx. 3.5cm

INVERTEBRATES

Anisogammarus (confervicolus?)
Pentidothea wosensenski
Crago alaskensis
Crago franciscorum
Mysid A
Harmothoe sp.

DS122 N.E.A.T. Beach Seine Data

PIKE ISLAND October 29,1974

FISH

Leptocottus armatus	16		average approx. 5.0cm			
Platichthys stellatus	20	34.5cm	37.2cm	28.3cm	23.3cm	23.5cm
		25.1	38.1	30.3	22.0	40.6
		23.1	35.4	27.0	24.7	26.8
		36.5	36.7	31.0	22.8	8.5
Gastereus aculeatus	1	3.8cm				
Clinocottus embryum	1	4.0cm				
Clupea harengus pallasi (*juvenile*)	400-500	average approx.3.5cm				

INVERTEBRATES

Cancer magister	1	17.0cm

RT SIMPSON November 6,1974

FISH

Platichthys stellatus	18	7.8cm 4.8cm 6.7cm 6.2cm 6.3cm 5.7cm 5.6cm 28.0cm 24.7cm 25.9cm 26.0cm 23.4cm 17.3cm 15.2cm 23.5cm 20.8cm 15.9cm 23.9cm
Leptocottus armatus	12	7.3cm 8.4cm 6.5cm 15.5cm 21.3cm 23.1cm 27.6cm 23.8cm 21.2cm 22.6cm 20.7cm 17.8cm
Enophrys bison	5	5.6cm 4.7cm 4.0cm 3.4cm 5.5cm
Cymatogaster aggregata	13	13.0cm 13.0cm 12.3cm plus 10 7.0cm-7.5cm
Inopsetta ischrya	14	7.0cm 6.3cm 6.6cm 6.6cm 6.6cm 7.2cm 7.2cm 7.6cm 7.8cm 7.9cm 7.9cm 7.8cm 8.1cm 8.6cm
Ammodytes hexapterus	2	9.8cm 9.6cm
Theragra chalcogramma	1	7.6cm
Gadus macrocephalus	3	12.9cm 13.6cm 16.4cm
Trichodon trichodon	3	13.7cm 12.2cm 12.5cm
Salvelinus malma	1	27.9cm

INVERTEBRATES

Cancer magister (all male)	8	13.7cm 6.8cm 8.7cm 7.3cm 6.6cm 7.2cm 6.2cm 7.0cm

Crago franciscorum
Mysid A
Pandalus danae

DLEY ISLAND October 31,1974

FISH

Platichthys stellatus	7	58.7cm 24.8cm 20.2cm 10.6cm 8.4cm 12.3cm 6.4cm
Gasterosteus aculeatus	4	3.5cm 4.0cm 3.8cm 3.1cm
Encphrys bison	15	average approx. 3.5cm
Aulorhynchus flavidus	25	average approx.12.6cm
Careproctus melanurus	17	2.8cm-7.6cm average approx.5.7cm
Liparis fucensis	5	6.0cm-11.7cm average approx. 9.0cm
Agonis acipenserinus	3	6.0cm 6.3cm 6.5cm
Hypomesus pretiosus pretiosus	1	12.6cm
Oncorhynchus keta (juvenile)	1	10.1cm
Thragra chalcogramma	3	5.0cm 6.3cm 10.3cm
Blepsias cirrhosus	3	10.4cm 10.6cm 13.0cm
Parophrys vetulus	64	21.6cm 17.0cm 15.6cm 11.0cm 11.5cm 28.0cm 16.5cm 14.9cm 13.0cm 16.3cm 13.8cm 18.7cm 16.6cm 15.2cm plus 50 others,various sizes(24 under 8.0cm)
Clinocottus acuticeps	4	1.8cm 2.2cm 2.4cm 2.7cm
Cymatogaster aggregata	25	15.4cm 14.4cm 14.3cm 13.0cm 14.3cm 14.5cm 12.5cm 14.9cm 14.3cm 12.4cm 15.0cm plus 14 others,various sizes.
Leptocottus armatus	28	26.1cm 17.5cm 19.9cm 17.8cm 22.5cm 19.0cm 21.5cm 18.6cm 21.0cm 8.2cm plus 18 others,various sizes.
Clupea harengus pallasi	43	average approx. 3.5cm

INVERTEBRATES

Cancer magister	4	12.6cm 14.5cm 17.0cm all female 16.1cm male

Crago alaskensis
Crago fransicorum
Anisogarmarus sp. (*confervicolus*?)
Penidotea wosensenski
Lacuna marmorataa

DLEY ISLAND October 31,1974

FISH

Platichthys stellatus	7	58.7cm 24.8cm 20.2cm 10.6cm 8.4cm 12.3cm 6.4cm
Gasterosteus aculeatus	4	3.5cm 4.0cm 3.8cm 3.1cm
Enophrys bison	15	average approx. 3.5cm
Aulorhynchus flavidus	25	average approx.12.6cm
Careproctus melanurus	17	2.8cm-7.6cm average approx.5.7cm
Liparis fucensis	5	6.0cm-11.7cm average approx. 9.0cm
Agonis acipenserinus	3	6.0cm 6.3cm 6.5cm
Hypomesus pretiosus pretiosus	1	12.6cm
Oncorhynchus keta (juvenile)	1	10.1cm
Thragra chalcogramma	3	5.0cm 6.3cm 10.3cm
Blepsias cirrhosus	3	10.4cm 10.6cm 13.0cm
Parophrys vetulus	64	21.6cm 17.0cm 15.6cm 11.0cm 11.5cm 28.0cm 16.5cm 14.9cm 13.0cm 16.3cm 13.8cm 18.7cm 16.6cm 15.2cm plus 50 others,various sizes(24 under 8.0cm)
Clinocottus acuticeps	4	1.8cm 2.2cm 2.4cm 2.7cm
Cymatogaster aggregata	25	15.4cm 14.4cm 14.3cm 13.0cm 14.3cm 14.5cm 12.5cm 14.9cm 14.3cm 12.4cm 15.0cm plus 14 others,various sizes.
Leptocottus armatus	28	26.1cm 17.5cm 19.9cm 17.8cm 22.5cm 19.0cm 21.5cm 18.6cm 21.0cm 8.2cm plus 18 others,various sizes.
Clupea harengus pallasi	43	average approx. 3.5cm

INVERTEBRATES

Cancer magister	4	12.6cm 14.5cm 17.0cm all female 16.1cm male

Crago alaskensis
Crago fransicorum
Anisogarmarus sp. (*confervicolus?*)
Penidotea wosensenski
Lacuna marmorataa

DS122 N.E.A.T. Beach Seine Data

PIKE ISLAND October 29,1974

FISH

Leptocottus armatus	16		average approx.		5.0cm	
Platichthys stellatus	20	34.5cm	37.2cm	28.3cm	23.3cm	23.5cm
		25.1	38.1	30.3	22.0	40.6
		23.1	35.4	27.0	24.7	26.8
		36.5	36.7	31.0	22.8	8.5
Gastereus aculeatus	1	3.8cm				
Clinocottus embryum	1	4.0cm				
Clupea harengus pallasi (*juvenile*)	400-500	average approx.3.5cm				

INVERTEBRATES

Cancer magister	1	17.0cm

EY COVE October 30, 1974

FISH

Platichthys stellatus	13	31.3cm 21.9cm 30.4cm 31.3cm 26.4cm 35.4cm 28.4cm 7.4cm 27.0cm 22.2cm 11.0cm 27.2cm 26.7cm
Aulorhynchus flavidus	36	
Clupea harengus pallasi	1	
Leptocottus armatus	26	28.0cm 24.5cm 22.2cm 19.0cm 10.5cm 13.3cm
Cymatogaster aggregata	1	
Clinocottus acuticeps	1	
Clupea harengus pallasi	14	average approx. 3.5cm

INVERTEBRATES

Anisogammarus (confervicolus?)
Pentidothea wosenenski
Crago alaskensis
Crago franciscorum
Mysid A
Harmothoe sp.

LEY ISLAND October 31,1974

FISH

Platichthys stellatus	7	58.7cm 24.8cm 20.2cm 10.6cm 8.4cm 12.3cm 6.4cm
Gasterosteus aculeatus	4	3.5cm 4.0cm 3.8cm 3.1cm
Enophrys bison	15	average approx. 3.5cm
Aulorhynchus flavidus	25	average approx.12.6cm
Careproctus melanurus	17	2.8cm-7.6cm average approx.5.7cm
Liparis fucensis	5	6.0cm-11.7cm average approx. 9.0cm
Agonis acipenserinus	3	6.0cm 6.3cm 6.5cm
Hypomesus pretiosus pretiosus	1	12.6cm
Oncorhynchus keta (juvenile)	1	10.1cm
Thragra chalcogramma	3	5.0cm 6.3cm 10.3cm
Blepsias cirrhosus	3	10.4cm 10.6cm 13.0cm
Parophrys vetulus	64	21.6cm 17.0cm 15.6cm 11.0cm 11.5cm 28.0cm 16.5cm 14.9cm 13.0cm 16.3cm 13.8cm 18.7cm 16.6cm 15.2cm plus 50 others,various sizes(24 under 8.0cm)
Clinocottus acuticeps	4	1.8cm 2.2cm 2.4cm 2.7cm
Cymatogaster aggregata	25	15.4cm 14.4cm 14.3cm 13.0cm 14.3cm 14.5cm 12.5cm 14.9cm 14.3cm 12.4cm 15.0cm plus 14 others,various sizes.
Leptocottus armatus	28	26.1cm 17.5cm 19.9cm 17.8cm 22.5cm 19.0cm 21.5cm 18.6cm 21.0cm 8.2cm plus 18 others,various sizes.
Clupea harengus pallasi	43	average approx. 3.5cm

INVERTEBRATES

Cancer magister	4	12.6cm 14.5cm 17.0cm all female 16.1cm male

Crago alaskensis
Crago fransicorum
Anisogarmarus sp. (*confervicolus*?)
Penidotea wosensenski
Lacuna marmorataa

RT SIMPSON November 6,1974

FISH

Platichthys stellatus	18	7.8cm 4.8cm 6.7cm 6.2cm 6.3cm 5.7cm 5.6cm 28.0cm 24.7cm 25.9cm 26.0cm 23.4cm 17.3cm 15.2cm 23.5cm 20.8cm 15.9cm 23.9cm
Leptocottus armatus	12	7.3cm 8.4cm 6.5cm 15.5cm 21.3cm 23.1cm 27.6cm 23.8cm 21.2cm 22.6cm 20.7cm 17.8cm
Enophrys bison	5	5.6cm 4.7cm 4.0cm 3.4cm 5.5cm
Cymatogaster aggregata	13	13.0cm 13.0cm 12.3cm plus 10 7.0cm-7.5cm
Inopsetta ischrya	14	7.0cm 6.3cm 6.6cm 6.6cm 6.6cm 7.2cm 7.2cm 7.6cm 7.8cm 7.9cm 7.9cm 7.8cm 8.1cm 8.6cm
Ammodytes hexapterus	2	9.8cm 9.6cm
Theragra chalcogramma	1	7.6cm
Gadus macrocephalus	3	12.9cm 13.6cm 16.4cm
Trichodon trichodon	3	13.7cm 12.2cm 12.5cm
Salvelinus malma	1	27.9cm

INVERTEBRATES

Cancer magister (all male)	8	13.7cm 6.8cm 8.7cm 7.3cm 6.6cm 7.2cm 6.2cm 7.0cm
Crago franciscorum		
Mysid A		
Pandalus danae		

5. SUMMARY OF BENTHIC INVERTEBRATE DATA

Summary of benthic fauna taken in 0.052 m^2 Ponar grab.

Station	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2
Depth, m	53	47	45	46	47	47	45	128	48	45
Number animals	49	48	58	48	91	27	39	10	44	30
Number species	16	17	19	12	28	14	15	5	12	10
Weight Total	22.53	52.38	34.05	14.05	24.59	22.80	9.92	34.09	195.02	186.24
Weight animals <4 g	4.55	8.26	7.15	9.28	14.70	3.85	5.22	5.99	4.01	3.44
Diversity	0.859	0.838	0.878	0.805	1.123	0.852	0.889	0.418	0.738	0.712
Median substrate size										
Sorting coefficient										

Station, m	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Depth	8m	8.5	13m	8.5	?	9	7
Number animals	626	737	112	140	74	37	88
Number species	12	16	20	11	9	7	17
Weight Total	7.45	6.45	72.37	3.52	2.19	3.47	5.11
Weight animals <4 g	7.45	6.45	4.23	3.52	2.19	3.47	5.11
Diversity	0.174	0.185	1.056	0.559	0.514	0.469	1.003
Median substrate size							
Sorting coefficient							

Bivalvia By numbers

	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Cyclocardia ventricosa ventricosa Gould, 1850					15							1					
Clinocardium fucanum Dall, 1907				2									1				
Acila castrensis Hinds, 1843					3												
Astarte alaskensis Dall, 1903				1	2												
Yolcia amygdalea Valenciennes, 1846	2		1		2	1.5	2		4.5	8							
Nuculana pernula Muller, 1771	3	1	2	5	9								1				
Compsomyax subdiaphana Crp, 1864		2	1			2	2		6	7			1			1	
Thyasira bisecta Conrad, 1846		4			3							2	8				
Chlamys rubida Hinds, 1845				1	1												
Nucula tenuis Montagu, 1908	2	4					4		2		2	13	1				
Axinopsida serricata Crp, 1864	12	17	20				2										11
Tellina nuculoides Reeve, 1854	4	4	1		4				3	3	2	7	2	11	4		1
Psephidia lordi Baird, 1863	-	-	-	-	-	-	-	-	-	-				91			
Solen sicarius Gould, 1850	-	-	-	-	-	-	-	-	-	-			1				
Cardiomya pectinata Crp, 1864	-	-	-	-	-	-	-	-	1	-							
Protothaca staminea var. *ruderata* Deshayes, 1853	-	-	-	-	-	-	-	-	-	-				1	1		7
Clinocardium californiense Deshayes, 1841	-	-	-	-	-	-	-	-	-	-	16	4	8	5	4	1	
Transennella tantilla Gould, 1853	-	-	-	-	-	-	-	-	-	-	578	681			47	14	

Gastropoda By numbers	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Mitrella gouldii Crp, 1856						1				2	1						
Acteocina eximia Baird, 1863			1			2	1						1				
Polinices pallida Broderip & Sowerby, 1829			1			1						1					
Thais lamellosa Gmelin, 1791																	
Trichotropis cancellata Hinds, 1843					2								2				
Margarites sp.					4								1				
Amphissa columbiana Dall, 1916					7								2				
Cidarina cidaris A. Adams, 1864					1												
Turrid A													4				
Puncturella multistriata Dall, 1914					1												
Polyplacophora																	
Lepidozona (mertensii?)				9													
Mopalia imporcata Crp, 1864				1	2												
Scaphopoda																	
Dentalium sp. (*rectius*?)		1	1						2								
Brachiopoda																	
Terebratalia transversa																	
Pennatulacea																	
Virgularia sp?			1														
Nemertea																	
Nemertean A	1																
Nemertean B		1					2										

Polychaeta, errant   By numbers

	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Phyllodoce sp.	1	1								1							
Nephtys punctata Hartman	2	1	3			4	4				8	2	1	6	1		
Goniada brunnea Treadwell	1		1				4	2	3					1			2
Nereis sp. 1		1															5
Halosydna brevisetosa					2												
Polynoid B															1		3
Glycera sp.					2												
Syllis sp.	1										1						
Trochochaetida A											10	3					
Lumbrineris sp.			4			1	2				3	3	4				2
Nephtys sp. 2					1			1									
Glycera sp. 2														1			
Nereis sp. 2													1				
Onuphius sp.																	6
Unidentifiable																	

Polychaeta, sedentary   By numbers

	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Crucigera irregularis Bush				7	3												
Sternaspis fossor Stimpson			5		1		8		2	1			2				
Artacama conifera Moore						2	4			1							
Pectinaria belgica Pallas																	
Stylarioides papillata Johnson				1	3											1	1
Maldane glebifex? Grube	1	3															
Thelepus setosus Quatrefages		1	1	4	2	1											
Praxillella affinis var. *pacifica*	5						1		1		5						
Ammochares fusiformis Delle Chiage															3		11
Terebellides stroemi Sars	10		3			2	1	1	17	2	3	4	30				
Phyllochaetopterus prolifica? Potts				1	1												
Melinna cristata Sars									1								
Sabella crassicornis? Sars				1													
Terebellid A						1											
Scoloplos armiger O.F. Muller												3		12		2	
Pista sp.												1					
Travisia brevic Moore															6		
Arenicola pusilla Quatrefages																	1
Prionospio malmgreni Claparide																	11
Sabellaria cementarium Moore																	
Ammotrypone aulogaster Rathke															7	17	

Echinodermata and Crustacea — By numbers

	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Asteroidea																	
Ctenodiscus crispatus Retzius																	
Ophiuroidea																	
Ophiura (*maculata* Clark, 1911?)				6		4											
Ophiura lutkeni Lyman					10			5		4							
Diamphiodia occidentalis Lyman											5	5					
Holothuroidea																	
Molpadia intermedia Ludwig	1	1	4				1	1	1								
Eupentacta pseudoquinquesemita Deichmann		2	2		1		1		1				1				
Parastichopus californicus Stimpson																	
Psolidium ballatum					4												
Crustacea																	
Pagurus sp. 1 (in *T. lamellosa* shells)																	
Pagurus sp. 2 (juveniles)																	8
Cancer sp. (juveniles)					1												6
Pentidotea resecata Stimpson																	5
Synidotea sp.												5					
Melita sp.		3	1			3											
Heterophoxus (*oculatus* Holmes?)		1	5				1										
Byblis sp.				10	2						2		1				
Ampithoe sp.														4			1
Ampelisca sp.					2							2					7
Anisogammarus (*confervicolus* Stimpson?)														7		1	
Amphipod A						1											
Amphipod B																	
Amphipod C																	
Amphipod D			1														

Bivalvia By weight

	Ho-2	Fl-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Cyclocardia ventricosa ventricosa Gould, 1850		0.01					
Clinocardium fucanum Dall, 1907			0.70				
Acila castrensis Hinds, 1843							
Astarte alaskensis Dall, 1903							
Yoldia amygdalea Valenciennes, 1846							
Nuculana pernula Muller, 1771			0.12				
Compsomyax subdiaphana Crp, 1864			55.48			1.90	
Thyasira bisecta Conrad, 1846		0.04	0.24				
Chlamys rubida Hinds, 1845							
Nucula tenuis Montagu, 1908	0.04	0.25	0.04				
Axinopsida serricata Crp, 1864							0.20
Tellina nuculoides Reeve, 1854	0.10	0.82	0.10	0.78	0.32		0.05
Psephidia lordi Baird, 1863				1.31			
Solen sicarius Gould, 1850			12.66				
Cardiomya pectinata Crp, 1864							
Protothaca staminea var. *ruderata* Deshayes, 1853				0.15	0.13		0.98
Clinocardium californiense Deshayes, 1841	0.44	0.23	0.22	0.10	0.16	0.01	
Transennella tantilla Gould, 1853	2.89	3.03			0.81	0.03	

Gastropoda By weight

	PO-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Mitrella gouldii Crp, 1856						0.08				0.27	0.04						
Actocina eximia Baird, 1863			0.02			0.30	0.05						0.05				
Polinices pallida Broderip & Sowerby, 1829			0.03			0.03						0.03					
Thais lamellosa Gmelin, 1791																	
Trichotropis cancellata Hinds, 1843					0.15								0.94				
Margarites sp.					0.27								0.08				
Amphissa columbiana Dall, 1916					0.82								0.08				
Cidarina cidaris A. Adams, 1864					0.04								0.39				
Turrid A																	
Puncturella multistriata Dall, 1914					0.10												
Polyplacophora																	
Lepidozona (mertensii?)				0.19													
Mopalia imporcata Crp, 1864				0.10	0.08												
Scaphopoda																	
Dentalium sp. (*rectius*?)		0.06	0.09						0.13								
Brachiopoda																	
Terebratalia transversa																	
Pennatulacea																	
Virgularia sp?			1.22														
Nemertea																	
Nemertean A	0.63	0.07					0.04										
Nemertean B																	

Polychaeta, errant By weight

	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	F1-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Phyllodoce sp.	0.17	0.21								0.38							
Nephtys punctata Hartman	0.20	0.05	0.37			1.05	1.78	0.24	0.82		1.83	0.23	0.16	0.49	0.20		
Goniada brunnea Treadwell	0.20		0.03				1.01	0.51	1.08					0.03			0.04
Nereis sp. 1		0.09															0.72
Halosynda brevisetosa					0.34												
Polynoid B															0.08		0.03
Glycera sp.	0.01				0.14												
Syllis sp.											0.01						
Trochochaetida A											0.08	0.03					
Lumbrineris sp.			0.04			0.03	0.02	3.71			0.04	0.02	0.09				0.02
Nephtys sp. 2					5.64												
Glycera sp. 2														0.07			
Nereis sp. 2													0.27				
Onuphius sp.																	0.15
Unidentifiable	0.38	0.21	0.14	0.13	0.26	0.60				0.36							

Polychaeta, sedentary By weight

	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2	Ho-2	Fl-3	Ri-3	Me-1	Ba-4	Oo-2	St-1
Crucigera irregularis Bush				0.46	0.33												
Sternaspis fossor Stimpson			0.31		0.03		1.40		0.02	0.01			0.19				
Artacama conifera Moore						0.67	0.20										
Pectinaria belgica Pallas										0.11							0.98
Stylarioides papillata Johnson				0.01	1.02											0.65	0.07
Maldane glebifex? Grube	0.40	3.99															
Thelepus setosus Quatrefages		0.19	0.13	2.18	3.37	0.18											
Praxillella affinis var. *pacifica*	0.06						0.01		0.02		0.39						
Ammochares fusiformis Delle Chiage															0.26		0.47
Terebellides stroemi Sars	0.08		0.02			0.03	0.04	0.04	0.84	0.06	0.05	0.09	0.50				
Phyllochaetopterus prolifica? Potts				0.35	0.91												
Melinna cristata Sars									0.04								
Sabella crassicornis? Sars				1.03													
Terebellid A						0.10											
Scoloplos armiger O.F. Muller												0.03		0.40		0.14	
Pista sp.										0.26		0.24					
Travisia brevis Moore															0.22		
Arenicola pusilla Quatrefages																	0.11
Prionospio malmgreni Claparide																	0.17
Sabellaria cementarium Moore																	
Ammotrypone aulogaster Rathke															0.01	0.73	

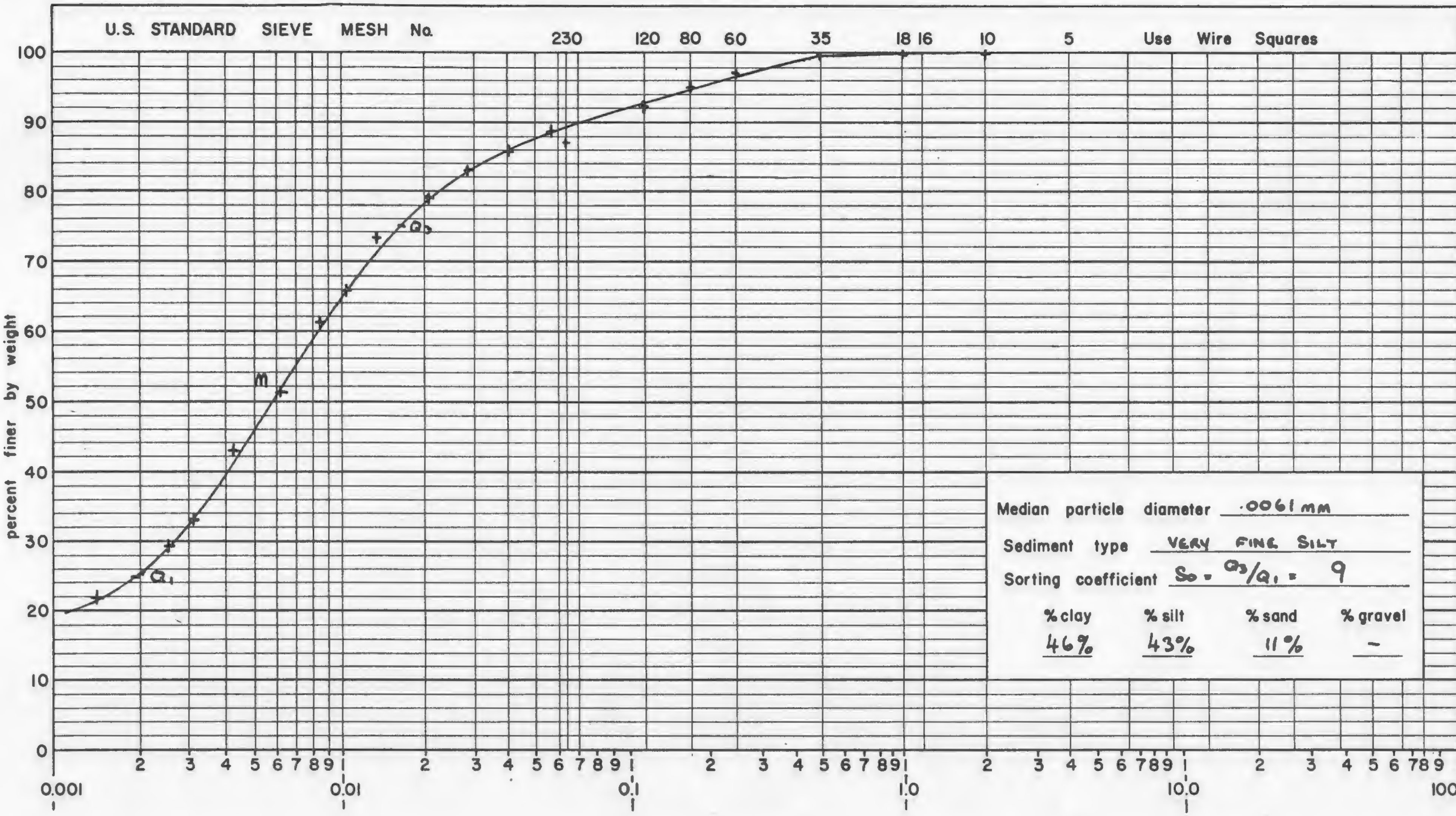
Echinodermata and Crustacea — By weight	P0-1	P1-1	P2a-1	P3-1	P4-1	P5-1	P7-1	S1-1	S2-2	S3-2
Asteroidea										
Ctenodiscus crispatus Retzius				2.90						0.26
Ophiuroidea										
Ophiura (*maculata* Clark, 1911?)						0.60				
Ophiura lutkeni Lyman					1.77			1.49		
Diamphiodia occidentalis Lyman										
Holothuroidea										
Molpadia intermedia Ludwig	17.98	36.06	26.90				4.70	28.10	63.23	
Eupentacta pseudoquinquesmita Deichmann		1.05	3.78		0.06		0.21		0.07	
Parastichopus californicus Stimpson										
Psolidium ballatum					1.18					
Crustacea										
Pagurus sp. 1 (in *T. lamellosa* shells)										
Pagurus sp. 2 (juveniles)										
Cancer sp. (juveniles)					0.26					
Pentidotea resecata Stimpson										
Synidotea sp.										
Melita sp.		0.05	<.01			.05				
Heterophoxus (*oculatus* Holmes?)		0.01	.03				<.01			
Byblis sp.				0.13	.08					
Ampithoe sp.										
Ampelisca sp.					.01					
Anisogammarus (*confervicolus* Stimpson?)										
Amphipod A						<.01				
Amphipod B										
Amphipod C										
Amphipod D			<.01							

6. SUMMARY OF BENTHIC SUBSTRATE DATA

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	PO-1	N.E.A.T.
DEPTH	53m	



Median particle diameter .0061 mm

Sediment type VERY FINE SILT

Sorting coefficient $S_0 = Q_3/Q_1 = 9$

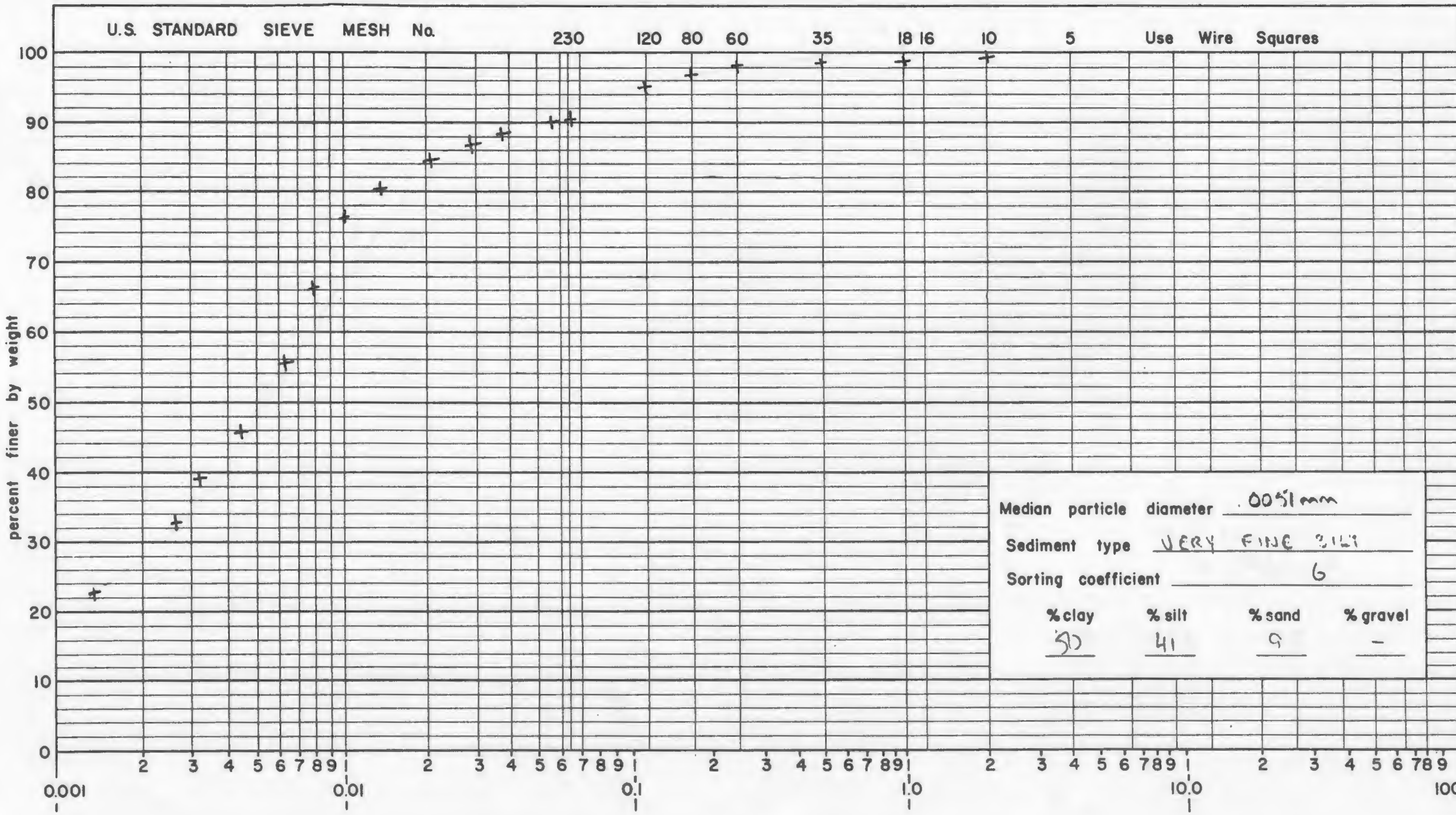
% clay	% silt	% sand	% gravel
46%	43%	11%	–

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT
STATION No.	PO-2
DEPTH	53 m
DATE TESTED	DEC. 23 1974
	N.E.A.T.



Median particle diameter .0051 mm

Sediment type VERY FINE SILT

Sorting coefficient 6

% clay	% silt	% sand	% gravel
50	41	9	–

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (ϕ) 8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0		−6.0
GRAIN SIZE (mm) .0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0		

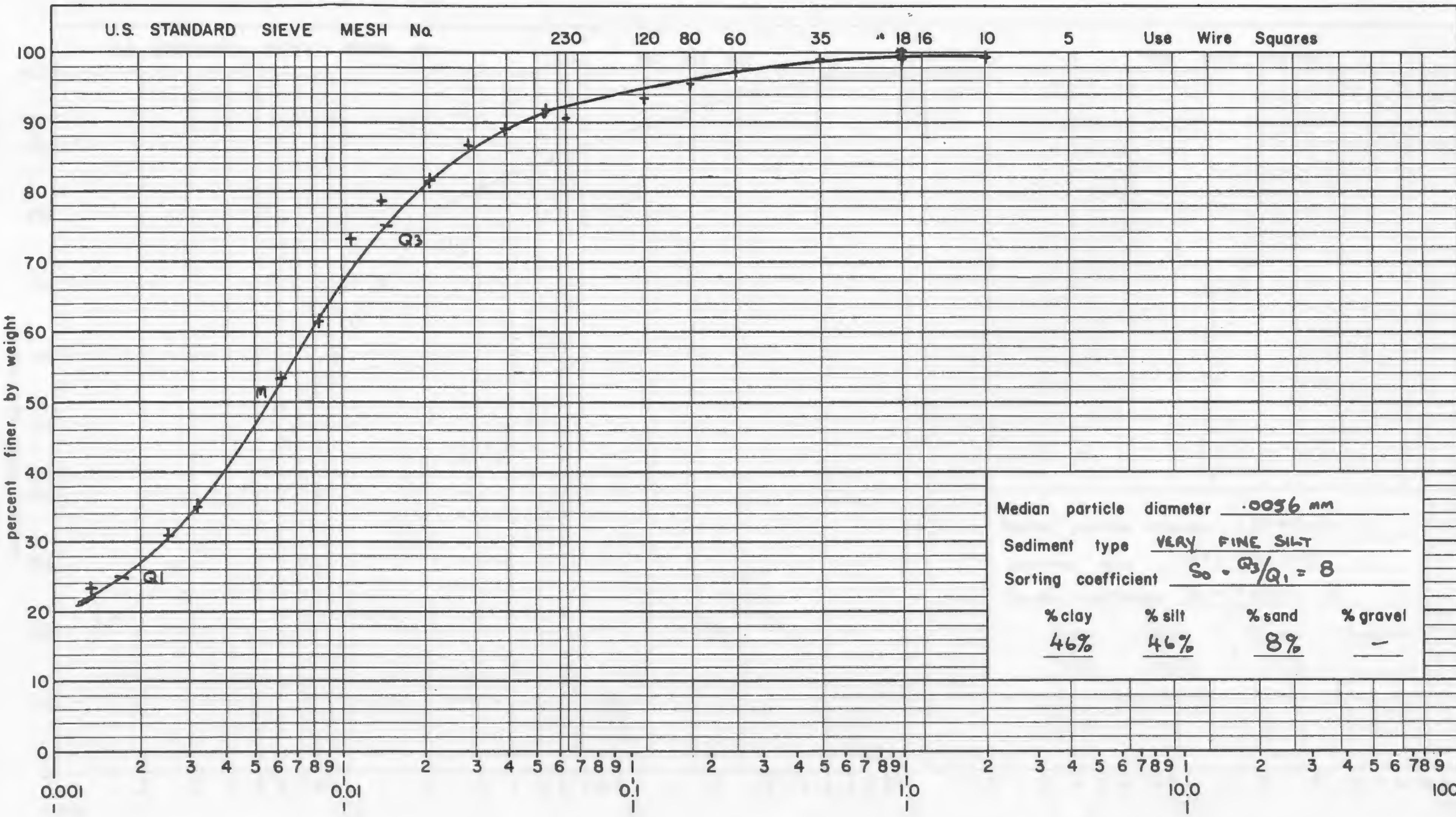
NEAT

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	P1-1
DEPTH	50m

N.E.A.T.



Median particle diameter .0056 mm

Sediment type VERY FINE SILT

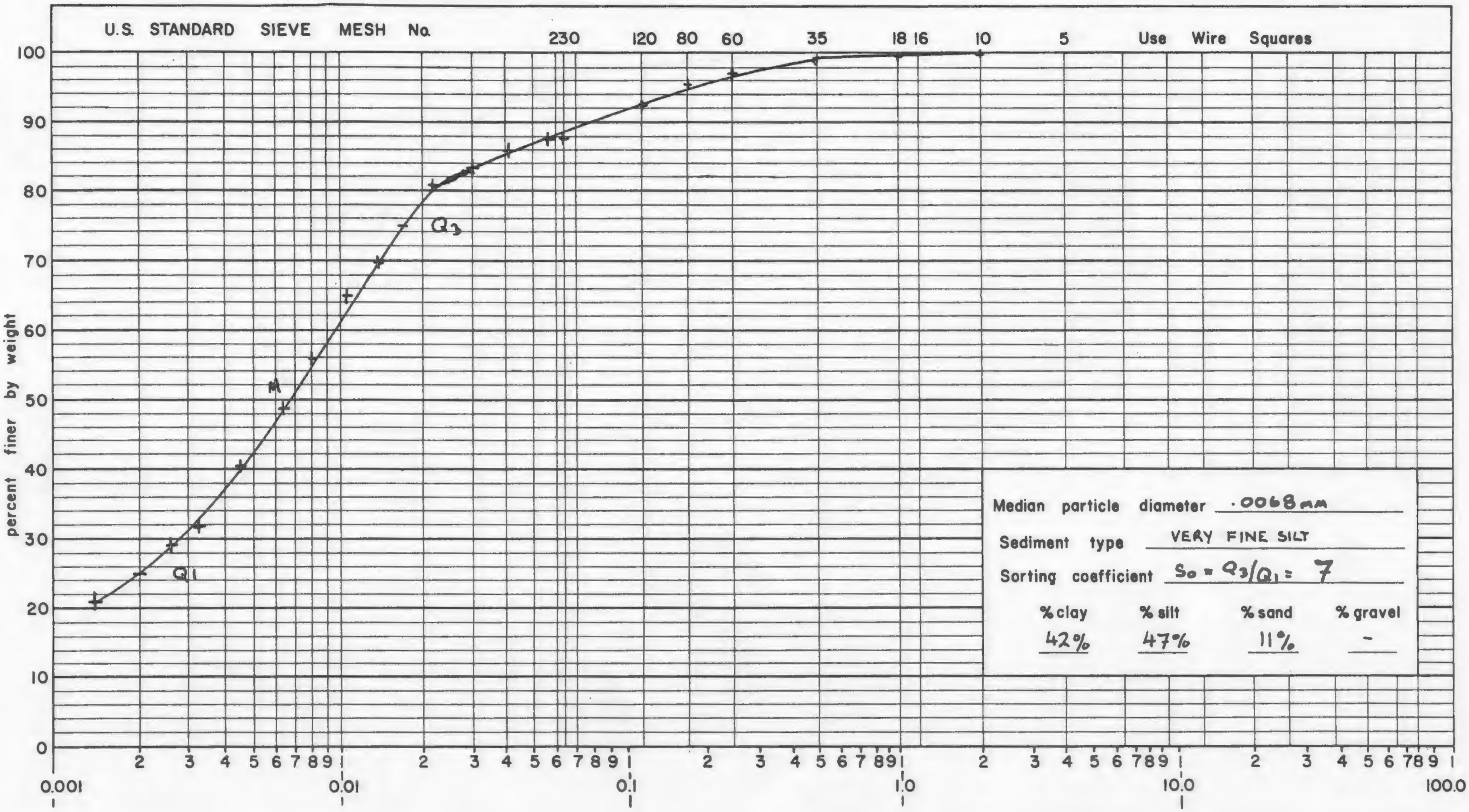
Sorting coefficient $S_0 = Q_3/Q_1 = 8$

% clay	% silt	% sand	% gravel
46%	46%	8%	—

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

NEAT

CUMULATIVE CURVE BASED ON WENTWORTH GRADE SCALE	LOCATION	PRINCE RUPERT	DATE TESTED	DEC. 23, 1974
	STATION No.	P1-2	N.E.A.T.	
	DEPTH	50m		

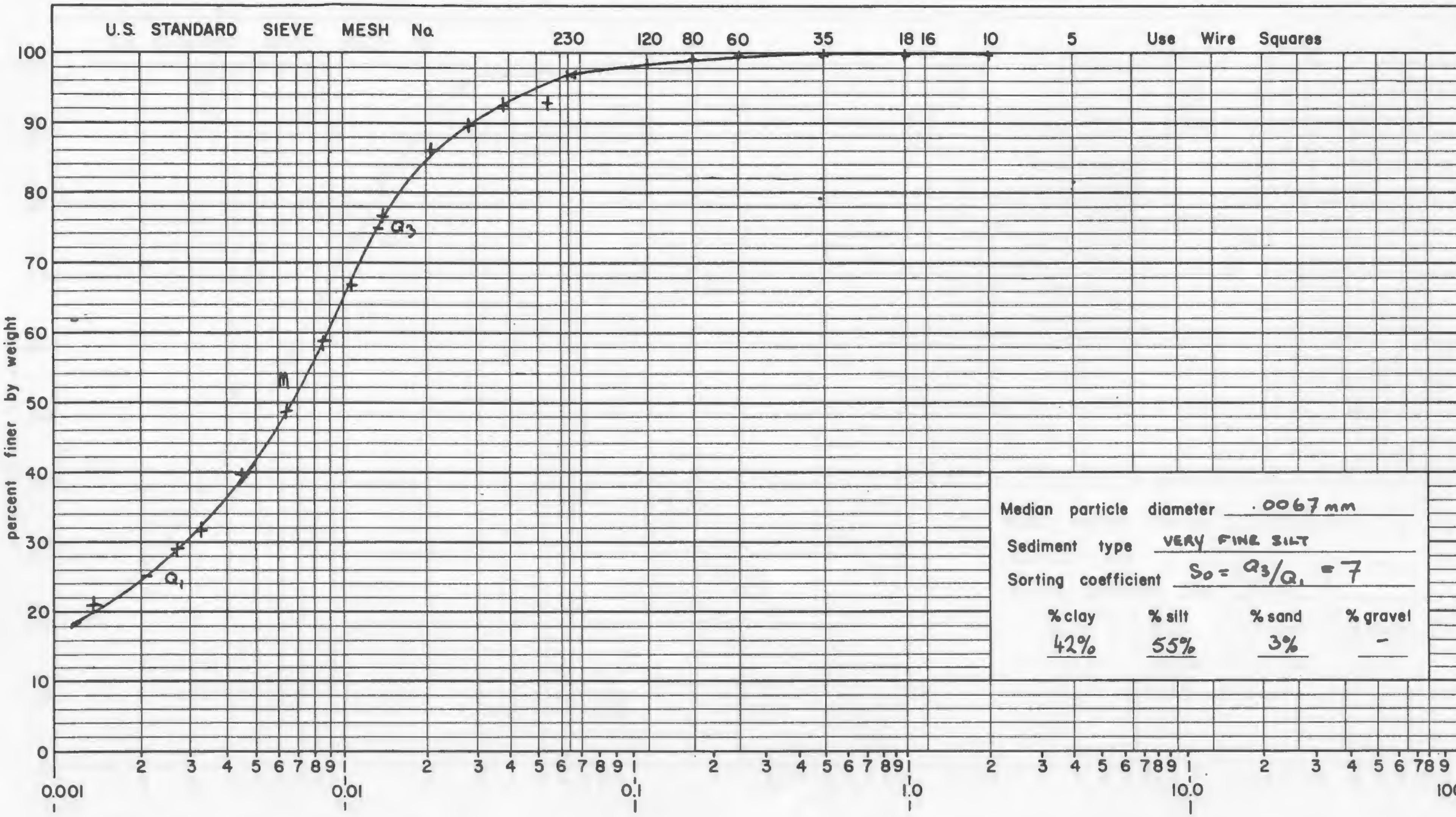


CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT	DATE TESTED	DEC. 27, 1974
STATION No.	P2-1	N.E.A.T.	
DEPTH	45 m		

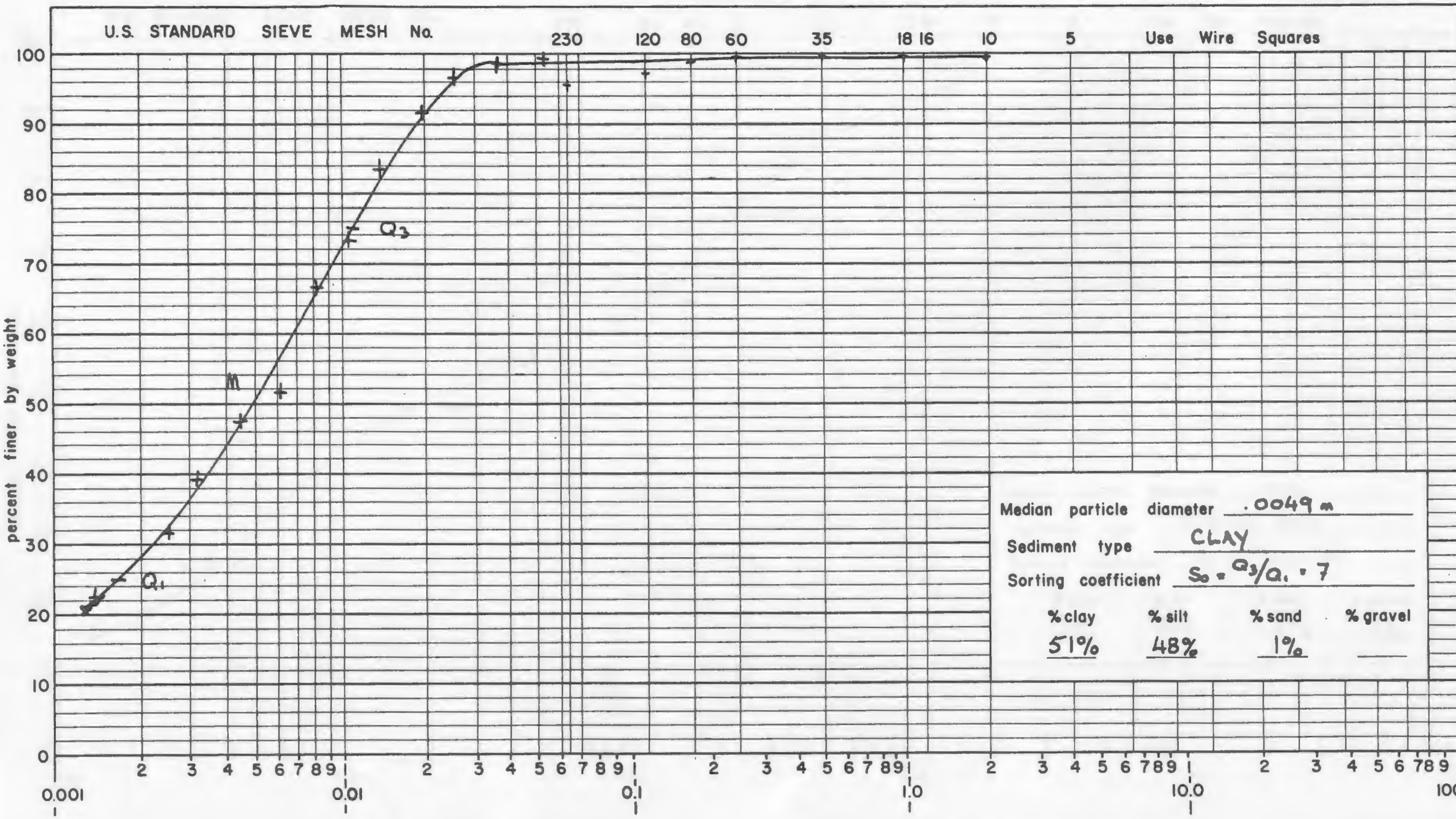


CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (ϕ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT	DATE TESTED	DEC. 23, 1974
STATION No.	P2a-2	N.E.A.T.	
DEPTH	45m		



Median particle diameter .0049 m

Sediment type CLAY

Sorting coefficient $S_0 = Q_3/Q_1 = 7$

% clay	% silt	% sand	% gravel
51%	48%	1%	—

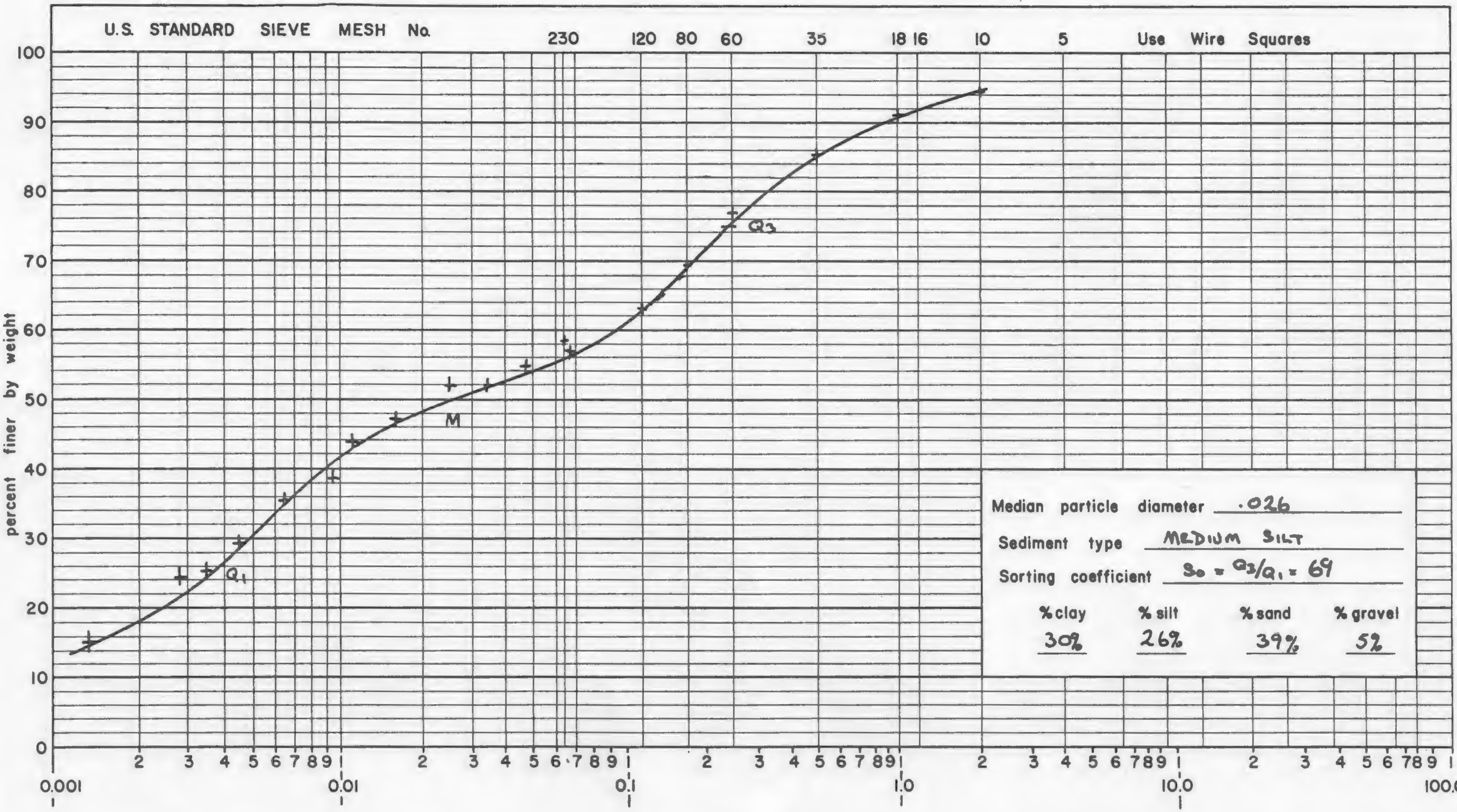
CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	P3-1
DEPTH	45.5 m

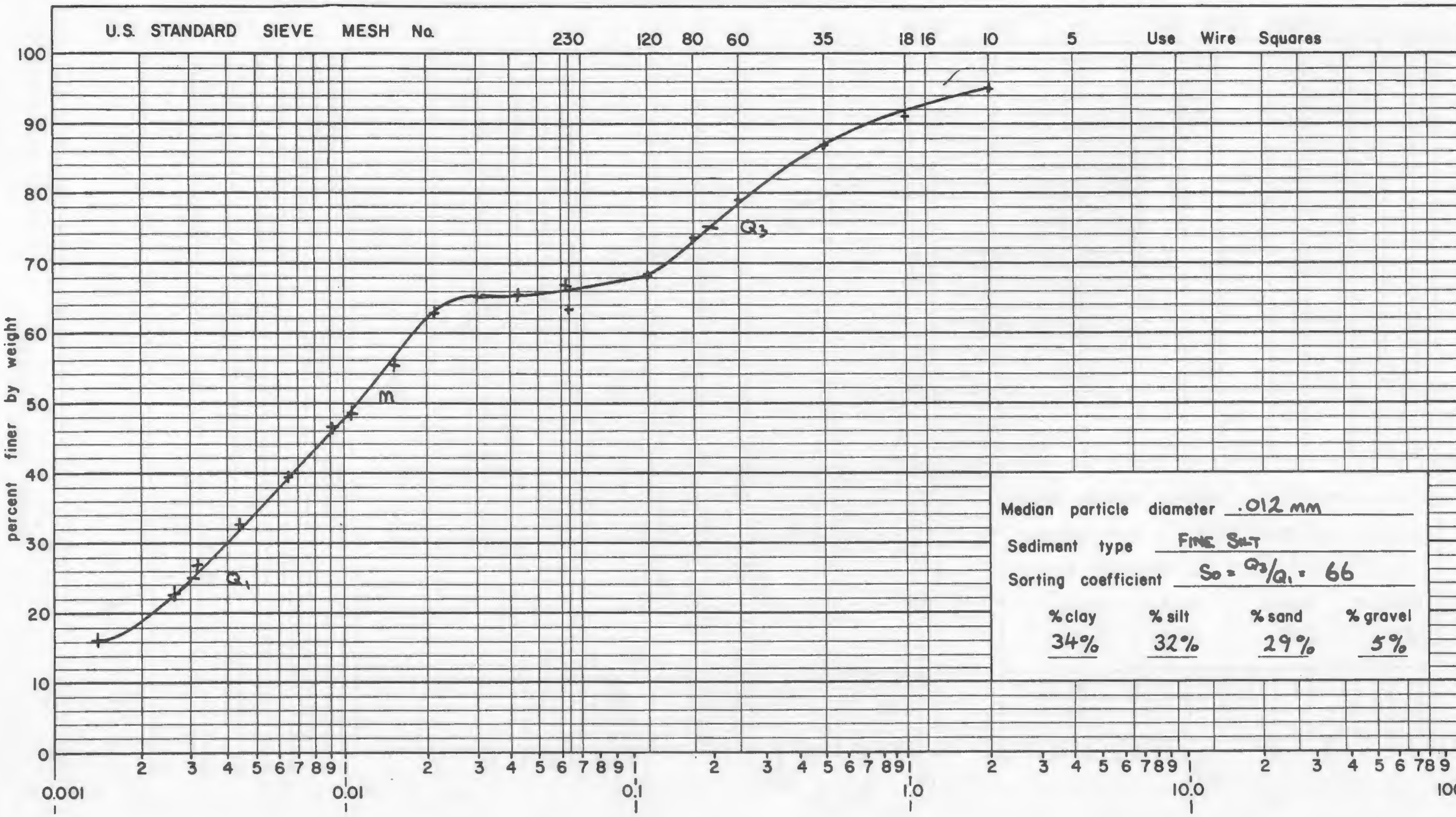
N.E.A.T.



CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (Φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

NEAT

CUMULATIVE CURVE	LOCATION	PRINCE RUPERT	DATE TESTED	DEC. 23, 1974
BASED ON WENTWORTH GRADE SCALE	STATION No.	P3-2		N.E.A.T.
	DEPTH	46m		



Median particle diameter .012 mm

Sediment type FINE SILT

Sorting coefficient $So = Q_3/Q_1 = 66$

% clay	% silt	% sand	% gravel
34%	32%	29%	5%

	CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class		very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0		−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0		

CUMULATIVE CURVE

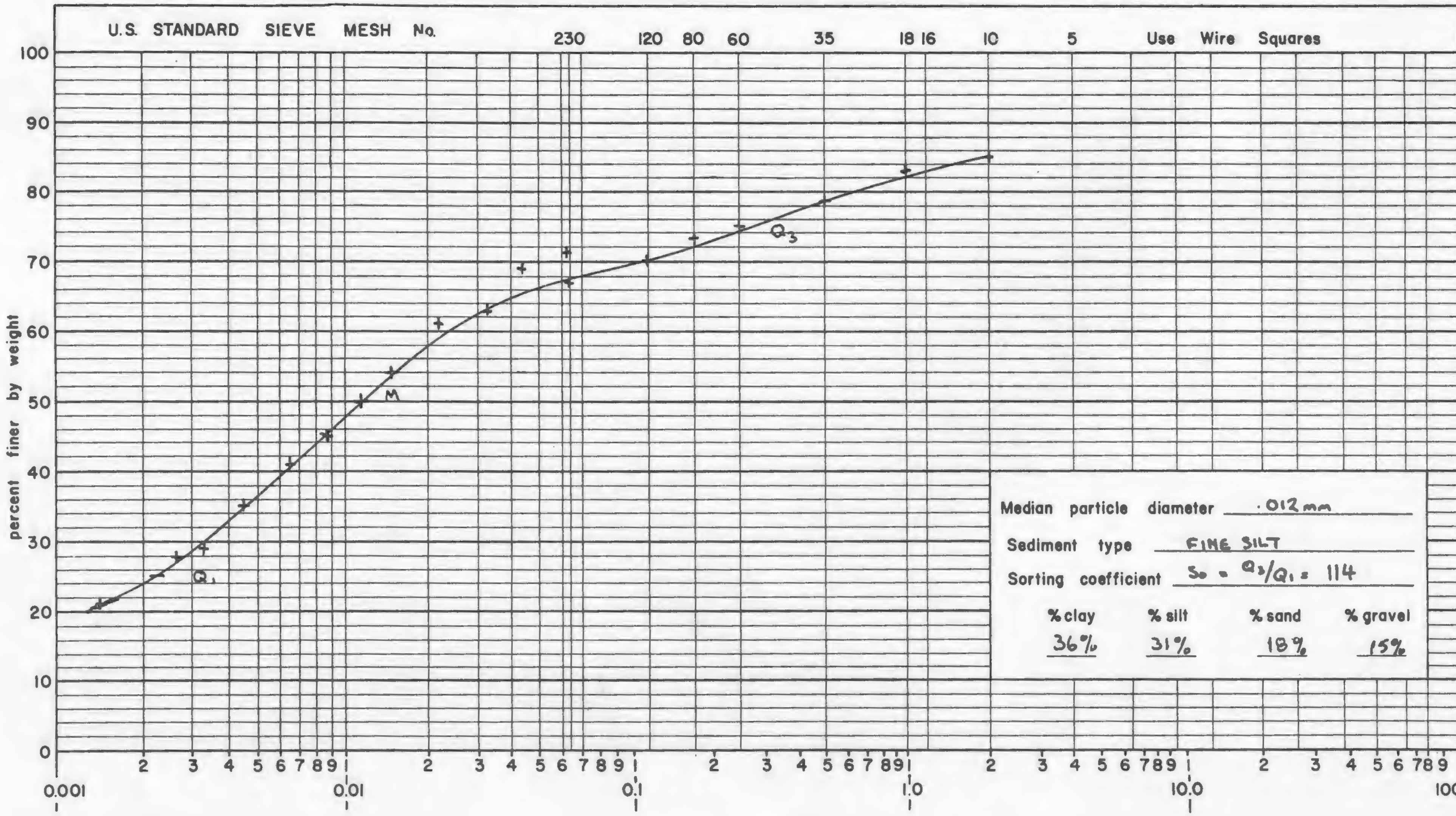
BASED ON WENTWORTH GRADE SCALE

LOCATION PRINCE RUPERT

STATION No. P4-1

DEPTH 47m

N.E.A.T.



Median particle diameter .012 mm

Sediment type FINE SILT

Sorting coefficient So = Q3/Q1 = 114

% clay	% silt	% sand	% gravel
36%	31%	18%	15%

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

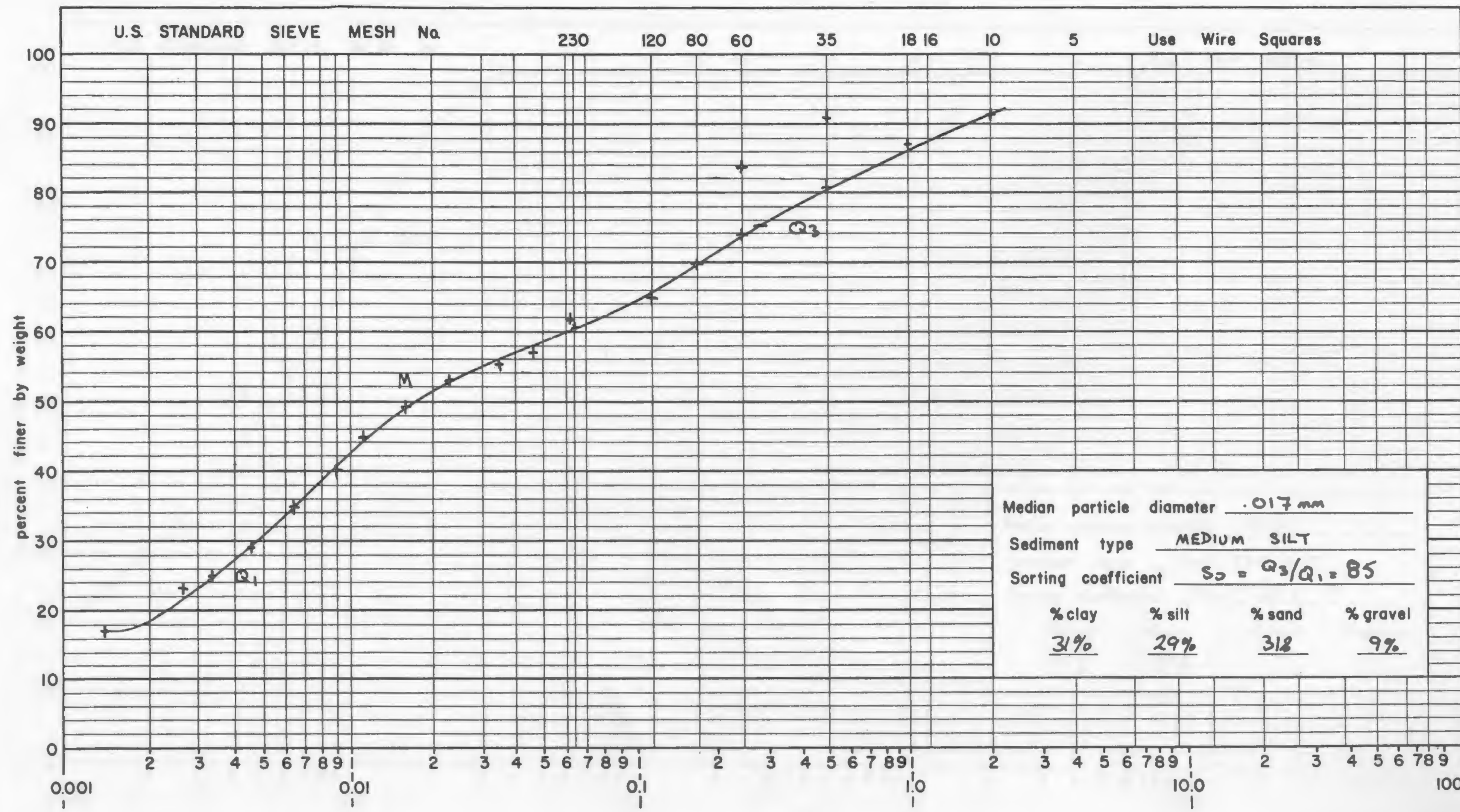
NEAT

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	PH-2
DEPTH	47 m

N.E.A.T.



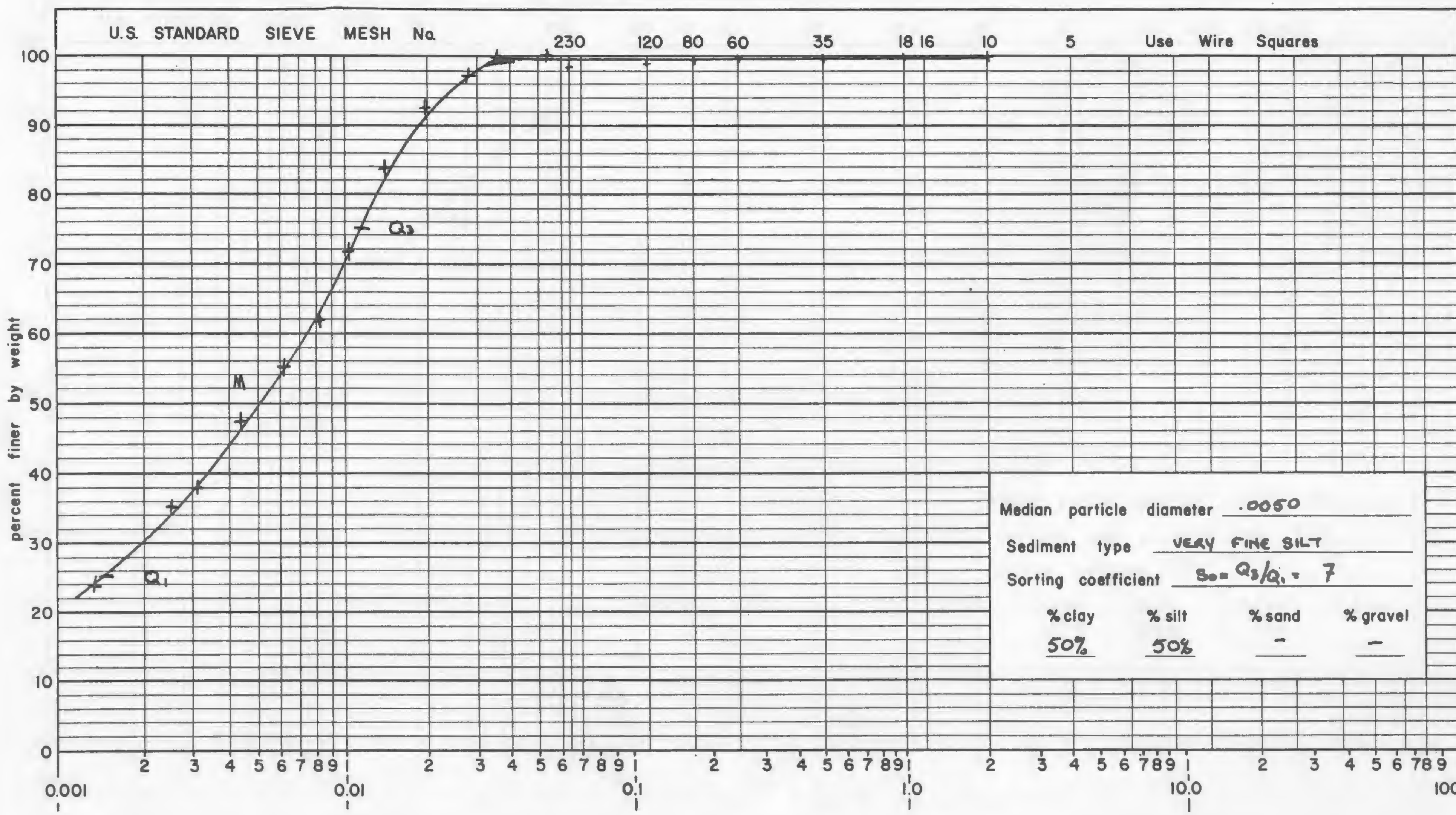
CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

NEAT

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT	DATE TESTED	DEC. 27. 1974
STATION No.	P5-1	N.E.A.T.	
DEPTH	47m		



Median particle diameter .0050

Sediment type VERY FINE SILT

Sorting coefficient So = Q3/Q1 = 7

% clay	% silt	% sand	% gravel
50%	50%	–	–

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm.)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

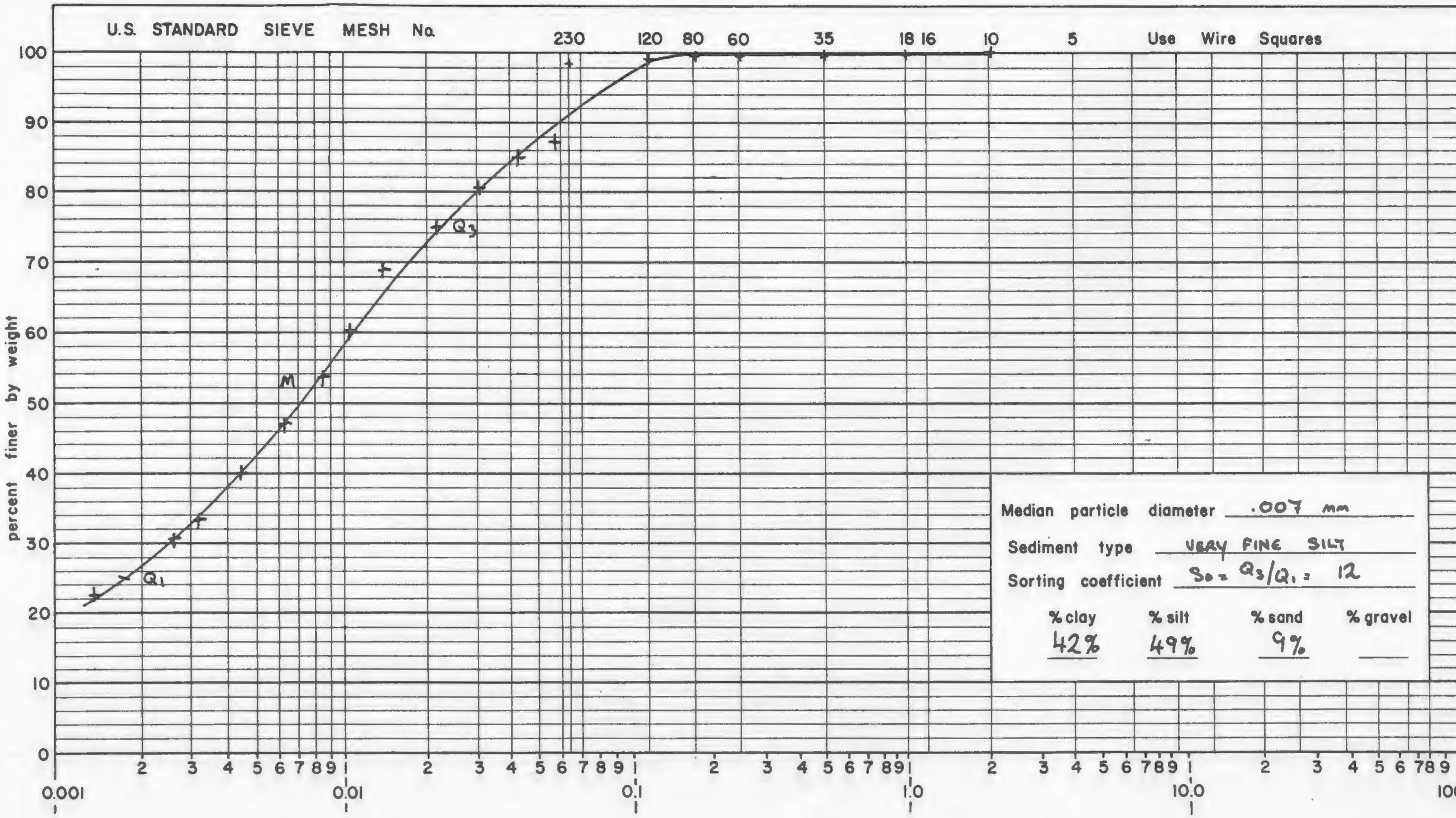
CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No. P5-2

DEPTH 47 m

N.E.A.T.



Median particle diameter .007 mm

Sediment type VERY FINE SILT

Sorting coefficient So = Q3/Q1 = 12

% clay	% silt	% sand	% gravel
42%	49%	9%	

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ) 8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0		−6.0
GRAIN SIZE (mm) .0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0		

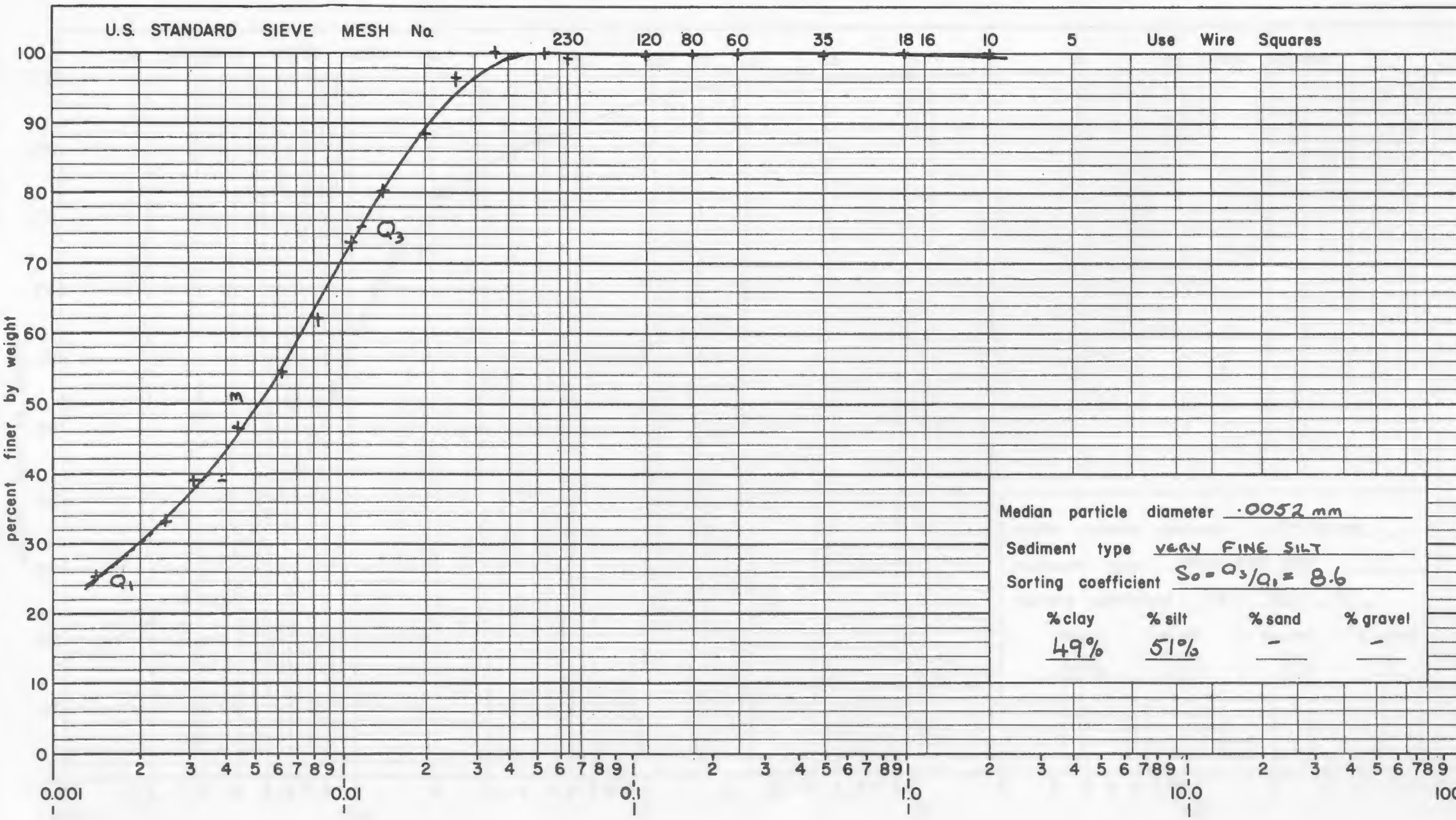
NEAT

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	P7-1
DEPTH	45 m

N.E.A.T.



Median particle diameter .0052 mm

Sediment type VERY FINE SILT

Sorting coefficient $S_o = Q_3/Q_1 = 8.6$

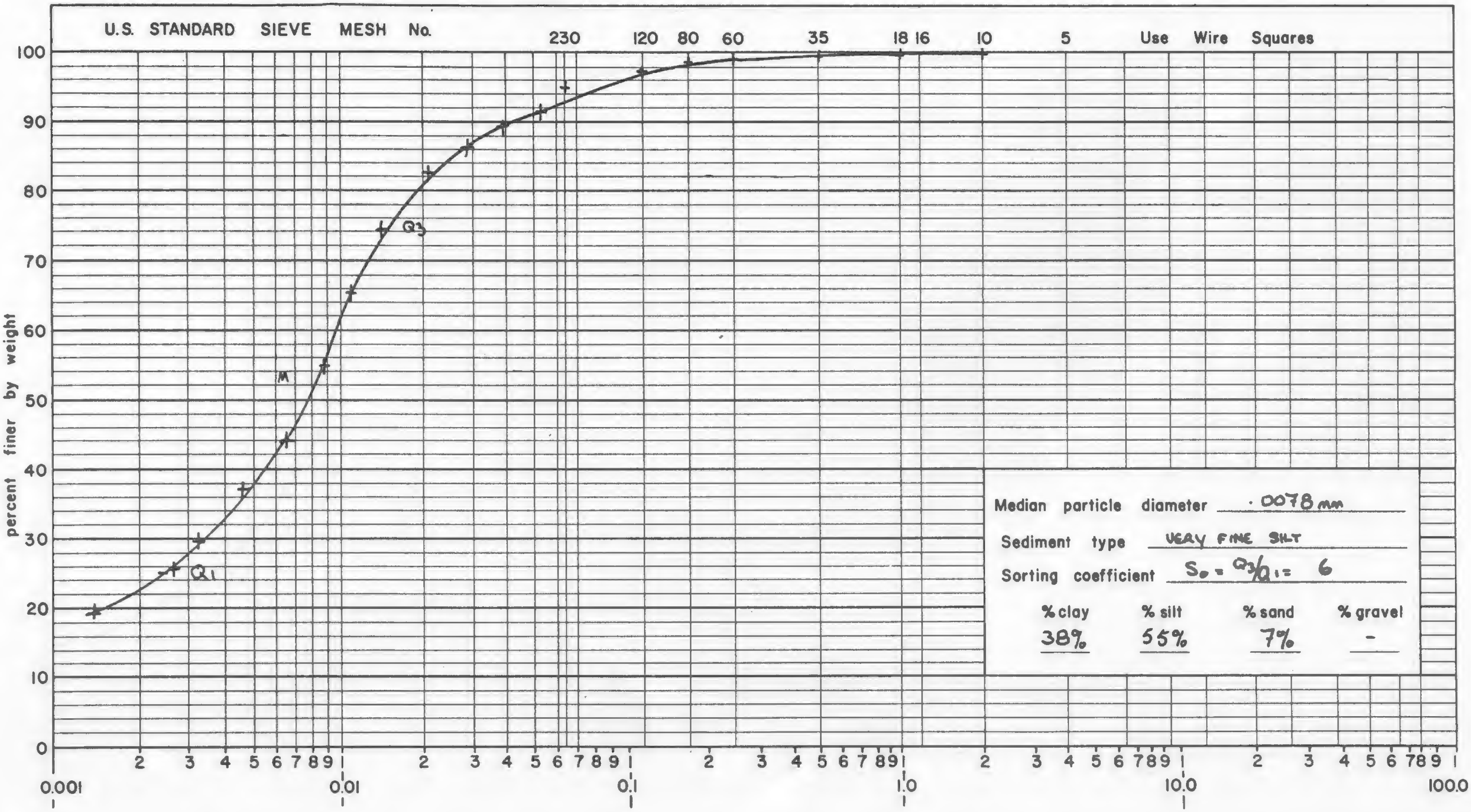
% clay	% silt	% sand	% gravel
49%	51%	–	–

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

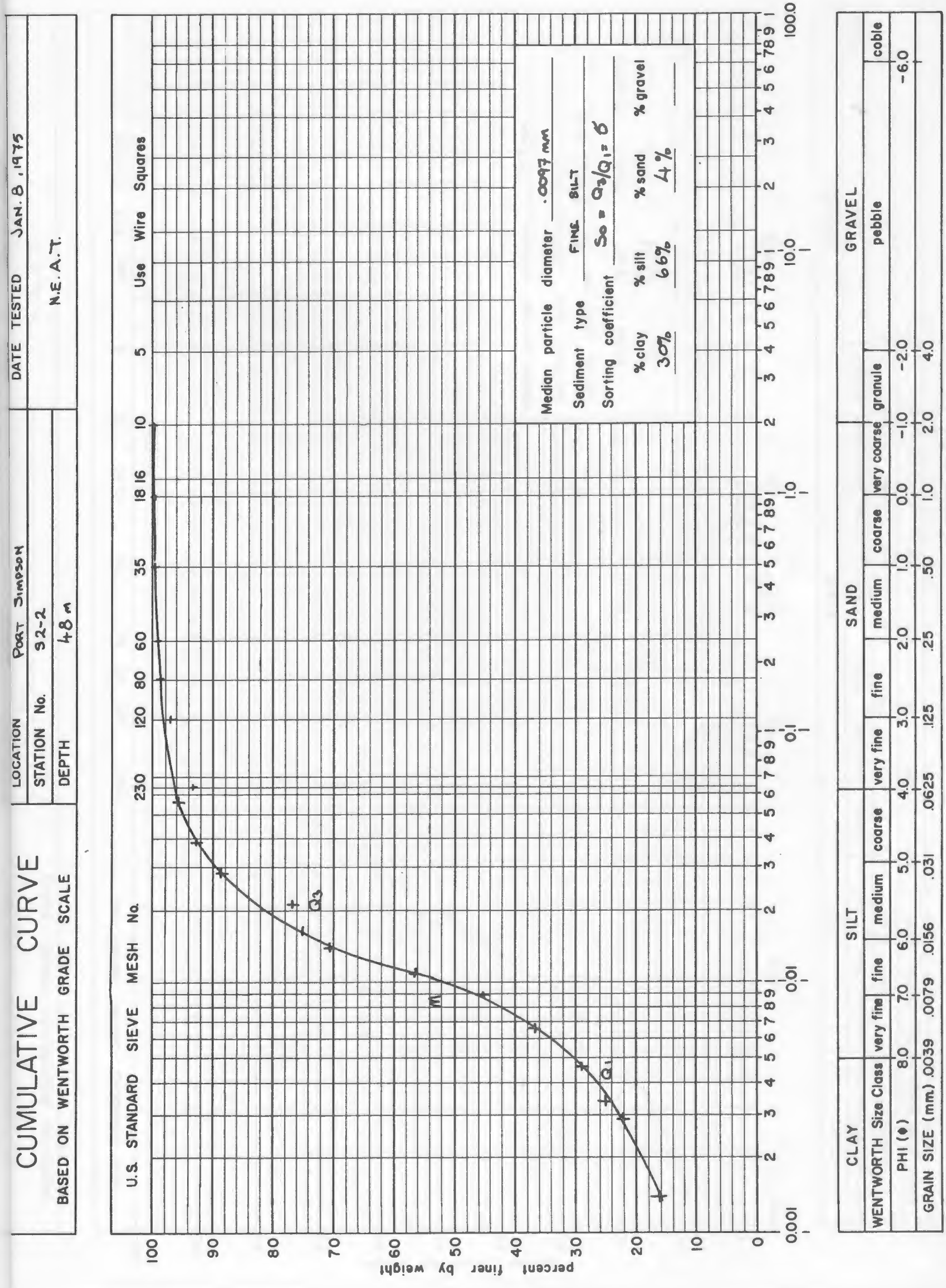
BASED ON WENTWORTH GRADE SCALE

LOCATION	PORT SIMPSON	DATE TESTED	JAN. 8, 1974
STATION No.	S1-1	N.E.A.T.	
DEPTH	128 m		



CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm.)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

NEAT

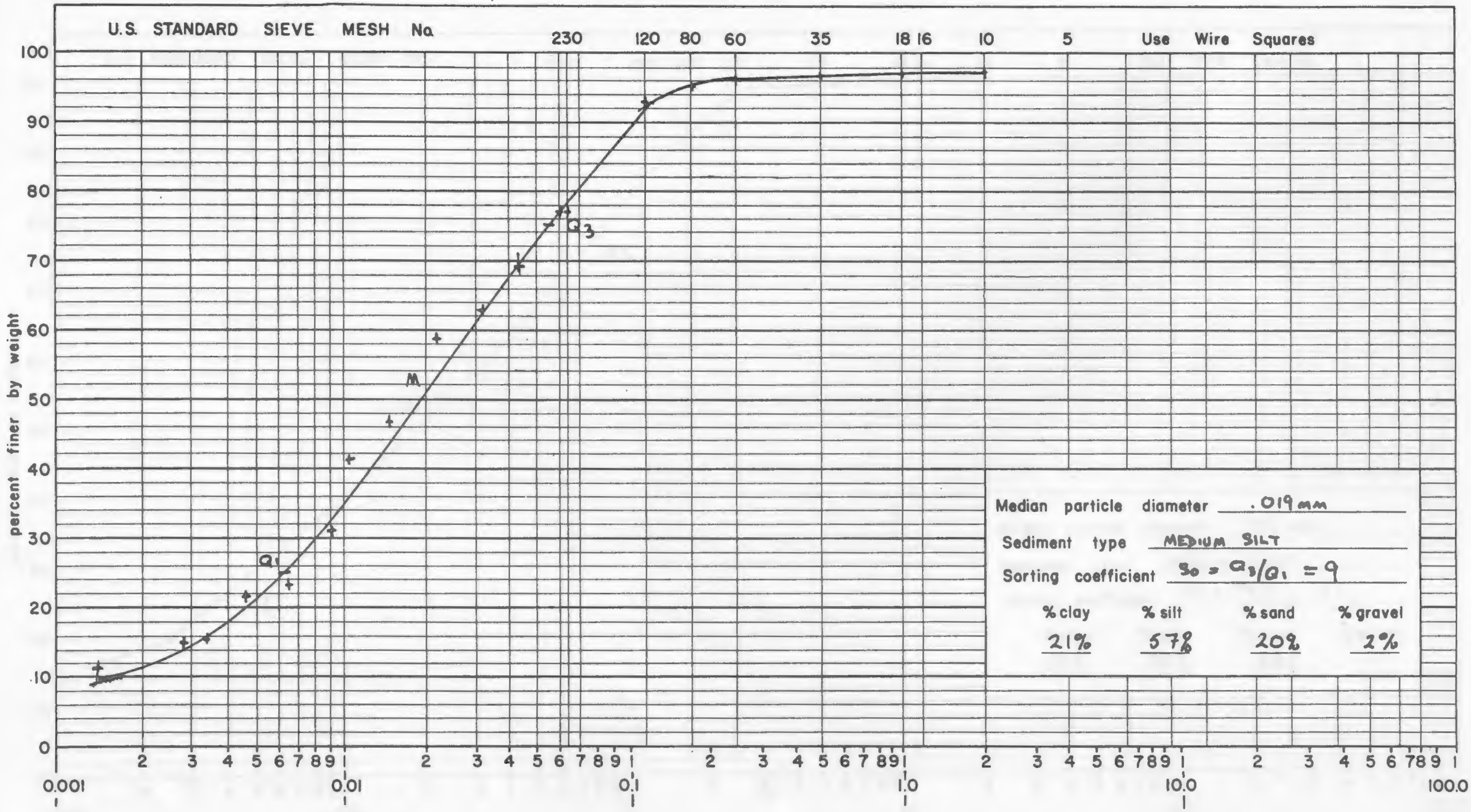

CUMULATIVE CURVE
BASED ON WENTWORTH GRADE SCALE
LOCATION Port Simpson
STATION No. 92-2
DEPTH 48 m
DATE TESTED Jan. 8, 1975
N.E.A.T.
U.S. STANDARD SIEVE MESH No.
230 120 80 60 35 18 16 10 5 Use Wire Squares
Median particle diameter .0097 mm
Sediment type Fine silt
Sorting coefficient So = Q3/Q1 = 6
% clay 30%
% silt 66%
% sand 4%
% gravel
Q3
M
Q1
percent finer by weight
100 90 80 70 60 50 40 30 20 10 0
0.001 0.01 0.1 1.0 10.0 100.0
CLAY SILT SAND GRAVEL
WENTWORTH Size Class
very fine fine medium coarse very fine fine medium coarse very coarse granule pebble coble
PHI (ϕ) 8.0 7.0 6.0 5.0 4.0 3.0 2.0 1.0 0.0 -1.0 -2.0 -6.0
GRAIN SIZE (mm.) .0039 .0079 .0156 .031 .0625 .125 .25 .50 1.0 2.0 4.0

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	S3-2
DEPTH	45m

N.E.A.T.



Median particle diameter .019 mm

Sediment type MEDIUM SILT

Sorting coefficient $S_o = Q_3/Q_1 = 9$

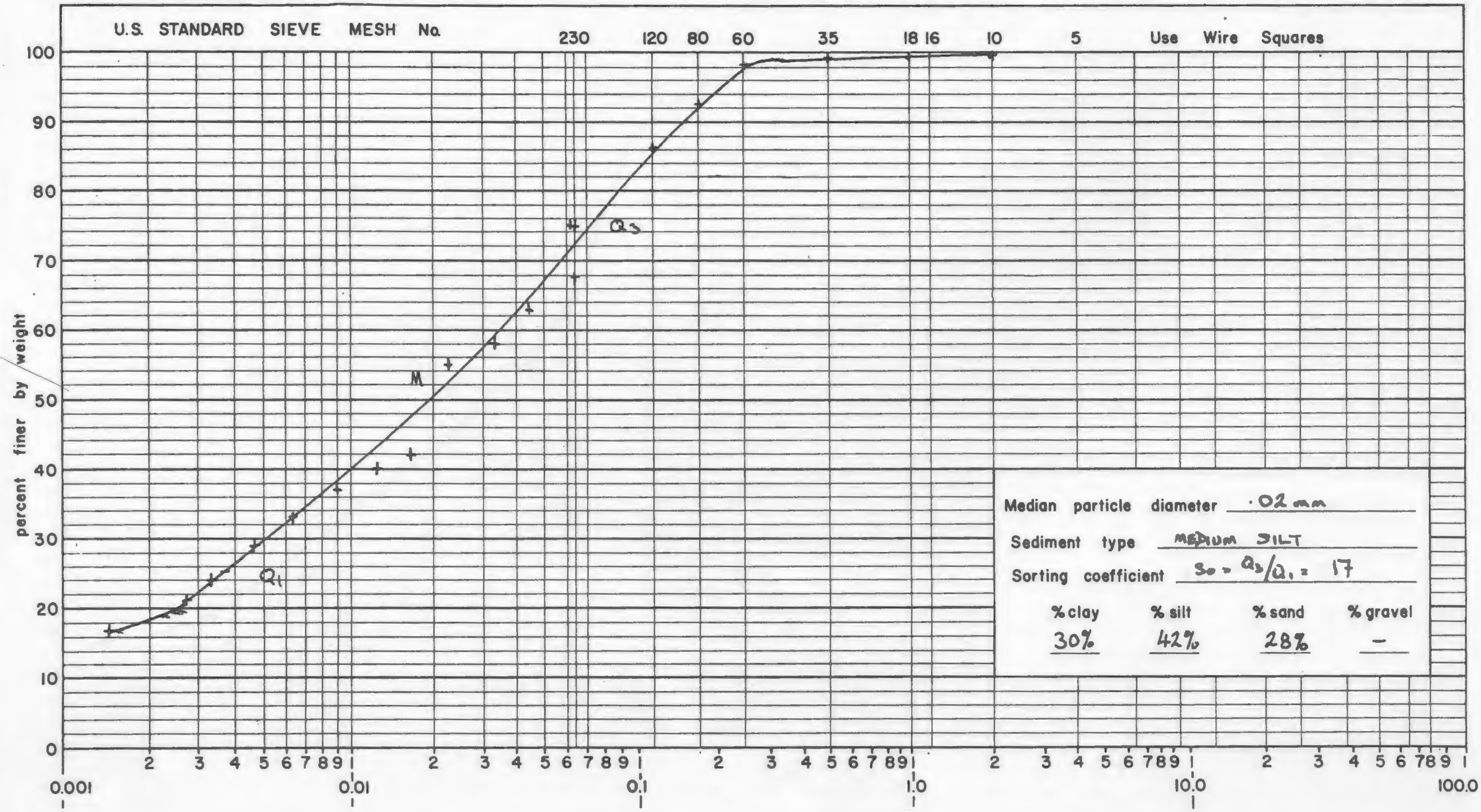
% clay	% silt	% sand	% gravel
21%	57%	20%	2%

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (ϕ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

NEAT

NEAT

CUMULATIVE CURVE BASED ON WENTWORTH GRADE SCALE	LOCATION PRINCE RUPERT	DATE TESTED JAN. 20, 1975
	STATION No. HORSEY 2	N.E.A.T.
	DEPTH 8m	



Median particle diameter .02 mm

Sediment type MEDIUM SILT

Sorting coefficient $S_o = Q_3/Q_1 = 17$

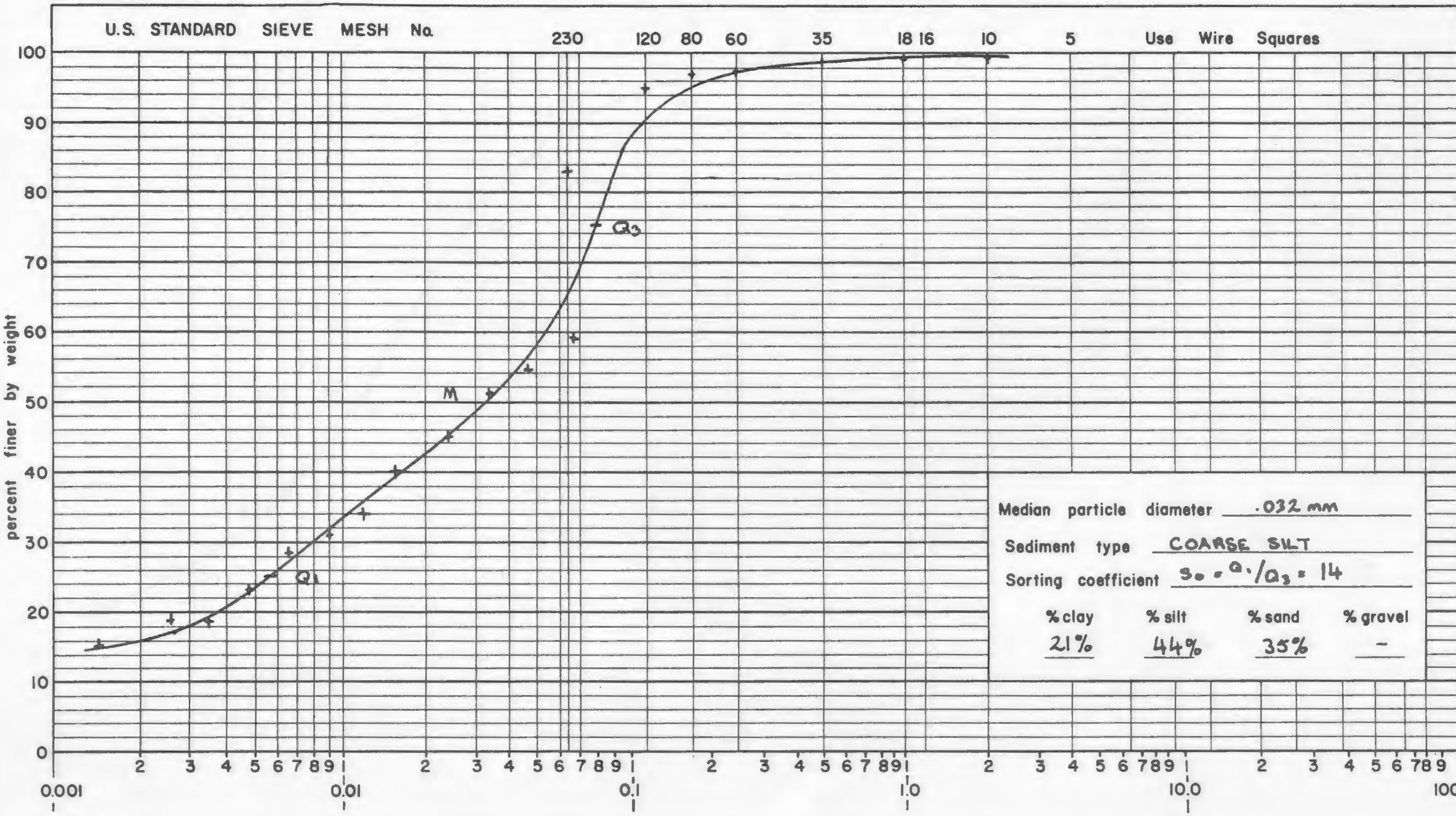
% clay	% silt	% sand	% gravel
30%	42%	28%	–

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT	DATE TESTED JAN. 16, 1975
STATION No.	FLORA 1	N.E.A.T.
DEPTH	10m	



Median particle diameter .032 mm

Sediment type COARSE SILT

Sorting coefficient $S_o = Q_1/Q_3 = 14$

% clay	% silt	% sand	% gravel
21%	44%	35%	-

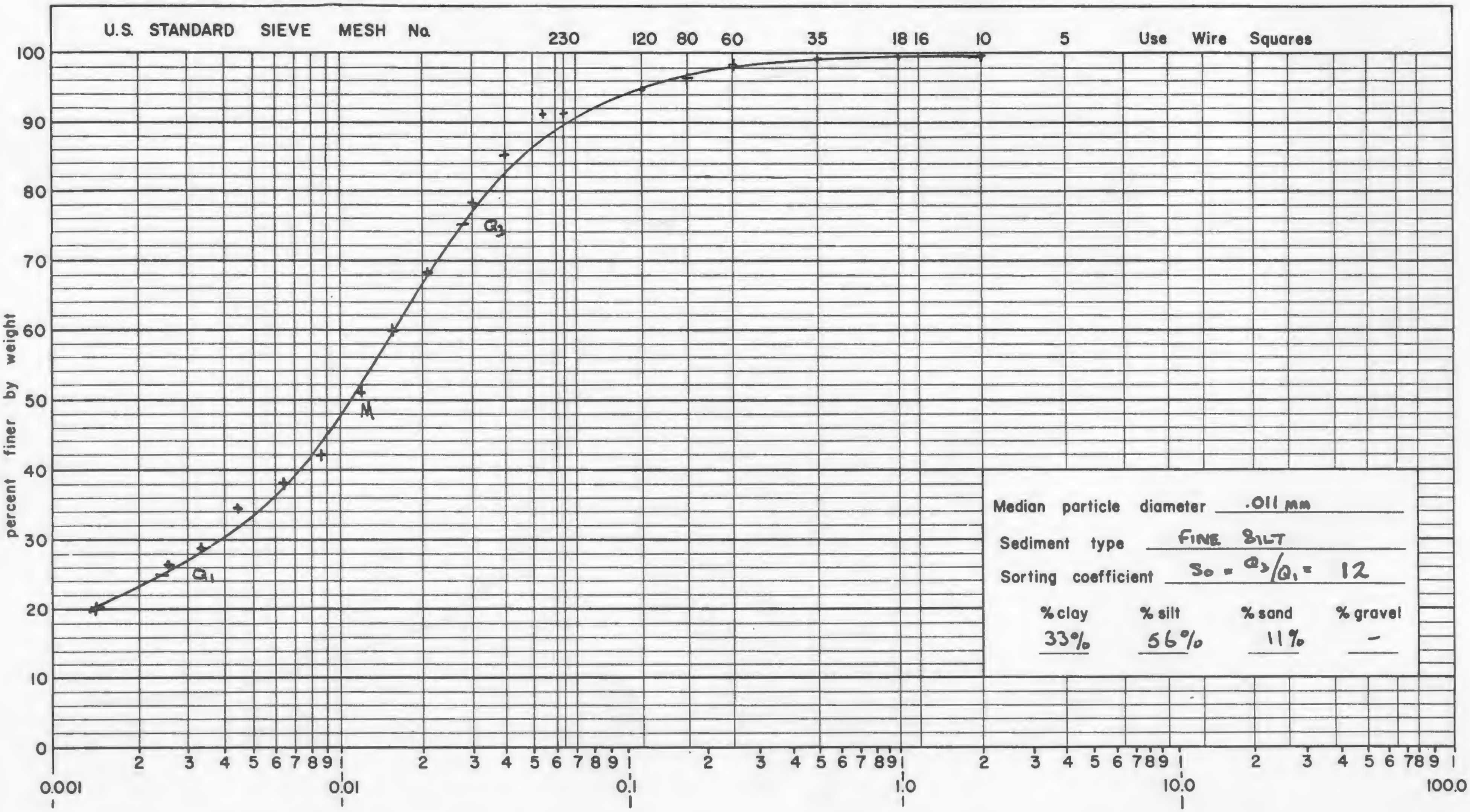
	CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class		very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (ϕ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0		-6.0
GRAIN SIZE (mm.)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0		

NEAT

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT
STATION No.	RIDLEY 4
DEPTH	12m
DATE TESTED	JAN. 16. 1975
	N.E.A.T.

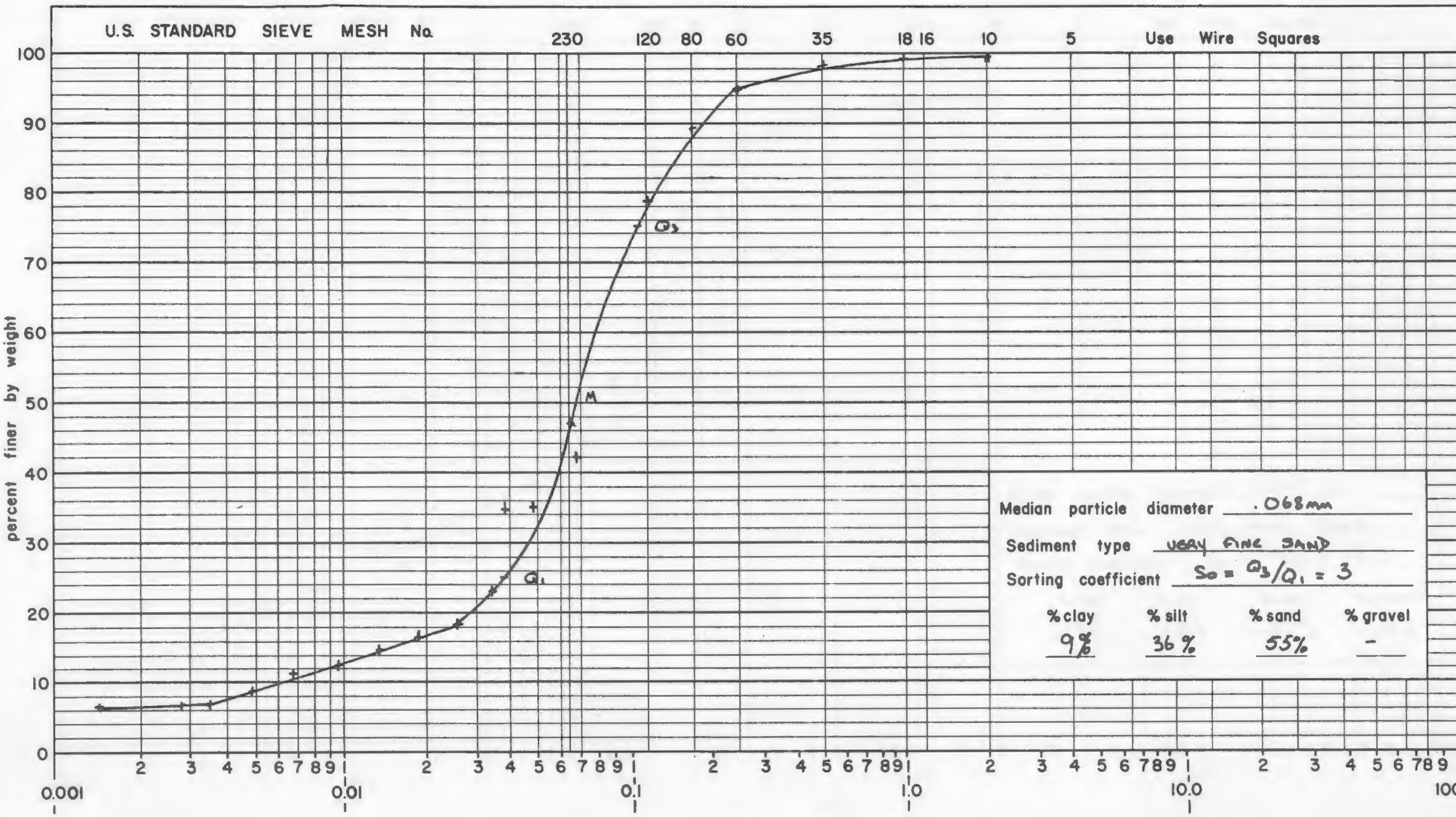


CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (Φ) 8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0		−6.0
GRAIN SIZE (mm) .0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0		

NEAT

NEAT

CUMULATIVE CURVE		
BASED ON WENTWORTH GRADE SCALE	STATION No. MELVILLE 1	N.E.A.T
	DEPTH 8.5 m	

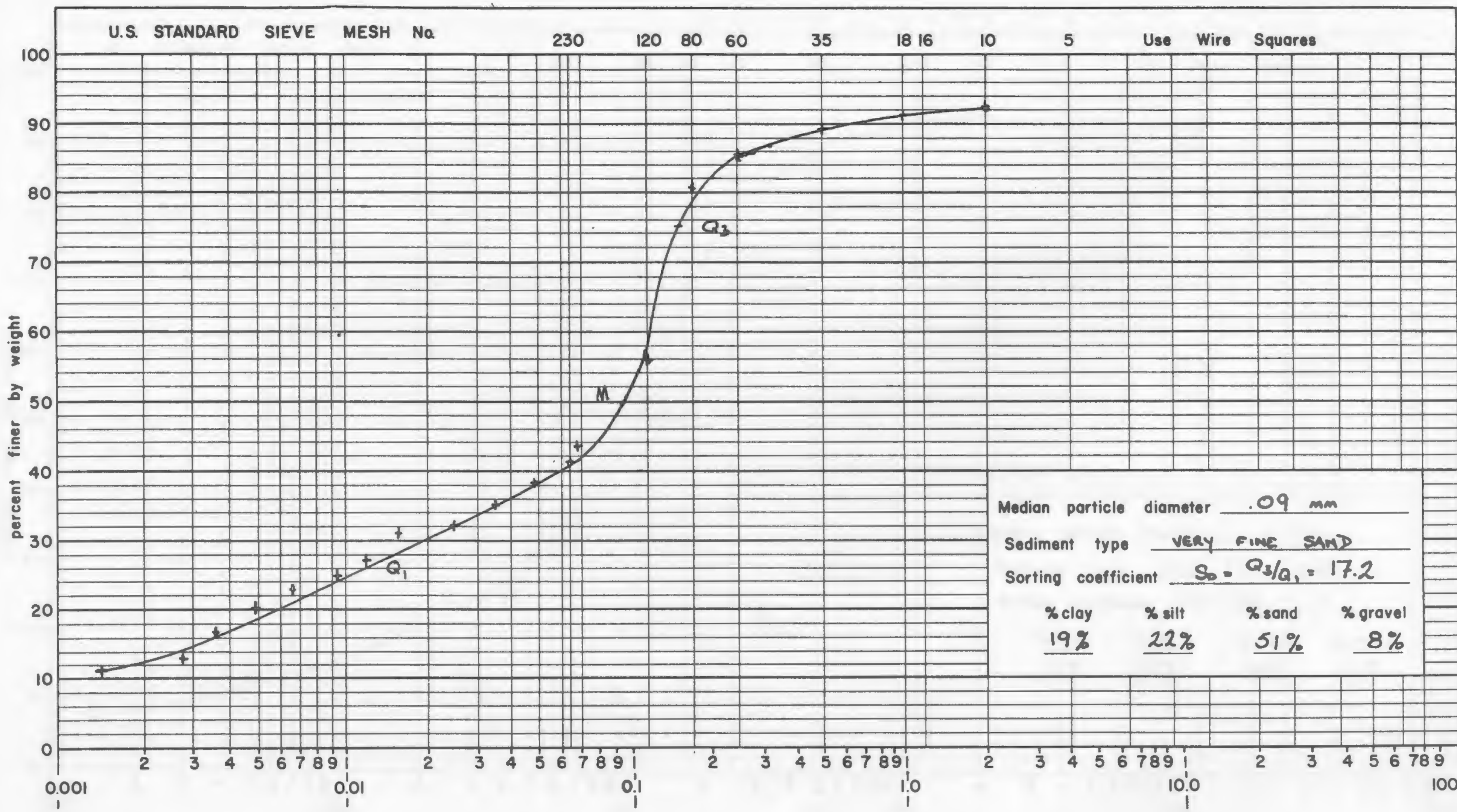


CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (ϕ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE
BASED ON WENTWORTH GRADE SCALE

STATION No. BACON 1
DEPTH 7.5m

N.E.A.T.

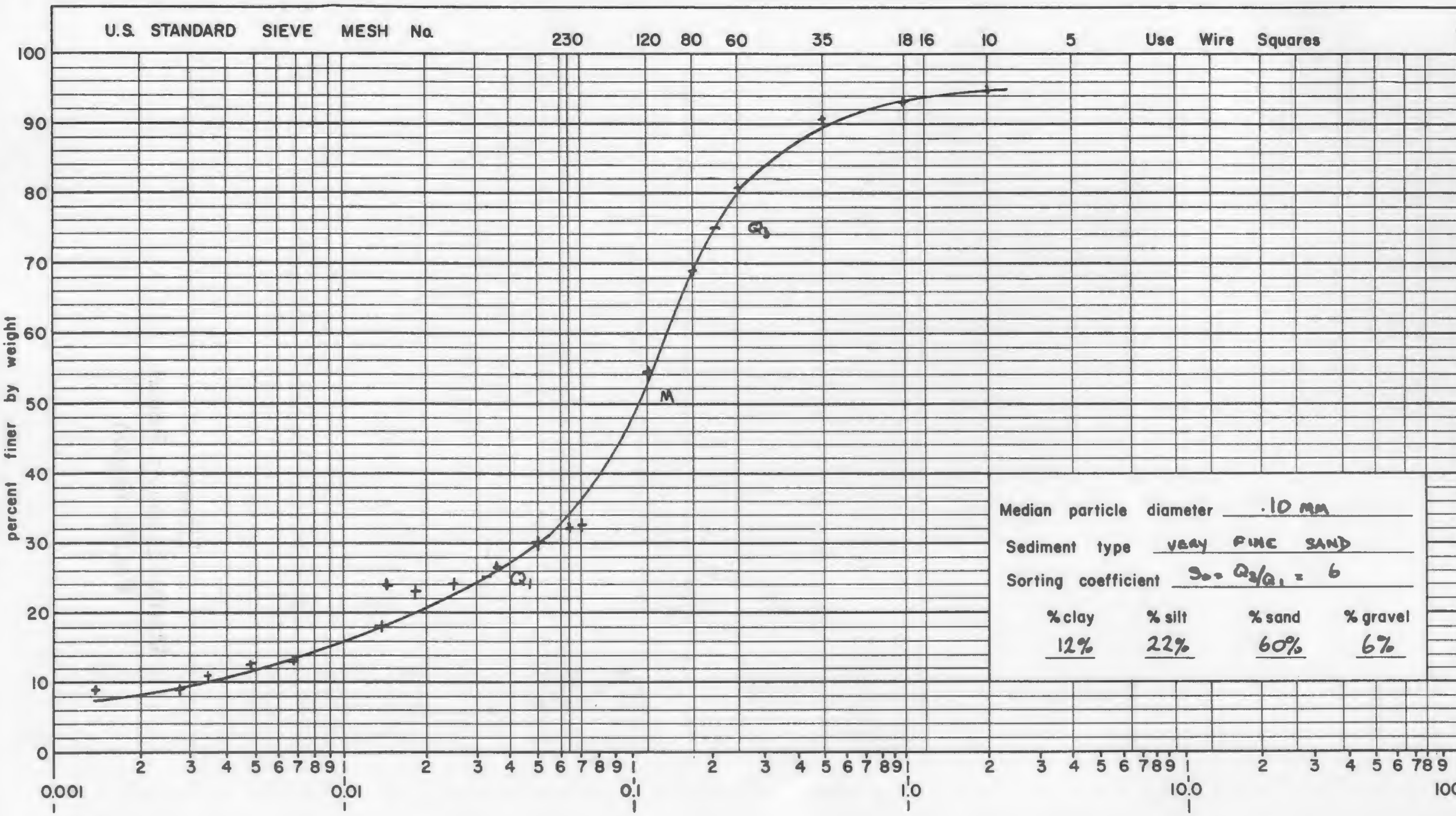


CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coorse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (φ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	-1.0	-2.0	-6.0
GRAIN SIZE (mm)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

LOCATION	PRINCE RUPERT
STATION No.	OSBORNE 1
DEPTH	9M
DATE TESTED	JAN. 20, 1975
	N.E.A.T.



Median particle diameter .10 MM

Sediment type VERY FINE SAND

Sorting coefficient $S_o = Q_3/Q_1 = 6$

% clay	% silt	% sand	% gravel
12%	22%	60%	6%

CLAY	SILT				SAND					GRAVEL		
WENTWORTH Size Class	very fine	fine	medium	coarse	very fine	fine	medium	coarse	very coarse	granule	pebble	coble
PHI (ϕ)	8.0	7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	−1.0	−2.0	−6.0
GRAIN SIZE (mm.)	.0039	.0079	.0156	.031	.0625	.125	.25	.50	1.0	2.0	4.0	

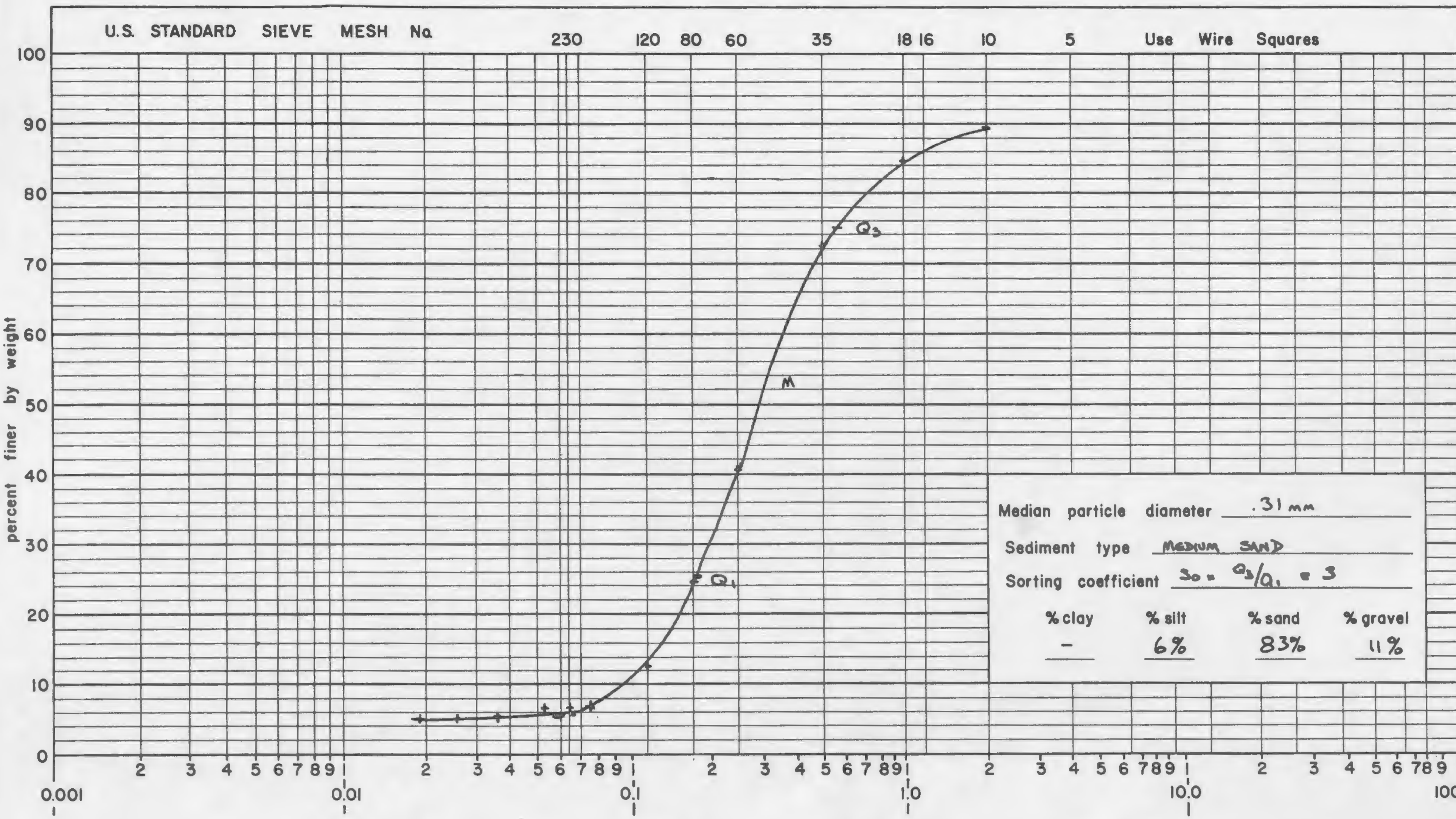
NEAT

CUMULATIVE CURVE

BASED ON WENTWORTH GRADE SCALE

STATION No.	STUMAN 2
DEPTH	7m

N.E.A.T.



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NEAT