MARTIN MARIETTA

Environmental Center

FINAL RESULTS OF THE 1981 FIELD PROGRAM FOR THE GREENS CREEK PROJECT

PART I -- HAWK INLET AND YOUNG BAY

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FOREWORD

This report is based on findings of field studies carried out by the Martin Marietta Environmental Center under contract to Noranda Mining, Inc.

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I. INTRODUCTION

Noranda Mining, Inc., is currently developing a mine in the Greens Creek area of Admiralty Island in southeastern Alaska. A former cannery site, located on Hawk Inlet near Greens Creek, will be the site of facilities to be used in loading ore concentrate into transport vessels and unloading supplies for the mining operation.

Studies of the aquatic biology of Hawk Inlet have been conducted over the past 3 years to assess potential impacts of the mining operation (Noranda Exploration, Inc., 1978; IEC, 1980). To provide a basis for establishing preoperational and baseline conditions, these studies were augmented with investigations of soft-bottom benthic organisms and sediments in Hawk Inlet (conducted from 8 July to 14 July 1981). Additional work on the soft-bottom benthos was performed in Young Bay, which is the proposed location of docking facilities for transporting personnel and supplies to the mine site.

Several different, but related, studies were conducted for baseline characterization of benthic communities, habitats, and heavy metals tissue levels:

- Replicated quantitative samples of benthic organisms were taken in: (1) intertidal and subtidal soft-bottom habitats in Young Bay near the vicinity of the proposed docking facility, (2) in similar habitats north and south of the location of the proposed docking facility, (3) at the cannery, (4) at the head of Hawk Inlet, and (5) at the Greens Creek delta near the mouth of Hawk Inlet.

- Sediment samples were taken and environmental variables measured at all sampling locations. Sediment samples were analyzed for physical properties, metal levels, hydrocarbons, and oil and grease.

- Three species of invertebrates (Mya arenaria, Mytilus edulis, and an unidentified starfish species, probably Pisaster ochraceus were collected at the cannery and analyzed for heavy metals tissue concentrations.

- Tissue samples of fish from a Zinc Creek tributary under consideration as a tailings pond site were analyzed for heavy metals concentrations (these data are presented in Appendix A).

Surveys of epifaunal benthos organisms inhabiting hard surfaces in Hawk Inlet were conducted previously and were not duplicated here (Noranda Exploration, Inc., 1978; IEC, 1980). Qualitative samples of epifaunal organisms were collected from Young Bay.

II. METHODS

A. BIOLOGICAL FIELD METHODS

A field survey was conducted from 8-14 July 1981 to quantitatively sample benthic macroinvertebrates in representative soft-bottom subtidal and intertidal habitats in Hawk Inlet and Young Bay (Fig. 1). Table 1 summarizes information on the depth of sampling locations, sampling gear used, area sampled, and number of replicate samples collected at each sampling station. Three stations at each study area were located in intertidal areas and three stations were located in subtidal areas. All intertidal stations were located in the mid-littoral zone characterized by epifaunal populations of *Fucus disticus* (brown algae), *Mytilus edulis* (mussel), and *Balanus glandula* (barnacles).

Quantitative data on major soft-bottom habitat types in regions likely to be developed were obtained by sampling at various stations in Hawk Inlet. Stations and habitats sampled were:

- One intertidal and one subtidal station located in the area of the Greens Creek delta -- sandy/gravel riverine delta
- One intertidal station located at the cannery -- sandy intertidal region
- One subtidal station located at the cannery -- soft muddy bottom
- One intertidal and one subtidal station at the head of the inlet -- muddy-sand tidal flat.

At Young Bay, two benthic stations (1 intertidal, 1 subtidal) were sampled at the site proposed as a docking facility, and two benthic stations (1 intertidal and 1 subtidal) were sampled at sites located north and south of the proposed docking facility.

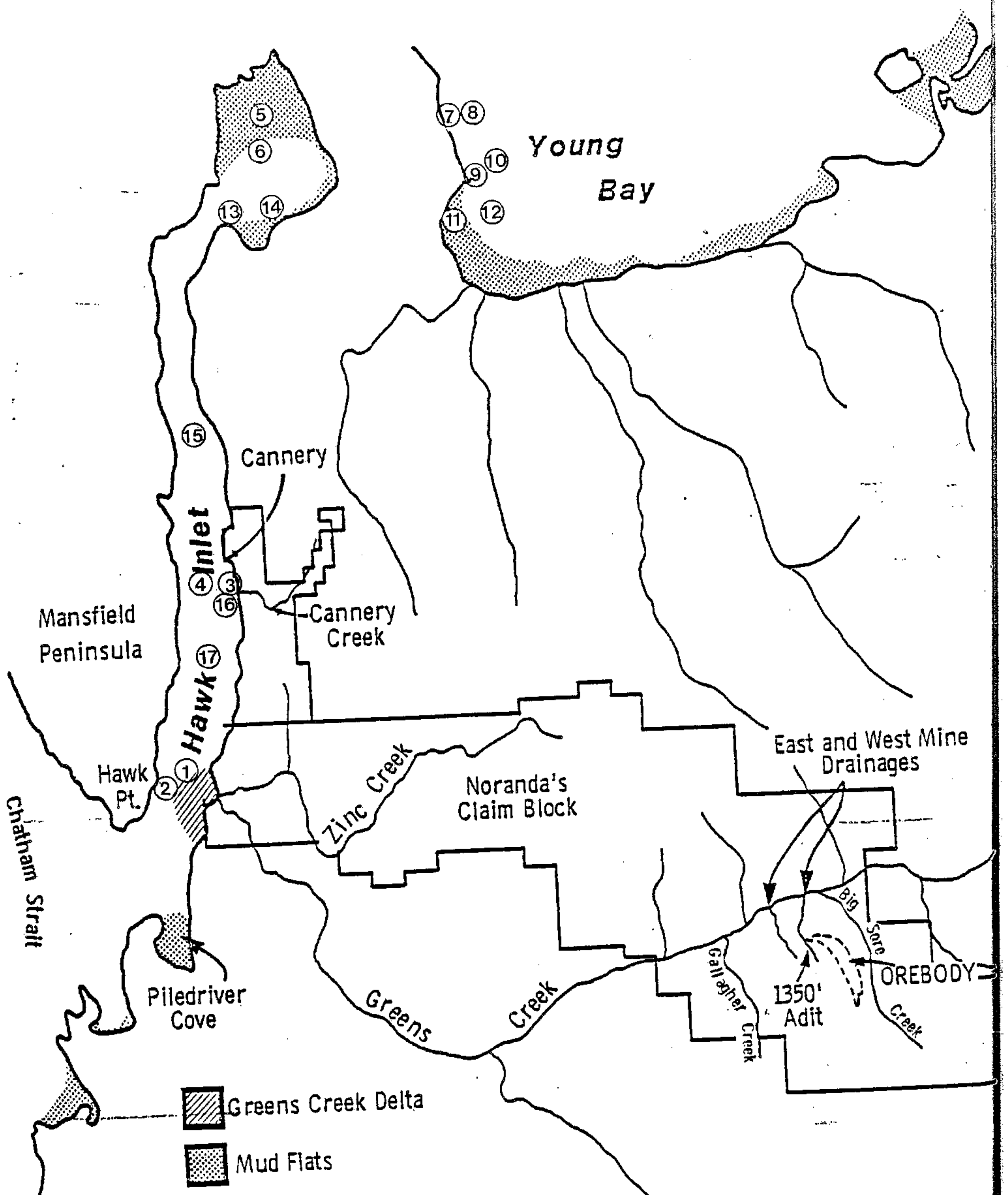

Figure 1. Map showing area where benthic sampling was conducted in July 1981

Table 1. Summary of sampling information for study sites. The sediment depth of all samples was approximately 15 cm.

Study Site	Station Location	Depth	Sampling Gear	Area Sampled	Number of Replicates Collected
Hawk Inlet	Greens Creek Delta	Intertidal	Hand core	77 cm^2	5
		8m	Ponar grab	262 cm^2	5
	Cannery	Intertidal	Hand core	153 cm^2	5
		63m	Ponar grab	262 cm^2	5
	Head of Inlet	Intertidal	Hand core	77 cm^2	5
		5m	Ponar grab	262 cm^2	5
Young Bay	Northern Reference	Intertidal	Hand core	100 cm^2	4
		3m	Hand core	77 cm^2	4
	Dock Site	Intertidal	Hand core	100 cm^2	4
		3m	Hand core	77 cm^2	4
	Southern Reference	Intertidal	Hand core	100 cm^2	4
		3m	Hand core	77 cm^2	4

The latter sites are referred to hereafter as reference areas since they were far enough removed from the proposed docking facility to be unaffected by its construction or operations. The physical appearance and environmental setting of the beach at the northern reference area were similar to the proposed dock site, while the beach at the southern reference area was more protected from wave action and appeared to contain less large-sized cobble and rocks. However, sand and other sediments under the cobble appeared similar to that at the proposed docking facility. Subtidal stations were established in sandy nearshore substrates that occurred throughout this region of Young Bay; all appeared to be relatively similar.

All biological samples were sieved shortly after collection through a 0.5-mm screen using an elutriative process. Materials retained on the screen were fixed in a 10% formalin-rose bengal solution at the cannery and transported back to Baltimore for sorting in the laboratory. During laboratory processing, all invertebrates collected were identified to the lowest practical taxonomic level and counted. A reference collection of the species observed is being maintained in Baltimore. Identifications have been verified by recognized experts at the National Museum of Canada and the Smithsonian Institute.

A sediment sample was collected along with the biological samples at each station for determination of mechanical properties, carbon content, and sediment burdens of metals and hydrocarbons. These sediment properties generally are related to the kinds and relative abundances of benthic species in soft-bottom habitats. Additional sediment samples, collected at locations in Hawk Inlet where the biota were not sampled (Fig. 1), served to establish the extent of various bottom types in subtidal habitats of the inlet, especially along the mainstem. Sediment samples were frozen at the cannery and remained frozen until processed in the laboratory in Baltimore. The samples were processed for physical characteristics by procedures outlined by Buchanan and Kain (1971):

- Chemical oxidation to determine the carbon content of sediments available to the benthos
- Combustion at 500°C to determine total carbon content
- Wet sieving through a 63-μm screen to determine the percentage of silts and clays
- Dry sieving through a series of screens to determine the median diameter and distribution of sediment particles.

Since salinity and temperature of the water are environmental factors that also determine the kinds and relative abundance of benthic organisms in an area, point measurements of these parameters were taken at several depths at each station when the biological samples were collected. Salinity and temperature measurements were also made throughout Hawk Inlet during sampling.

B. PROCESSING METHODS FOR METALS ANALYSIS OF BIOLOGICAL TISSUE

To prepare freeze-dried samples for tissue metals analyses, living specimens were collected at the cannery and suspended for 24 hours in inlet water to purge intestinal tracts of sediments and other material. Shellfish were removed from shells using stainless steel and Teflon-coated instruments. All instruments were soaked in 4N reagent-grade nitric acid overnight and triple rinsed with double-distilled water before use.

Samples were homogenized using an acid-washed glass or polyethylene blender container with a stainless steel and Teflon blade assembly. Triple-distilled water was added to each sample to provide sufficient fluidity for blending. Blended samples were then poured back into the original bottle, along with rinse water from the blender container.

Homogenized samples were frozen, bottle caps were loosened, and the samples were freeze dried for at least 96 hours at a temperature of -5°C or lower. Samples were weighed daily, and freeze drying was continued until no additional weight loss was observed. Sample bottle caps were then tightened, and the samples were shipped to analytical laboratories for metal and hydrocarbon determinations.

C. PROCESSING METHODS FOR METALS AND HYDROCARBON ANALYSES OF SEDIMENTS

Sediment samples to be used for metals and hydrocarbon determinations were frozen at the cannery in Teflon containers and dried to a constant weight in the laboratory. Sediments were treated by acid digestion and then analyzed as described below. Hydrocarbons were extracted using a dichloromethane-methanol mixture. Saturated (F_1) and unsaturated (F_2) fractions were separated by column chromatography and concentrated on a rotary evaporator. Total lipids were measured gravimetrically. Composition of fractions was determined by gas chromatography.

D. METALS CONCENTRATIONS ANALYTICAL METHODS

Metals analyzed for included zinc, copper, lead, manganese, nickel, chromium, silver, cadmium, mercury, arsenic, and selenium. Two blind standard biological tissue samples from the National Bureau of Standards were included in the set of samples sent out for analysis to provide a measure of the accuracy of the analyses. The two standard materials were albacore tuna (NBS Research Materia 50) and bovine liver (NBS Standard Reference Material 1577). Only a number was used to mark the polyethylene bottles containing the freeze-dried samples. Thus, the analytical laboratory technicians did not know the type of tissue being analyzed or which samples were replicates. This procedure complicated the analysis of samples but ensured unbiased results.

Sample analysis was performed by Energy Resources Co., Inc. (ERCO), Cambridge, Massachusetts. Each freeze-dried sample container was opened on a laminar-flow clean bench and three

representative subsamples were removed from each specimen. Acid-rinsed plastic or Teflon utensils were used for all sample manipulations to avoid contamination. One subsample was used for the determination of Ag, Cd, Cr, Cu, Mn, Ni, Pb, and Zn. The second subsample was used for determination of Hg. The third subsample was used for determination of As and Se. Analyses of Ag, Cd, Cr, Cu, Hg, Mn, Ni, Pb, and Zn were conducted according to methods described by Goldberg (1976) and U.S. EPA (1977, 1979). Analyses for As and Se were conducted according to methods described by Agemian and Cheam (1978).

III. RESULTS

A. SEDIMENT AND PHYSICAL/CHEMICAL DATA

The physical and chemical characteristics of the water (e.g., salinity, temperature) and mechanical properties of sediments (e.g., carbon content, silt-clay content, median diameter) generally are the major environmental factors determining the kinds and abundances of benthic organisms that occur in soft-bottom habitats. Data on these factors were collected at each study site jointly with biological samples and are summarized in Table 2.

Salinities in Hawk Inlet were polyhaline to marine (22 to 32 ppt) and varied 2 to 5 ppt over a tidal cycle. Salinity also varied with depth. Highest salinities (32 ppt) occurred in deepest areas. Water temperature decreased with depth: the highest water temperature (about 13°C) occurred in surface waters at the head of the inlet, while lowest temperatures (8.5°C) occurred in deep water in the center of the inlet. Variations in salinity and temperature with depth resulted in a stratified water column. These data were similar to those collected from Hawk Inlet during summers of other years, suggesting that the 1981 data were representative of "normal" conditions (e.g., Binkerd and Johnston, 1980; IEC, 1980; Noranda Exploration, Inc., 1978).

Salinities at the proposed dock site in Young Bay were much lower than those in Hawk Inlet -- 19 to 24 ppt compared to 25 to 32 ppt (Table 2). Water temperatures in Young Bay were comparable to those observed in shallow water habitats of Hawk Inlet (Table 2). No previous salinity or temperature data were available from Young Bay for comparison.

Sediments composing intertidal regions of the Greens Creek delta were heterogeneous, and consisted of isolated patches of gravel, cobble, and large rocks on top of sands. The physical properties of the sand appeared to be similar over most of the

Table 2. Summary of physical/chemical and sediment data collected at benthic sampling locations between 8 and 14 July 1981. Dashes indicate determinations were not made.

Station Location and Designations	Bottom Depth (m)	Water* Column Salinity (ppt)	Temp. (°C)	SEDIMENT CHARACTERISTICS — With Carbonates: Inter-stitial Salinity (ppt)	Moisture (%)	Carbonate (%)	Organic (ignition) (%)	Organic (wet oxidation) (%)	Silts & Clays (%)	Median Diameter (ϕ)	Skewness	Quartile Deviation	Without Carbonate: Silts & Clays (%)	Median Diameter (ϕ)	Skewness	Quartile Deviation
Hawk Inlet Samples																
1) Green's Creek Delta	Mid-littoral	29.8	11.8	25.0	22.6	5.1	2.29	0.31	7.8	0.21	-0.04	1.28	7.2	0.57	-0.20	1.42
2) Green's Creek Delta	8	26.8	11.1	17.0	26.7	4.0	2.52	0.16	1.9	0.53	-0.18	1.60	1.9	0	-0.05	1.60
3) Cannery	Mid-littoral	29.8	11.2	25.0	54.1	3.4	2.41	0.34	3.2	1.10	-0.42	1.59	5.3	1.08	-0.38	1.65
4) Cannery	63	32.0	8.9	32.5	64.4	0.0	15.45	4.79	48.8	3.95	1.00	1.95	—	—	—	—
5) Head of Inlet	Mid-littoral	27.2	13.4	26.0	30.3	0.6	3.31	0.98	32.1	1.40	-1.13	3.58	—	—	—	—
6) Head of Inlet	5	27.2	13.4	28.0	36.3	1.8	3.66	1.00	17.7	-2.05	-2.40	3.75	—	—	—	—
Young Bay Samples																
7) North Reference Young Bay	Mid-littoral	—	—	—	2.0	12.8	1.06	0.02	0.3	-2.20	-0.15	1.75	0.3	-2.45	0.03	1.83
8) North Reference Young Bay	3	—	—	24.0	36.5	9.8	2.40	0.25	2.0	1.93	0	0.40	2.2	1.98	0.25	0.63
9) Dock Site Young Bay	Mid-littoral	19.3	12.4	23.5	12.8	28.5	1.40	0.07	1.6	-2.40	-0.03	1.13	1.1	-3.10	0.10	1.05
10) Dock Site Young Bay	3	19.3	12.4	22.5	25.1	12.4	2.58	0.16	2.2	1.78	0.05	0.50	3.0	1.68	0.18	0.50
11) South Reference Young Bay	Mid-littoral	—	—	22.0	8.8	25.6	1.29	0.11	0.3	-2.25	0.73	2.98	0.8	-4.25	-6.94	2.04
12) South Reference Young Bay	3	—	—	23.5	25.5	17.0	2.26	0.29	1.4	1.39	0.09	0.79	1.9	1.39	0.11	0.78
Hawk Inlet Misc. Samples																
13) Entrance to "Mud Hole" area	12	28.5	13.0	28.0	62.0	1.7	5.74	1.80	38.0	3.35	-0.04	1.43	—	—	—	—
14) Inside "Mud Hole" area	12	29.0	12.9	30.0	28.4	4.4	6.99	0.56	9.6	-3.30	7.23	3.93	—	—	—	—
15) Upstream of cannery	40	31.9	9.9	30.0	51.5	1.8	9.80	2.49	47.1	3.87	1.16	2.23	—	—	—	—
16) Cannery	25	26.9	10.9	29.5	30.0	1.2	4.26	1.05	13.5	1.95	-2.13	2.93	—	—	—	—
17) Near proposed tailing pond discharge	60	27.3	10.6	29.0	63.6	0.4	5.82	1.81	18.7	3.33	-0.07	0.52	—	—	—	—

*Salinity was measured in bottom water of subtidal sample sites and in water over intertidal sample sites just before or after samples were collected.

delta. However, the amount of gravel and cobble varied considerably from location to location. Intertidal sediments from the site where biological samples were collected were classified as poorly sorted, coarse sands, as indicated by large median diameters and skewness and quartile deviation values (Table 2). They contained about 7 to 8% silts and clays, 2.3% organic material, and 5% carbonates (Table 2). The silt-clay and organic content were higher than anticipated. The large populations of mussels (e.g., Mytilus edulis), seaweeds (e.g., Fucus disticus), and other unidentified invertebrates at the collection site probably contributed to the deposition of fine-grained materials, either through biodepositional processes (such as feeding activities and feces production) or by slowing down currents and entrapping finer sediment particles. Relatively large quantities of fecal material from invertebrates were noted on the surface of sediments.

Subtidal sediments from the Greens Creek delta were also heterogeneous and were similar to intertidal sediments (Table 2). However, the silt-clay content was slightly lower. The poor sorting and heterogeneous nature of sediments composing subtidal and intertidal habitats of the Greens Creek delta indicated that sediments of the delta were glacial deposits that had been mixed with modern deposits and reworked by tidal action.

Intertidal sediments in the vicinity of the cannery were poorly sorted, coarse sands containing about 3% silts and clays, 2.4% organic material, and 3.4% carbonates (Table 2). Mechanical properties (e.g., median diameter and silt-clay content) of cannery deposits were similar to those from the Greens Creek delta, suggesting that intertidal sediments from the cannery site could also have been derived from glacial and recent erosion processes associated with Cannery Creek. Based on observations, intertidal sediments at the cannery were not as heterogeneous as at the Greens Creek delta.

Subtidal sediment characteristics in the vicinity of the cannery varied with depth. At 25 m, sediments were coarse-grained muddy-sands composed of about 14% silts and clays, 4% organic material, and 12% carbonates. At 63 m, sediments contained about 50% silts and clays, 15% organic material, and essentially no carbonates. Deep-water sediments north and south of the cannery were generally similar in physical properties to those at the cannery site except they contained less organics (5.74 to 9.8%) and more sands. The higher organic content of sediments in the immediate vicinity of the cannery could have been a result of discharge associated with cannery operations. However, since this part of the fjord was also the deepest, some undetermined portions of the organic content of sediments there could also have been the result of natural sedimentation processes. The muddy, deep-water sediments from the central area of Hawk Inlet, especially in the vicinity of the cannery, contained considerable amounts of plant detritus. Although the extent of the muddy sediments in deep-water environments of Hawk Inlet was not quantitatively determined, they appeared to extend from near the cannery to the head of the inlet along the eastern shore. Deep-water hard bottoms appeared to be confined to the region near the Greens Creek delta and the western shore.

Intertidal sediments at the head of the inlet were coarse muddy-sands that contained about 32% silts and clays, 3.3% organic material and 0.6% carbonates (Table 2). Properties of subtidal sediments at the head of the inlet were similar to those of intertidal sediments except they contained less silts and clays (≈17%). Large beds of bull kelp, Nereocysts luetkeana, occurred in this area. Detritus, especially kelp-like material, appeared to constitute much of the organic material in sediments. The sand component of sediments at this site was poorly sorted and could have been of glacial origin. Large boulders, rocks, and cobble were frequently observed scattered throughout the intertidal zone, another indication that some of the deposits at this site were probably derived from glacial processes. The high silt-clay content of sediments at the head of the inlet suggested the area was a depositional environment for fine sediment particles.

Intertidal sediments at the proposed dock site in Young Bay were predominantly cobble mixed with sand. These poorly sorted sediments contained 1.6% silts and clays, 1.4% organic material, and 28% carbonates. Properties of intertidal sediments at the northern and southern reference areas were similar to those at the dock site.

Depth in Young Bay increased rapidly with distance from shore beginning at about 100 to 200 m offshore where depth was 3 to 4 m. The cobble intertidal sediments rapidly changed to sand along this gradient. No sediment samples were obtained from depths greater than 3 m. Subtidal sediments at the proposed dock site were well-sorted, medium sands containing 2.2% silts and clays, 2.6% organic material, and 12.4% carbonates. Properties of subtidal sediments at the northern and southern reference areas were similar to those at the dock site. The sediment characteristics in the Young Bay samples suggested that the sample sites were located in moderate-energy environments (i.e., that the area was exposed to some wave activity). The large amounts of carbonates in sediments at this location were predominately shell fragments of molluscs and barnacles.

Sediment characteristics generally appeared to be similar from replicate to replicate at all sample sites where biological samples were collected (i.e., bottoms were homogeneous), except for the subtidal stations located at the head of Hawk Inlet and in the vicinity of the Greens Creek delta. At these two locations, there was considerable replicate-to-replicate variability in sediment characteristics and volume of material collected by the grab sampler. At both locations, rocks, cobble, and large shell fragments appeared to be dispersed among the finer grained sediments, and properties of sediments changed rapidly over distances of tens of meters. Because only a single sediment sample was collected with the five biological samples from each of these sites, the effects of the heterogeneous nature of the sediments on the biota could not be quantitatively determined -- only a qualitative association could be established.

The data collected on sediment metals levels in Hawk Inlet are summarized in Table 3. The concentrations observed were comparable to levels reported for "pristine" and "unpolluted" marine areas of the northeast Pacific coast and were orders of magnitude lower than levels reported for "polluted" or "semi-polluted" environments such as Baltimore or Los Angeles Harbors (e.g., Pfeiffer et al., 1972). Station-to-station variability in metals levels did not appear to be closely related to station-to-station variability in physical properties of sediments. These data were quantitatively similar to data previously collected from Hawk Inlet by VTN, indicating that year-to-year variability in sediment metals is small (IEC, 1980).

Sediment burdens of oil and grease, lipids, aliphatic hydrocarbons, and aromatic hydrocarbons at Hawk Inlet stations are also summarized in Table 3. Sediment levels of oil and grease were 2 to 6 times the levels observed in "unpolluted" environments (Pfeiffer et al., 1972). Levels of lipids, aliphatics, and aromatics were also higher by about a factor of 2 than would be expected for "unpolluted" nearshore marine environments (Malins, 1977). Results of gas chromatography are presented in a recent report by Energy Resources Company, Inc. (1981). Chronic petroleum contamination, as evidenced by high-molecular weight unresolved compounds, was the predominant source of hydrocarbons in the intertidal and subtidal samples taken at the cannery. A spill of diesel fuel of undetermined size (<1000 gallons) in early July could have accounted for these results. Terrigenous (land) plant hydrocarbons represented by n-alkanes with odd-numbered carbon chains, were present in all samples and were most abundant in those from the Greens Creek delta area. Marine biogenic (algal) hydrocarbons were predominant in samples from the head of the inlet. These data indicated that the only stations contaminated by anthropogenic hydrocarbons were those at the cannery site.

Table 3. Summary of data in sediment burdens of heavy metals and hydrocarbons in Hawk Inlet for samples between 8 and 14 July 1981.

	Sample	Moisture (%)	METALS CONCENTRATION (ppm dry wt.)											Oil & Grease (µg/g dry wt.)	Total Lipids (mg/g dry wt.)	Aliphatics (F_1) (mg/g dry wt.)	Aromatics (F_2) (mg/g dry wt.)
			Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn				
GREENS CREEK DELTA	Intertidal	78.39	<0.22	20	0.24	43	18	0.078	320	26	11	0.028	59	630	0.258	0.029	0.023
	Subtidal	81.14	<0.2	22	<0.15	57	17	0.35	370	43	8.4	0.55	110	270	0.118	0.003	0.004
CANNERY	Intertidal	33.16	0.39	24	1.0	60	39	0.15	250	39	19	1.7	110	2300	1.01	0.052	0.95
	Subtidal	76.33	<0.14	13	0.22	14	18	0.049	240	17	4.8	0.30	50	930	0.223	0.007	0.013
HEAD OF INLET	Intertidal	40.37	<0.22	18	1.3	35	27	0.11	250	23	8.7	0.79	57	820	0.919	0.30	0.099
	Subtidal	74.51	<0.15	17	0.48	55	16	0.034	320	42	7.4	0.38	110	1100	0.128	0.002	0.004

B. METALS CONCENTRATIONS IN BENTHIC INVERTEBRATES

Three types of benthic organisms were collected at the cannery for analysis of metals burdens in tissues: the soft clam (Mya arenaria), the mussel (Mytilus edulis), and starfish (species probably Pisaster ocharceus). Results of analyses of metal levels in tissues, summarized in Table 4, were comparable to or lower than those reported for mussels and clams collected at the Greens Creek delta in 1980-1981 (Richkus and Johnson, 1981). Differences in concentrations of metals between Mya and Mytilus are evident in Table 4. Arsenic, cadmium, and lead tended to be higher in Mytilus while copper and manganese were higher in Mya. Values for zinc and copper in both Mya and Mytilus were comparable to values reported for these species in marine waters of British Columbia (Table 5). Values for most metals were lower in starfish than in shellfish. No literature data were available for comparison to the starfish data. However, the starfish is a predator on clams, mussels, and other benthic organisms, and thus should be an indicator of prevailing bioaccumulation of metals and other toxic substances through the marine food web at this location. In general, these data indicated the absence of metal pollution near the cannery and could serve as baseline data for future monitoring of the cannery area.

C. QUANTITATIVE MACROBENTHIC DATA

The quantitative macrobenthic data collected during July 1981 are presented in Appendix B and summarized in Tables 6 and 7. Juvenile organisms dominated collections at all locations, indicating that the sampling program was conducted during or shortly after the peak summer recruitment period. The peak recruitment period for most benthic communities of the northeast Pacific is summer (Lie, 1968). Thus, numerical values presented here are higher than would be the case if sampling had been conducted at other times of the year, when these juveniles had been exposed to predation and other sources of natural mortality for a period of time.

Table 4. Metals concentrations in tissue samples of the indicated organisms taken from the vicinity of the cannery in Hawk Inlet between 8 and 14 July 1981.

Sample No.	Tissue	Number of Individuals	Sample Wet Wt. (g)	Metals Concentration (µg/g dry wt.)										
				Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn
1	Clam (Mya)	2	55	21	1.9	0.69	1.6	14	0.041	15	1.7	<0.34	3.2	100
2	Clam (Mya)	2	49	9.7	1.9	0.40	1.1	10	0.044	7.4	0.96	<0.28	2.9	48
3	Clam (Mya)	2	44	7.3	3.4	0.78	1.4	18	0.067	17	2.2	<0.41	4.1	140
4	Clam (Mya)	2	41	2.4	2.7	1.4	1.1	16	0.066	15	1.7	<0.33	4.3	130
5	Clam (Mya)	2	40	5.3	3.5	0.81	1.7	22	0.071	23	2.9	0.74	4.7	110
6	Mussel (Mytilus)	7	23	9.3	4.0	9.0	1.8	7.3	0.066	14	2.1	0.75	2.7	120
7	Mussel (Mytilus)	7	38	11	4.0	5.8	1.4	8.1	0.10	12	0.65	1.1	1.8	94
8	Mussel (Mytilus)	7	40	8.1	3.7	5.2	2.1	6.8	0.063	11	1.1	0.61	2.1	100
9	Mussel (Mytilus)	7	45	5.7	2.9	3.7	0.84	5.7	0.049	6.4	0.50	0.33	2.6	76
10	Mussel (Mytilus)	7	35	5.5	4.1	14	1.4	6.9	0.073	9.8	0.87	1.5	2.8	110
21	Starfish	1	31	0.19	1.8	2.6	1.2	6.8	0.042	13	1.1	3.3	2.9	70
22	Starfish	1	34	0.24	2.6	3.3	1.0	5.4	0.058	8.8	0.68	0.99	3.4	87
23	Starfish	1	24	0.10	2.6	2.2	1.3	8.0	0.019	11	0.69	3.0	3.0	96
24	Starfish	1	31	1.1	2.7	2.7	0.93	8.0	0.056	8.2	0.46	1.5	3.5	100
25	Starfish	1	18	0.12	2.1	1.9	1.7	4.6	0.037	7.5	0.74	0.95	3.4	74
26	Bovine Liver (NBS)	—	—	0.045	<7.9	0.31	0.56	210	0.005	11	0.28	0.42	1.1	140
27	Albacore Tuna (NBS)	—	—	<0.01	<5.7	0.049	0.51	3.6	0.65	<2.0	0.39	0.49	3.1	15
16	Coho Smolt	9	22	0.53	<10	0.14	0.77	3.8	1.14	18	<0.35	<0.35	1.6	170
17	Coho Smolt	9	23	0.86	<11	0.13	<0.2	3.7	0.13	16	<0.41	<0.41	1.4	190
18	Coho Smolt	9	23	0.44	<5.3	0.10	0.23	2.5	0.095	14	0.21	<0.19	1.3	140
19	Coho Smolt	9	23	0.39	<11	0.13	<0.2	3.3	0.12	15	0.4	<0.4	1.6	150
20	Coho Smolt	9	26	0.28	<10	0.13	0.65	3.6	0.11	23	0.69	<0.36	1.6	150

Table 5. Metals concentrations, μg/g (ppm dry weight), in invertebrates (all bivalve molluscs) of Rupert and Holberg inlets, British Columbia, 1971-1974. (From Waldichuk and Buchanan, 1980).

Station	Species	Sampling Date	Zn		Cu	
			Average	Range	Average	Range
Red Island (Rupert Inlet)	*Macoma iris*	Aug. 1971	260		460	
	"	June 1972	140		100	
	"	June 1973	340	300-380	330	310-350
SCUBA Stn. 6 (West of mill site)	"	June-Aug. 1971	233	110-370	57	42-71
	"	Sept 1971	170		70	
	"	June 1973	270	230-300	74	38-130
Apple Bay (Holberg Inlet)	"	June 1973	180		9	
	"	June 1974	156	140-180	34	9-61
Red Island	*Mya arenaria*	Aug. 1971	105		77	
"	"	June 1972	68		34	
"	"	June 1973	130	16-19	31	29-33
"	"	May 1974	81	61-110	28	24-33
SCUBA Stn. 6	"	Aug. 1971	135	110-160	19	13-24
"	"	Sept 1971	120	80-160	31	(31)[a]
"	"	June 1973	167	150-180	31	27-37
"	"	May 1974	63	42-110	22	12-31
Apple Bay	"	June 1972	140	(140)[a]	16	16-17
"	"	June 1973	133	110-160	28	13-55
"	"	May 1974	62	48-69	22	16-29
Red Island	*Mytilus edulis*	July-Aug. 1971	215	89-340	30	16-44
"	"	June 1973	220		87	
"	"	June 1974	98	33-120	15	13-20
SCUBA Stn. 6	"	July-Aug. 1971	145	100-190	35	17-52
"	"	June 1973	190		43	
"	"	May 1974	93	75-130	14	10-17
Apple Bay	"	June 1972	51		5	
"	"	June 1973	120		9	
"	"	May 1974	71	51-95	9	5-13

[a]All samples gave the same value.

Table 6. Number of benthic species collected at each sample site during July 1981 surveys.

Sample Sites	Intertidal	Subtidal
Hawk Inlet		
Greens Creek delta	36	80
Cannery	57	52
Head of inlet	36	41
Young Bay		
Northern reference area	15	33
Proposed dock site	21	27
Southern reference area	24	25

Table 7. Mean number of individuals per m^2 for macrobenthic organisms by major taxonomic groups.

	HAWK INLET					
	Greens Creek Delta		Cannery		Head of Inlet	
	Intertidal	Subtidal	Intertidal	Subtidal	Intertidal	Subtidal
Polychaetes	4,206	19,775	11,038	5,222	24,313	3,494
Snails	675	2,047	1,643	108	4,779	519
Bivalves	156	1,300	2,588	1,581	15,896	3,665
Amphipods	338	3,682	9,485	153	156	39
Other crustacea	442	1,207	4,365	1,749	4,181	65
Other worms	676	977	2,340	594	182	161
Misc. species	78	847	274	0	52	0
Total All Species	6,391	29,835	31,733	9,407	49,558	7,943
	YOUNG BAY					
	Northern Reference Area		Proposed Dock Site		Southern Reference Area	
	Intertidal	Subtidal	Intertidal	Subtidal	Intertidal	Subtidal
Polychaetes	1,675	7,826	1,075	17,533	1,600	906
Snails	350	0	546	86	2,200	96
Bivalves	300	583	13,075	346	6,050	3,375
Amphipods	0	3,083	200	6,450	0	195
Other crustacea	300	96	6,050	43	22,300	1,201
Other worms	1,075	162	3,400	87	2,300	4,611
Misc. species	75	0	375	0	150	0
Total All Species	3,775	11,750	20,246	24,545	3,460	10,384

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The total number of species observed in samples and estimates of mean density of abundant species at all locations generally leveled off after four or five replicates, i.e., it is unlikely that significant numbers of new species would have been collected or estimates of mean density would have changed had additional samples or larger samples been collected. Five replicates of the sample sizes collected were thus considered sufficient to: (1) characterize the species composition and relative abundance of the organisms sampled and (2) establish a quantitative baseline for use in monitoring potential effects during mining operations.

Thirty-six species of macrobenthic invertebrates were collected from the sandy intertidal station on the Greens Creek delta (Table 6). Snails (e.g., Littorina sitkana), polychaetes (e.g., unidentified juvenile Capitellidae, Fabricia sabella, Spio filicornis, and Sternaspis scutata), shellfish (e.g., Mytilus edulis), and the isopod Gnorimosphaeroma oregonensis were numerically dominant organisms. The number of species observed in these samples was higher than that reported for the Greens Creek delta area by VTN (IEC, 1980), primarily because of the higher number of polychaete species in the present samples. Polychaete species were probably more numerous because the soft-bottom habitats which they inhabit were rigorously sampled in this study, while the VTN samples were random collections from the area. Macrobenthic densities in intertidal samples from the Greens Creek delta were within ranges reported for similar habitats along the northeast Pacific coast (Table 7), and the communities were typical of those expected for sandy, soft-bottom, mid-littoral habitats of the region (e.g., O'Clair et al., 1978; Broad et al., 1979).

More macrobenthic species were collected in subtidal samples from the Greens Creek delta than from any other sampling station (Table 6). One reason may have been the slightly higher salinities there, but more likely, more than one habitat was sampled, as indicated by the heterogeneity of the sediments at that location. Numerically dominant organisms were clams (e.g., Psephidia lordi), polychaetes (e.g., Armandia brevis, unidentified juvenile Chaetopteridae, Owenia fusiformis, Prionospio sp., and Spiophanes sp.), an unidentified amphipod species, and unidentified juvenile sea urchins (<2 mm). The species composition of the benthic community inhabiting this site was similar to that reported by IEC for subtidal areas near the cannery (IEC, 1980). Densities of abundant species and taxa (Appendix B and Table 7) were also similar to those reported for similar habitats along northeast Pacific coasts (IEC, 1980, O'Clair et al., 1978; Carey, 1979). Replicate-to-replicate variation in density of abundant species was larger at this site than at most other locations probably because the physical properties of the sediments varied greatly from replicate to replicate. Because of this large variability, any plans for monitoring studies in this region, or a similar habitat type, should include sampling at more than one station. In addition, a sediment sample should be taken with each biological sample collected. Only in this way can the biological variability associated with replicate-to-replicate variability in sediment properties be rigorously separated from that due to mining operations. These data indicated macrobenthic communities inhabiting subtidal habitats of the Greens Creek area were typical of shallow-water subtidal areas of the northeastern Pacific (e.g., Ricketts et al., 1939; Lie, 1968; O'Clair et al., 1978; Carey, 1979).

Intertidal samples collected from the vicinity of the cannery were dominated by bivalves (e.g., Macoma balthica and Mytilus edulis), snails (e.g., Littorina sitkana), and polychaetes (e.g., Fabricia sabella). A total of 57 species was collected from this habitat (Table 6), a slightly greater number than was collected from other intertidal habitats in Hawk Inlet or Young Bay. However, sample sizes at the cannery were about twice those at other sample sites, and the number of species in benthic collections is known to increase as the area sampled increases. The number of benthic species per unit area sampled at the cannery was lower or about equal to that at other Hawk Inlet sample sites. Over 50 macrobenthic species were observed in the vicinity of the cannery

by VTN, and the VTN species list includes most of the numerically dominant species observed in this study (IEC, 1980). Macrobenthic densities observed in the intertidal habitat sampled at the cannery were within ranges that would be expected from similar habitats (Table 7), and the species composition indicated a macrobenthic community typical of the northeast Pacific coast (e.g., O'Clair et al., 1978; Broad et al., 1979).

Subtidal samples from the vicinity of the cannery contained about the same number of species as intertidal samples from this location (Table 6). Polychaetes (e.g., unidentified juvenile Capitellidae, Cossura sp., Harmothoe imbricata, Lumbrineris sp. Pholoe minuta, and Prionospio sp.) were the dominant organisms. The species composition of the macrobenthic community at this site was similar to that reported for a similar habitat by VTN (IEC, 1980). Standing stocks in subtidal habitats in the vicinity of the cannery were in ranges reported for mud habitats of the northeast Pacific coast (Table 7; Lie, 1968; O'Clair et al., 1978; Carey, 1979). There were no previous data on densities in this habitat for comparison. Characteristics of deep-water mud communities in Hawk Inlet were similar to those of deep-water mud communities of the northeast Pacific coast where large amounts of organic material accumulate (Lie, 1968).

Thirty-six species of macrobenthic invertebrates were collected in samples from the muddy-sand intertidal flat at the head of the inlet (Table 6). Snails (e.g., Lacuna variegata and Moelleria sp.), clams (e.g., Mysella sp.), polychaetes (e.g., unidentified juvenile Capitellidae, Haploscoloplos elongatus, Nephtys ciliata, and unidentified polychaetes of the family Spionidae), and an unidentified mysid shrimp were the dominant organisms collected. These habitats were highly productive benthic habitats and harbored the highest standing stocks observed (Table 7). Communities inhabiting this site appeared to be typical of those in mud flats of the northeast Pacific coast (e.g., Ricketts et al., 1939; O'Clair et al., 1978).

Subtidal samples from the head of Hawk Inlet contained fewer individuals, by an order of magnitude, and about the same number of species as did intertidal samples from this area (Tables 6 and 7). Clams (e.g., Mysella sp.) and polychaeate worms (e.g., Haplos-coloplos elongatus) were the dominant organisms both here and in intertidal samples at this location. Replicate-to-replicate variability in species composition and abundances in subtidal habitats at this location were relatively large, probably because of the observed replicate-to-replicate variation in sediment characteristics. Plans for future field studies at the head of the inlet should include more than one station from subtidal habitats. In addition, a sediment sample should be collected with each biologica sample to rigorously account for biological variability associated with replicate-to-replicate variability in sediment properties and to better describe sediment characteristics of the region. The data reported here indicated that subtidal habitats at the head of Hawk Inlet were very productive and were inhabited by macrobenthic communities typical of the northeast Pacific coast (e.g., Ricketts et al., 1939; O'Clair et al., 1978; Lie, 1968). One reason for the relatively low densities in this habitat could have been predation by bottom-feeding flatfish, which are known predators of soft-bottom benthic organisms. Large numbers of these fish were observe in subtidal areas at the head of the inlet during sampling.

The cobble intertidal habitats of Young Bay were characterized by few species as is typical of moderate-energy cobble beach enviro-ments (Table 6). The blue mussel (e.g., Mytilus edulis) was a dominant species at all three intertidal sampling sites. Most of the M. edulis collected were juveniles (<1 mm in shell length) attached to the cobble. Other dominant species were limpets (e.g., Acomacia digitalis), snails (e.g., Littorina sitkana), polychaetes (e.g., unidentified juvenile Capitellidae, Fabricia sabella), isopods (Gnorimosphaeroma oregonensis), clams (e.g., Protothaca staminea and Psephidia lordi) and other segmented worms (e.g., Dinophilidae sp.). Data on the species composition of comparable

habitats were not available for the Young Bay area, but the composition of the epifaunal community on the intertidal rocks and ledges in the Young Bay area was similar to that for rocky intertidal habitats in Hawk Inlet and typical of that expected for cobble beaches along the northeast Pacific coast (IEC, 1980; O'Clair et al., 1978; Ricketts et al., 1939). Shells of the butter clam, Saxidomus giganteus, and the goeduck, Panope generosa, occurred along the beach, and siphons of these clams were observed by divers collecting subtidal samples. However, these clams burrowed too deep to be collected in the core samples for this study. Densities for the cobble intertidal habitats in Young Bay are summarized in Appendix B and Table 7. The distributions of dominant species characteristic of this habitat, particularly Mytilus edulis, were patchy, as indicated by the large replicate-to-replicate variability in their densities. This variability was typical of moderate-energy cobble beaches, where physical disturbances play a major role in determining community characteristics and abundance of dominant organisms (O'Clair et al., 1978). These data indicated that the cobble beaches in Young Bay were inhabited by a community typical of the northeast Pacific coast (Ricketts et al., 1939; O'Clair et al., 1978).

Sandy subtidal samples from Young Bay contained about twice as many species as intertidal samples (Table 6). Dominant species in this habitat were clams (e.g., Macoma balthica, and Protothaca staminea), polychaetes (e.g., Aricidea sp., Armandia brevis, Chaetozone setosa, Glycinde sp., Nephtys sp., and Spiophanes sp.), and an unidentified amphipod of the family Lysianassidae. The species composition of these samples appeared to be typical of that anticipated for moderate-energy shallow water coastal embayments (e.g., Lie, 1968; Carey, 1979; O'Clair et al., 1978). Densities for the sandy subtidal habitats of Young Bay were generally within ranges reported for similar habitats along the northeast Pacific coast (Lie, 1968; Carey, 1979; O'Clair et al., 1978). The fauna at the southern reference area comprised slightly fewer species, lower abundances of polychaetes, and higher abundances of the clam, Macoma balthica, than those at the dock site and the northern reference area (which were very similar to each other). These These differences could have been due to the slight variations in sediment characteristics noted between this station and other subtidal sample sites in Young Bay. The more protected location of the southern reference area, compared to the other two subtidal Young Bay stations, may have also contributed to the results.

IV. DISCUSSION, SUMMARY, AND CONCLUSIONS

A. DISCUSSION

- Species composing soft-bottom benthic communities feed directly on phytoplankton (filter feeders) and seaweeds (grazers), or they utilize carbon from primary producers and other sources after it has been incorporated into sediments (deposit feeders). The kinds and relative abundances of benthic organisms (i.e., benthic community structure) observed at a location are generally considered a good indicator of environmental conditions characteristic of that location. Temporal changes in the kinds and abundances of soft-bottom benthic organisms are also good indicators of changes in environmental conditions, and surveys of organisms composing soft-bottom benthic communities are frequently major elements of baseline studies or monitoring programs associated with development activities.

- Species composing soft-bottom benthic communities are generally important food items (especially as juveniles) in the diets of higher trophic levels, such as bottom-feeding fish (e.g., flounders and other flat fish), crabs (e.g., dunginess), and small mammals (e.g., otters). They are thus important intermediate linkages in marine food webs through which energy and materials pass to higher trophic levels. Many of the higher trophic levels that feed upon soft-bottom benthic organisms are harvested by commercial and recreational fisheries.

B. SUMMARY

- Soft-bottom habitats are a dominant habitat type at the sites of proposed developments in Hawk Inlet and in nearshore regions of Young Bay. Biological and sediment samples were collected from the major soft-bottom habitats at these locations to provide quantitative baseline data. The data collected are useful:

  -- To gauge the importance of these habitats to the marine environment, particularly to higher trophic levels

  -- To determine the vulnerability of these habitats to proposed development, based on the kinds and relative abundances of organisms observed.

- Rocky habitats are also a predominant habitat type occurring in both Hawk Inlet and at the site of the proposed docking facility in Young Bay. The characteristics of rocky intertidal communities in Hawk Inlet were qualitatively sampled and characterized previously in reports prepared for Noranda (Noranda Exploration, Inc., 1978; IEC, 1980). Benthic communities inhabiting rocky intertidal areas of Young Bay appear to be composed of species typical of rocky coasts of the northeast Pacific and similar to those occurring in Hawk Inlet.

- Benthic habitats sampled in Hawk Inlet were:

  -- Sandy intertidal areas (Greens Creek delta and cannery)

  -- A muddy-sand tidal flat (head of Hawk Inlet)

  -- A deep-water mud area (in the vicinity of the cannery)

  -- A gravel/sand subtidal bottom (Greens Creek delta)

  -- A muddy-sand subtidal area (head of Hawk Inlet)

  The physical nature of the bottom at some of the sample sites was heterogeneous, probably because of their glacial origins. Cobble, gravel, and boulders were dispersed throughout the area and provided habitats for benthic organisms that were not quantitatively sampled by this survey. However, the sand and mud under the cobble and rocks were similar to that sampled and probably contained similar kinds and relative abundances of benthic organisms. Thus, information obtained by this survey is considered representative of major soft-bottom benthic habitats in Hawk Inlet.

- Habitats sampled in Young Bay were moderate-energy cobble beachs and coarse nearshore sand sediments. A sand-to-cobble gradient occurred from depths of about 3 to 4 m up to intertidal areas at all Young Bay sample locations. The habitats sampled by this survey compose the majority of available nearshore habitats in the Fowler Creek area of Young Bay. South of the southern reference area, cobble intertidal beaches slowly grade into coarse sand beachs. The coarse sand beach habitat was not sampled because it was sufficiently south of the location of the proposed docking facility to remain unaffected by construction or operations of the proposed docking facility.

- The number of replicate biological samples collected at all sites was generally sufficient to characterize the species composition and to determine relative abundances of macrobenthic organisms inhabiting soft-bottom sediments.

- Total densities (and presumably productivity) of benthic organisms were similar to or slightly higher than those anticipated from similar habitats along the northeast Pacific coast following peak recruitment.

- Standing stocks of most abundant species at all stations were dominated by juveniles, suggesting sampling coincided with the peak summer recruitment period. Juveniles are generally the fraction of soft-bottom benthic populations selectively eaten by predators.

- The species compositions of soft-bottom intertidal and subtidal benthic assemblages in Hawk Inlet and Young Bay were typical of what would be expected from similar habitats along the northeast Pacific coast. Species compositions were different between intertidal and subtidal habitats, between sand and mud habitats, and between soft-bottom and cobble habitats. Sample sites where physical characteristics were comparable were inhabited by benthic communities composed of similar species. The findings imply that soft-bottom benthic communities in the Hawk Inlet/Young Bay area are good indicators of existing environmental conditions as well as changes in these conditions, i.e., those likely to be associated with development of the area. The physical/chemical environmental factors can be measured and associated with species distributions. These communities are thus suitable as elements of a monitoring program.

- Sediment loads and macrobenthic body burdens of metals in the sampled areas were similar to those reported for "unpolluted" areas.

- Hydrocarbon burdens in sediments were high. However, gas chromatography demonstrated that the high values near the delta and at the head of the inlet were of natural origin, while those at the cannery were a result of chronic petroleum contamination.

C. CONCLUSIONS

- The data presented here demonstrate that benthic communities in all areas sampled are typical for the northeast Pacific. The quantitative data presented provide an excellent baseline for use in monitoring to ensure the detection of any effects of mine operation.

- Benthic communities in Young Bay are composed of species that would be insensitive to development of the proposed docking facility. Dominant species there are adapted to stressful moderate-energy environments since cobble and sands are constantly being moved by waves. The proposed docking facility will not alter the dynamic nature of the habitat, but its pilings will provide additional habitat for epifaunal species such as barnacles and mussels, which presently do not occur in offshore regions.

- Benthic communities occurring in Hawk Inlet are relatively insensitive to the potential environmental alterations associated with development of the mine. Most of the dominant species are ubiquitous organisms and can tolerate a wide range of stresses. Operation of the cannery in Hawk Inlet has apparently not had significant long-lasting, adverse effects on distributional patterns. Impacts associated with the proposed mining facility would be less in magnitude than those associated with the cannery.

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APPENDIX A

HEAVY METALS CONCENTRATIONS IN JUVENILE COHO SALMON FROM A ZINC CREEK TRIBUTARY

HEAVY METALS CONCENTRATIONS IN JUVENILE COHO SALMON FROM A ZINC CREEK TRIBUTARY

The upper end of a small tributary of Zinc Creek is currently under consideration as part of the site of the tailings pond for the Greens Creek mining operation. The proposed pond would be created by building a dike, and the pond outflow would presumably be piped and discharged into Hawk Inlet. A possibility exists that metal levels in the tributary may rise as a result of the mining operation. To establish baseline levels of metals in juvenile coho salmon inhabiting the tributary, samples were collected during the July 1981 field trip and analyzed.

Field Methods

Juvenile coho salmon were collected on 12 July 1981 with four plastic minnow traps baited with salmon roe. Traps were set for 4 hours, approximately 100 yards apart, beginning where the tributary enters Zinc Creek. Fish were placed in polyethylene bags, put on ice, and later were frozen.

Processing and Analytical Procedures

Analytical procedures were the same as are described in the main text of this report. Fish guts were removed before whole fish were homogenized.

Results and Conclusions

Metal levels measured in freeze-dried fish tissue are presented in Table A-1. In comparison to data from Zinc Creek coho sampled in 1980 (Richkus and Johnson, 1981), silver values in 1981 were an order of magnitude lower, zinc and copper values were slightly higher, and mercury was slightly lower.

The significance of the large difference in silver values is not clear. The possibility of contamination and/or measurement error always exists. Values by other methods fall within the range of values found in other salmonid species, as is discussed in Richkus and Johnson (1981).

Table A-1. Metals concentrations in juvenile coho salmon taken from a Zinc Creek tributary.

Sample No.	Tissue	Number of Individuals	Sample Wet Wt. (g)	Metals Concentration (μg/g dry wt.) Ag	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn
16	Coho juveniles	9	22	0.53	<10	0.14	0.77	3.8	1.14	18	<0.35	<0.35	1.6	170
17	Coho juveniles	9	23	0.86	<11	0.13	<0.2	3.7	0.13	16	<0.41	<0.41	1.4	190
18	Coho juveniles	9	23	0.44	<5.3	0.10	0.23	2.5	0.095	14	0.21	<0.19	1.3	140
19	Coho juveniles	9	23	0.39	<11	0.13	<0.2	3.3	0.12	15	0.4	<0.4	1.6	150
20	Coho juveniles	9	26	0.28	<10	0.13	0.65	3.6	0.11	23	0.69	<0.36	1.6	150

APPENDIX B

SUMMARIES OF QUANTITATIVE BENTHIC DATA

Table B-1. Number of macrobenthic organisms per m^2 by species in samples collected from the Greens Creek delta

GREENS CREEK DELTA

	Intertidal 1	2	3	4	5	X̄	SD	Subtidal 1	2	3	4	5	X̄	SD
Foraminifera														
Unidentified forams	64935	90909	64935	1.1E5	1.4E5	93351	30340				1794	763	512	789
Cnidaria														
Unidentified anemones								38					8	17
Platyhelminthes														
Acoela sp.		130	130			52	71		229				46	102
Unidentified flatworms														
Nematoda														
Unidentified nematodes					649	130	290	38					8	17
Rhynchocoela														
Unidentified nemertean (red)	130	260	260		1169	364	463	458	992	229	611	76	473	356
Unidentified nemertean (red w/white head)	260		130	260		130	130							
Phoronida														
Phoronopsis harmeri								305	305	229	878	534	450	265
Chaetognatha														
Unidentified chaetognath														
Gastropoda														
Acomacea sp (Limpets)	1169		260			286	506							
Alvinia sp.								38		38	38		23	21
Boreotrophon pacificus								3588	4542	153	76	76	1687	2197
Cylichna sp.														
Lacuna variegata	909	260	260	260		338	339	76	229	38			69	95
Littorina sitkana	130				130	52	71	687	305	114	38	153	260	258
Littorina scutulata														
Moellaria sp.														
Natica sp.														
Nucella emarginata														
Odostomia sp.											38		8	17
Polinices pallidus														
Unidentified nudibranchs														
Bivalvia														
Clinocardium ciliatum														
Lucinoma annulata														
Nuculana hamata									153				30	68
Nucula tenuis														
Macoma balthica														
Macoma calcarea														
Macoma nasuta											38		8	17
Macoma obliqua														
Macoma sp.														
Mya arenaria			390	130		104	169	76	76	38			38	38
Mya arenaria siphon			130			26	58	38	76		38	76	46	32
Mysella sp.														
Mytilus edulis								38		38	229		61	96
Pandora filosa								76	191	76	38	305	137	110
Panomya ampla			130			26	58							
Protothaca staminia								1107	3130	305	191	153	980	1265
Psephidia lordi														
Yoldia myalis														
Oligochaeta														
Oligochaetes											38		8	17
Polychaeta														
Ampharetidae sp. 1									38				8	17
Ampharetidae sp. 2					130	26	58			1107			221	495
Arabellidae					130	26	58	4504	5191		1908	1985	2718	2114
Aricidea jefreysii														
Armandia brevis			130			26	58							
Capitellidae(unidentified juvenile)					260	52	116	1488	3053	153	1527	534	1351	1124
Capitellidae (short)									38		38		15	21
Chaetopteridae								496	229	114		458	260	215
Chaetozone setosa											114		23	51
Chone sp.														
Cossura longocirrata	130					26	58	153	153	229	114	267	183	63
Dorvillea sp.														
Eteone longa								76		153	191	420	168	159
Eunoe uniseriata								38	76	153			53	64
Euchone analis			130		130	52	71		76		76		30	42
Exogone gemmifera	909	130	1299	260	1948	909	752				76	38	25	34
Fabricia sabella					130	26	58							
Glycinde sp.								229	496	305	191	153	275	136
Gyptis sp.									76				15	34
Harmothoe imbricata														
Haploscoloplos elongatus (Orbiniidae)														
Lumbrineris sp.								76		38	38	114	53	44
Maldanidae sp. 1									114				23	51
Nephtys ciliata														
Nephtys sp. 1														

GREENS CREEK DELTA

	Intertidal 1	2	3	4	5	X̄	SD	Subtidal 1	2	3	4	5	X̄	SD
Nephtys sp. 2														
Nephtys sp. 3														
Nereidae										38	38		15	21
Onuphis geophiliformis								114	38	38		153	69	63
Owenia fusiformis								114	1107	153	267	191	366	413
Pectinaria sp.								382	1794	267	114	534	618	675
Pholoe minuta	390		260	130	130	182	148		76	38		76	38	38
Phyllodoce groenlandica									38		38	38	23	21
Pilargidae														
Polydora socialis				130	390	104	169		38		38		15	21
Praxillella														
Prionospio malmgreni					520	104	232	12214	5153	3168	5191	2672	5680	3826
Prionospio (filament gills)														
Prionospio sp. (large eyes)								114					23	51
Potamilla sp.														
Scolelepis sp.														
Sphaerosyllis erinaceus									38	38			15	21
Sphaerosyllis sp.								916	1221	344	534	305	664	394
Spio filicornis	1299		1169		1169	727	666	38	114	38	153	114	91	51
Spiophanes sp.			130		779	182	339	370	15458	2252	8702	5878	6532	5939
Spionidae sp. 1 (forked nose)								76	76	38		114	61	43
Spionidae sp. 2 (stubby nose)								76			114	153	67	68
Spionidae sp. 3 (large eyes)									114				23	51
Spionidae sp. 4 (black cheeks)														
Sternaspis scutata	390	390	130	260	2857	805	1152				38		8	17
Syllis adamantea														
Syllis sp.	130	390	390			182	197							
Syllidae sp. 2				260	779	208	339							
Syllidae sp. 3								38						
Tharyx secundus														
Travisia sp. 1								38					8	17
Travisia sp. 2			260	260	909	286	382	38		114			30	50
Archiannelida														
Dinophilidae														
Protodriloides sp.														
Amphipoda														
Bateidae									76			114	38	54
Caprella laeviuscula									114				23	51
Corophium sp. 1				130	390	104	169	382	458	305		2214	672	879
Corophium sp. 2			260		260	104	142		76		2214	38	466	787
Gammaridae sp.														
Hyperiidae sp.											38		8	17
Lysianassidae sp. 1					260	52	116							
Lysianassidae sp. 2								38	38	344		344	153	175
Marinogammarus sp.									38				8	17
Mesogammaridae														
Oedicerotidae sp. 1											38	76	23	34
Oedicerotidae sp. 2								153					31	68
Photis sp.					130	26	58	153	267	344			153	155
Phoxocephalidae								153	305	38	38	114	130	110
Stenothoidae											38		8	17
Talitridae								305	305	191	687	382	374	188
Unidentified amphipod sp. 2					260	52	116	229	153	496	3511	3015	1481	1641
Unidentified amphipod sp. 3								38		114	38	38	46	42
Unidentified amphipod sp. 4								76		267		38	76	111
Cumacea														
Unidentified cumacean									191	114		38	69	83
Isopoda														
Asellota										38			8	17
Gnorimosphaeroma oregonense			520	260	130	182	217				38		8	17
Idotea aculatea									38			38	15	21
Tanaidacea														
Unidentified tanaids					130	26	58	267	38	229	114		130	116
Mysidacea														
Unidentified mysids														
Caridea														
Crangon munitella								38					8	17
Sclerocrangon alata														
Euphausiacea														
Unidentified euphausids											38		8	17
Copepods														
Cyclopiod copepod														
Unidentified Calanoid sp.								38			114	153	61	69
Unidentified Harpacticoid sp.	260		520	260	130	234	193	458	3740	38	76	305	923	1589
Ostracod														
Unidentified ostracods									38				8	17

GREENS CREEK DELTA

	Intertidal							Subtidal						
	1	2	3	4	5	$\overline{X}$	SD	1	2	3	4	5	$\overline{X}$	SD
Cirripedia														
Unidentified barnacles			1558			312	697	76	38	382		38	107	156
Paguroidea														
Pagurus sp.									38				8	17
Brachyura														
Unidentified crab								76	38			38	30	32
Unidentified zoea														
Arachnida														
Unidentified mite														
Unidentified Pseudoscorpionida														
Insecta														
Unidentified insect larvae			390			78	174							
Unidentified species								687	1145	1336	420	458	809	412
Echinodermata														
Unidentified sea urchins														
Unidentified sand dollars								38	114				30	50
Unidentified sea cucumbers														
Unidentified star fish														
Tunicata														
Unidentified tunicates														

Martin Marietta Environmental Center

Table B-2. Number of macrobenthic organisms per m^2 by species in samples collected in the vicinity of the cannery.

CANNERY

	Intertidal							Subtidal						
	1	2	3	4	5	X̄	SD	1	2	3	4	5	X̄	SD
Foraminifera														
Unidentified forams	3.0E5	2.0E5	1.1E5			1.2E5	1.2E5	2786	2176	2099	534	1374	1796	865
Cnidaria														
Unidentified anemones														
Platyhelminthes														
Acoela sp.														
Unidentified flatworms														
Nematoda														
Unidentified nematodes	654	2158	1046	1242	4837	1647	1810	305	611	382	114	305	344	179
Rhynchocoela														
Unidentified nemertean (red)	65	65	65	131	131	92	36	191	382	38	496	153	252	184
Unidentified nemertean (red w/white head)														
Phoronida														
Phoronopsis harmeri														
Chaetognatha														
Unidentified chaetognath								38	229	191	229	153	168	79
Gastropoda														
Acmaea sp. (Limpets)	196	196	654	261	65	274	224			38			8	17
Alvinia sp.	131	65	38	196		86	78							
Boreotrophon pacificus										229	38		53	100
Cylichna sp.			196	65	65	65	80							
Lacuna variegata	1307	458	327	392		497	486							
Littorina sitkana	588		327	2680	196	758	1095					38	8	17
Littorina scutulata								38				38	8	17
Moellaria sp.								38				38	15	21
Natica sp.												38	8	17
Nucella emarginata	65					13	29							
Odostomia sp.									38				8	17
Polinices pallidus														
Unidentified nudibranchs														
Bivalvia														
Clinocardium ciliatum								687	649	1336	992	1450	1023	366
Lucinoma annulata									38				8	17
Nuculana hamata								229	420	38	114	191	198	144
Nucula tenuis									229	305	496	267	260	178
Macoma balthica	1372	1307	1569	1634	1438	1464	136							
Macoma calcarea								153				38	38	66
Macoma nasuta														
Macoma obliqua														
Macoma sp.				65		13	29							
Mya arenaria				65		13	29							
Mya arenaria siphon	65			65	65	39	36							
Mysella sp.	1372	65	1307	327	1438	902	653							
Mytilus edulis														
Pandora filosa				65		13	29							
Panomya ampla	65		131	523	65	157	210	38					8	17
Protothaca staminia								76	38	38	38	38	46	17
Psephidia lordi														
Yoldia myalis														
Oligochaeta														
Oligochaetes				3006		601	1344					38	8	17
Polychaeta														
Ampharetidae sp. 1			65			13	29	38	114	76	76	114	84	32
Ampharetidae sp. 2	65					13	29	38	76	76			38	38
Arabellidae									38	76		76	38	38
Aricidea jefreysii			65			13	29							
Armandia brevis								725	458	534	458	114	458	221
Capitellidae (unidentified juvenile)	131	654	588	1046	131	510	388							
Capitellidae (short)	654		1076	1046	915	738	445			38			8	17
Chaetopteridae									191	114		153	92	88
Chaetozone setosa								611	1221	1221	1107	1679	1168	381
Chone sp.								38				76	23	34
Cossura longocirrata														
Dorvillea sp.	392	261	456	1176	523	562	357							
Eteone longa								38	76				23	34
Eunoe uniseriata									38	38			15	21
Euchone analis			196	392	65	131	167	76			153		46	68
Exogone gemmifera	6601	3399	8039	10458	4902	6680	2741			38	38		15	21
Fabricia sabella					65	13	29		76				15	34
Glycinde sp.								382	458	916	344	267	473	259
Gyptis sp.			131	65		39	68	611	534	114	38	496	359	262
Harmothoe imbricata		131				26	58	878	1145	611	1260	840	947	258
Haploscoloplos elongatus (Orbiniidae)								267	191		38	38	107	116
Lumbrineris sp.														
Maldanidae sp. 1														

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CANNERY

	Intertidal							Subtidal						
	1	2	3	4	5	X̄	SD	1	2	3	4	5	X̄	SD
Nephtys ciliata	65	65	131			65	53	76	267	38		229	122	119
Nephtys sp. 1														
Nephtys sp. 2				65	65	26	36							
Nephtys sp. 3														
Nereidae		65				13	29							
Onuphis geophiliformis														
Owenia fusiformis		65				13	29							
Pectinaria sp.														
Pholoe minuta		65		131		39	58	649	229	458	267	229	366	184
Phyllodoce groenlandica											76		15	34
Pilargidae														
Polydora socialis		131		196	196	105	99					38	8	17
Praxillella sp.									114				23	51
Prionospio malmgreni			65		131	39	58					76	15	34
Prionospio (filament gills)								267	1260	496	458	344	565	399
Prionospio sp. (large eyes)														
Potamilla sp.														
Scolelepis sp.	65				65	26	36							
Sphaerosyllis erinaceus	65	65				26	36							
Sphaerosyllis sp.				65		13	29							
Spio filicornis	196	654	654	1242	1503	850	521							
Spiophanes sp.										38			8	17
Spionidae sp. 1 (forked nose)	458	523	261	654	719	523	179							
Spionidae sp. 2 (stubby nose)	196			261		92	127							
Spionidae sp. 3 (large eyes)														
Spionidae sp. 4 (black cheeks)														
Sternaspis scutata		65				13	29							
Syllis adamantea					65	13	29							
Syllis sp.		65	65			26	36							
Syllidae sp. 2			131	523	131	157	215							
Syllidae sp. 3														
Tharyx secundus				65		13	29	38	305	114	191	305	191	118
Travisia sp. 1														
Travisia sp. 2	196			980	65	248	417							
Archiannelida														
Dinophilidae														
Protodriloides sp.														
Amphipoda														
Bateidae														
Caprella laeviuscula														
Corophium sp. 1	1307					261	585							
Corophium sp. 2		3006	850	327	654	9067	1185							
Gammaridea sp.														
Hyperiidae sp.								114	76	153	114	76	107	32
Lysianassidae sp. 1														
Lysianassidae sp. 2														
Marinogammarus sp.														
Mesogammaridae														
Oedicerotidae sp. 1												76	15	34
Oedicerotidae sp. 2									114				23	51
Photis sp.														
Phoxocephalidae		65	65	131	392	131	153			38		38	8	17
Stenothoidae												38	8	17
Talitridae														
Unidentified amphipod sp. 2														
Unidentified amphipod sp. 3		65	65			26	36							
Unidentified amphipod sp. 4														
Cumacea														
Unidentified cumacean	1830	392	1895	850	2549	1503	868		38				8	17
Isopoda														
Asellota														
Gnorimosphaeroma oregonense			131		196	65	92							
Idotea aculatea														
Tanaidacea														
Unidentified tanaids														
Mysidacea														
Unidentified mysids														
Caridea														
Crangon munitella														
Sclerocrangon alata								38					8	17
Euphausiacea														
Unidentified euphausids								1145	1336	2099	1260	2290	1626	528
Copepods														
Cyclopiod copepod			1503	1307	784	719	707							
Unidentified Calanoid sp.			65			13	29	2290	2977	3321	1221	3702	2702	977
Unidentified Harpacticoid sp.	915	65	1046	1961	4248	1647	1602		38					

	Intertidal							Subtidal						
CANNERY	1	2	3	4	5	$\overline{X}$	SD	1	2	3	4	5	$\overline{X}$	SD
Ostracod														
Unidentified ostracods														
Cirripedia														
Unidentified barnacles				64		13	29							
Paguroidea														
Pagurus sp.	65	196	523	588	719	413	276		38				8	17
Brachyura														
Unidentified crab								76	38	114	38	229	99	79
Unidentified zoea														
Arachnida														
Unidentified mite				65		13	29							
Unidentified Pseudoscorpionida														
Insecta														
Unidentified insect larvae	65		131		1111	261	478							
Unidentified species														
Echinodermata														
Unidentified sea urchins														
Unidentified sand dollars														
Unidentified sea cucumbers														
Unidentified star fish														
Tunicata														
Unidentified tunicates														

Table B-3. Number of macrobenthic organisms per m^2 by species in samples collected from the head of Hawk Inlet.

HEAD OF INLET

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Foraminifera														
Unidentified forams														
Cnidaria														
Unidentified anemones														
Platyhelminthes														
Acoela sp.	130					26	58							
Unidentified flatworms														
Nematoda														
Unidentified nematodes	130	130	260	130		130	92	76			305	76	92	125
Rhynchocoela														
Unidentified nemertean (red)	130					26	58	76	38	76	38	114	69	32
Unidentified nemertean (red w/white head)														
Phoronida														
Phoronopsis harmeri														
Chaetognatha														
Unidentified chaetognath														
Gastropoda														
Acmaea sp. (Limpets)								38		76	38	38	38	27
Alvinia sp.														
Boreotrophon pacificus														
Cylichna sp.	1558	1948	1558	5844	519	2285	2059	191	38	382	153	267	206	128
Lacuna variegata											763	611	275	380
Littorina sitkana														
Littorina scutulata	1688	4545	3247	1948	1039	2493	1400							
Moellaria sp.														
Natica sp.								38		76	38	38	38	27
Nucella emarginata														
Odostomia sp.														
Polinices pallidus														
Unidentified nudibranchs														
Bivalvia											38		8	17
Clinocardium ciliatum								153			840	4008	1000	1717
Lucinoma annulata											76	153	46	68
Nuculana hamata														
Nucula tenuis	390	390	519	130	130	312	174							
Macoma balthica														
Macoma calcarea		130		130		52	71	229		38	267	649	237	258
Macoma nasuta														
Macoma obliqua														
Macoma sp.														
Mya arenaria														
Mya arenaria siphon	25714	19870	10519	13766	7662	15506	7292	191		229	4008	7443	2374	3293
Mysella sp.		130				26	58							
Mytilus edulis														
Pandora filosa														
Panomya ampla														
Protothaca staminia														
Psephidia lordi														
Yoldia myalis														
Oligochaeta														
Oligochaetes														
Polychaeta														
Ampharetidae sp. 1														
Ampharetidae sp. 2									38		38		15	21
Arabellidae											38		8	17
Aricidea jefreysii														
Armandia brevis	1558	3766	2987	3117	390	2364	1366	76	114		573	305	214	230
Capitellidae (unidentified juvenile)														
Capitellidae (short)														
Chaetopteridae												38	8	17
Chaetozone setosa												76	15	34
Chone sp.											153	76	46	68
Cossura longocirrata												76	15	34
Dorvillea sp.	260	1039	390	260	130	416	360							
Eteone longa														
Eunoe uniseriata														
Euchone analis														
Exogone gemmifera				130		26	58							
Fabricia sabella	130		130	130	390	156	142	114		38	153	191	99	79
Glycinde sp.														
Gyptis sp.	130	779	390	519	390	442	236	305		420	649	76	290	262
Harmothoe imbricata	390	2468	390	1299	390	987	917			3511	1260		954	1530
Haploscoloplos elongatus (Orbiniidae)										38	1069	840	389	552
Lumbrineris sp.														
Maldanidae sp. 1														

Martin Marietta Environmental Center

HEAD OF INLET

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Nephtys ciliata	3636	7662	11169	2857	2727	5610	3705			38	611	267	183	264
Nephtys sp. 1		909	519	260	260	390	343				840	382	144	372
Nephtys sp. 2														
Nephtys sp. 3														
Nereidae														
Onuphis geophiliformis														
Owenia fusiformis														
Pectinaria sp.											38		8	17
Pholoe minuta								229		38	344	267	176	149
Phyllodoce groenlandica											38		8	17
Pilargidae				130		26	58	38				420	92	184
Polydora socialis														
Praxillella sp.						26	58				726	153		
Prionospio malmgreni	130									153	153	114	84	78
Prionospio sp. (filament gills)														
Prionospio sp. (large eyes)														
Potamilla sp.	649	649	519	649	390	571	116				76		15	34
Scolelepis sp.														
Sphaerosyllis erinaceus														
Sphaerosyllis sp.														
Spio filicornis	1169	1299	2338	1039	260	1221	744							
Spiophanes sp.		130				26	58							
Spionidae sp. 1 (forked nose)	11688	7792	12987	4545	2857	7974	4385				1298	191	298	565
Spionidae sp. 2 (stubby nose)			130			26	58							
Spionidae sp. 3 (large eyes)														
Spionidae sp. 4 (black cheeks)														
Sternaspis scutata														
Syllis adamantea														
Syllis sp.											38		8	17
Syllidae sp. 2	3636	5065	5195	647		2909	2449				38	38	15	21
Syllidae sp. 3														
Tharyx secundus														
Travisia sp. 1														
Travisia sp. 2	779	1429	2468	909	130	1143	873	38			229	114	76	97
Archiannelida														
Dinophilidae														
Protodriloides sp.														
Amphipoda														
Bateidae														
Caprella laeviuscula														
Corophium sp. 1														
Corophium sp. 2											38		8	17
Gammaridae														
Hyperiidae														
Lysianassidae sp. 1														
Lysianassidae sp. 2														
Marinogammarus sp.			390		260	130	184							
Mesogammaridae														
Oedicerotidae sp. 1														
Oedicerotidae sp. 2														
Photis sp.														
Phoxocephalidae														
Stenothoidae														
Talitridae											38		8	17
Unidentified amphipod sp. 2											38		8	17
Unidentified amphipod sp. 3		130				26	58			76			15	34
Unidentified amphipod sp. 4														
Cumacea														
Unidentified cumacean	130	260	260		130	156	109				76	114	38	54
Isopoda														
Asellota														
Gnorimosphaeroma oregonense														
Idotea aculatea														
Tanaidacea														
Unidentified tanaids	130					26	58							
Mysidacea														
Unidentified mysids	130	260	1688	779	4545	1480	1819							
Caridea														
Crangon munitella				130		26	58					38	8	17
Sclerocrangon alata														
Euphausiacea														
Unidentified euphausids														
Copepods														
Cyclopiod copepod														
Unidentified Calanoid sp.														
Unidentified Harpacticoid sp.	779	2597	8831	130		2467	3705				76	38	19	38

HEAD OF INLET

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Ostracod														
Unidentified ostracods		130	1039			234	454							
Cirripedia														
Unidentified barnacles														
Paguroidea														
Pagurus sp.				130		26	58							
Brachyura														
Unidentified crab														
Unidentified zoea														
Arachnida														
Unidentified mite														
Unidentified Pseudoscorpionida														
Insecta														
Unidentified insect larvae			130			26	58							
Unidentified species														
Echinodermata														
Unidentified sea urchins														
Unidentified sand dollars														
Unidentified sea cucumbers														
Unidentified star fish														
Tunicata														
Unidentified tunicates	130					26	58							

Table B-4. Number of macrobenthic organisms per m^2 by species in samples collected from a reference area south of the proposed docking facility in Young Bay.

SOUTHERN REFERENCE AREA

	Intertidal							Subtidal						
	1	2	3	4	5	X̄	SD	1	2	3	4	5	X̄	SD
								5844	13247	10520	7922		9383	3208
Foraminifera														
Unidentified forams														
Cnidaria														
Unidentified anemones														
Platyhelminthes														
Acoela sp.														
Unidentified flatworms														
Nematoda														
Unidentified nematodes	700	800	1600	1400		1375	479	779	260				260	367
Rhynchocoela														
Unidentified nemertean (red)	500	800	400	900		650	238	11039	5065	130	909		4286	4996
Unidentified nemertean (red w/white head)														
Phoronida														
Phoronopsis harmeri														
Chaetognatha														
Unidentified chaetognath														
Gastropoda														
Acmaea sp. (Limpets)	500	1300	1200	300		825	499				130		32	65
Alvinia sp.														
Boreotrophon pacificus														
Cylichna sp.														
Lacuna variegata								130					32	65
Littorina sitkana	1300	900	1800	600		1150	520							
Littorina scutulata										130			32	65
Moellaria sp.														
Natica sp.														
Nucella emarginata														
Odostomia sp.	100	300	300	200		225	96							
Polinices pallidus														
Unidentified nudibranchs														
Bivalvia														
Clinocardium ciliatum														
Lucinoma annulata														
Nuculana hamata														
Nucula tenuis														
Macoma balthica								2078	1429	520	779		1201	698
Macoma calcarea														
Macoma nasuta														
Macoma obliqua														
Macoma sp.														
Mya arenaria														
Mya arenaria siphon														
Mysella sp.	100					25	50	130					32	65
Mytilus edulis	2000	10500	4000	300		4200	4464				130		32	65
Pandora filosa														
Panomya ampla				100		25	50		130				32	65
Protothaca staminia	1000	1800	3000	1200		1750	900	3247	2338	1948	779		2078	1023
Psephidia lordi		200				50	100							
Yoldia myalis														
Oligochaeta														
Oligochaetes														
Polychaeta														
Ampharetidae sp. 1											130		32	65
Ampharetidae sp. 2														
Arabellidae														
Aricidea jefreysii														
Armandia brevis														
Capitellidae(unidentified juvenile)														
Capitellidae (short)														
Chaetopteridae														
Chaetozone setosa		100				25	50		260		260		130	150
Chone sp.														
Cossura longocirrata														
Dorvillea sp.														
Eteone longa														
Eunoe uniseriata														
Euchone analis														
Exogone gemmifera														
Fabricia sabella	100			200		75	96							
Glycinde sp.								260	390	260	260		292	65
Gyptis sp.														
Harmothoe imbricata														
Haploscoloplos elongatus (Orbiniidae)														
Lumbrineris sp.														
Maldanidae sp. 1														

SOUTHERN REFERENCE AREA

	Intertidal							Subtidal						
	1	2	3	4	5	X̄	SD	1	2	3	4	5	X̄	SD
Nephtys ciliata														
Nephtys sp. 1														
Nephtys sp. 2								130					32	65
Nephtys sp. 3											130		32	65
Nereidae														
Onuphis geophiliformis														
Owenia fusiformis														
Pectinaria sp.									130				32	65
Pholoe minuta														
Phyllodoce groenlandica														
Pilargidae														
Polydora socialis														
Praxillella sp.														
Prionospio malmgreni														
Prionospio sp. (filament gills)														
Prionospio sp. (large eyes)														
Potamilla sp.														
Scolelepis sp.														
Sphaerosyllis erinaceus														
Sphaerosyllis sp.														
Spio filicornis														
Spiophanes sp.								260	260		130		162	124
Spionidae sp. 1 (forked nose)														
Spionidae sp. 2 (stubby nose)														
Spionidae sp. 3 (large eyes)														
Spionidae sp. 4 (black cheeks								130	130	130	260		162	65
Sternaspis scutata														
Syllis adamantea			200			50	100							
Syllis sp.														
Syllidae sp. 2	100					25	50							
Sillidae sp. 3														
Tharyx secundus														
Travisia sp. 1														
Travisia sp. 2	500	700	2500	2000		1425	978	130					32	65
Archiannelida														
Dinophilidae		200		500		175	236							
Protodriloides sp.	400					100	200				260		65	130
Amphipoda														
Bateidae														
Caprella laeviuscula														
Corophium sp. 1														
Corophium sp. 2														
Gammaridea sp.														
Hyperiidae sp.														
Lysianassidae sp. 1											260		65	130
Lysianassidae sp. 2														
Marinogammarus sp.									130	260	130		130	106
Mesogammaridae														
Oedicerotidae sp. 1														
Oedicerotidae sp. 2														
Photis sp.														
Phoxocephalidae														
Stenothoidae														
Talitridae														
Unidentified amphipod sp. 2														
Unidentified amphipod sp. 3														
Unidentified amphipod sp. 4														
Cumacea														
Unidentified cumacean		200	300	200		175	126			260			65	130
Isopoda														
Asellota														
Gnorimosphaeroma oregonense	18500	28300	24800	14600		21550	6157	130	130				65	75
Idotea aculatea														
Tanaidacea														
Unidentified tanaids														
Mysidacea														
Unidentified mysids														
Caridea														
Crangon munitella														
Sclerocrangon alata														
Euphausiacea														
Unidentified euphausids														
Copepods														
Cyclopiod copepod														
Unidentified Calanoid sp.	100					25	50	390	260	390	130		292	124
Unidentified Harpacticoid sp.			100	200		75	96	1688	390	1688	520		1071	714

SOUTHERN REFERENCE AREA

	Intertidal							Subtidal						
	1	2	3	4	5	$\overline{X}$	SD	1	2	3	4	5	$\overline{X}$	SD
Ostracod														
Unidentified ostracods	200					50	100		130				32	65
Cirripedia														
Unidentified barnacles	100	1400	300			450	646							
Paguroidea														
Pagurus sp.		100	100			50	58							
Brachyura														
Unidentified crab														
Unidentified zoea														
Arachnida														
Unidentified mite				200		50	100							
Unidentified Pseudoscorpionida														
Insecta														
Unidentified insect larvae		200	100	100		100	82							
Unidentified species														
Echinodermata														
Unidentified sea urchins														
Unidentified sand dollars														
Unidentified sea cucumbers														
Unidentified star fish														
Tunicata														
Unidentified tunicates														

Table B-5. Number of macrobenthic organisms per m^2 by species in samples collected for the proposed docking facilities in Young Bay.

DOCK SITE

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Foraminifera														
Unidentified forams														
Cnidaria														
Unidentified anemones														
Platyhelminthes														
Acoela sp.														
Unidentified flatworms														
Nematoda														
Unidentified nematodes		100				25	50							
Rhynchocoela														
Unidentified nemertean (red)	200	500	300	1000		500	356	130	130				87	75
Unidentified nemertean (red w/white head)														
Phoronida														
Phoronopsis harmeri														
Chaetognatha														
Unidentified chaetognath														
Gastropoda														
Acmaea sp. (Limpets)	100	800	200	700		450	351	130					43	75
Alvinia sp.														
Boreotrophon pacificus														
Cylichna sp.														
Lacuna variegata	100	200	200			125	96	130					43	75
Littorina sitkana														
Littorina scutulata														
Moellaria sp.														
Natica sp.														
Nucella emarginata														
Odostomia sp.														
Polinices pallidus														
Unidentified nudibranchs														
Bivalvia														
Clinocardium ciliatum														
Lucinoma annulata														
Nuculana hamata														
Nucula tenuis														
Macoma balthica														
Macoma calcarea														
Macoma nasuta														
Macoma obliqua														
Macoma sp.														
Mya arenaria														
Mya arenaria siphon														
Mysella sp.	25100	22100	2400	2500		13025	12272	130					43	75
Mytilus edulis														
Pandora filosa	100	100				50	58	130	390	130			216	150
Panomya ampla								130	130				87	75
Protothaca staminia														
Psephidia lordi														
Yoldia myalis														
Oligochaeta														
Oligochaetes														
Polychaeta														
Ampharetidae sp. 1								390	649	130			390	260
Ampharetidae sp. 2	300					75	150	1818	1429	1948			1732	270
Arabellidae								130	130	130			130	0
Aricidea jefreysii														
Armandia brevis														
Capitellidae (unidentified juvenile)														
Capitellidae (short)								7922	7273	13896			9697	3651
Chaetopteridae														
Chaetozone setosa														
Chone sp.														
Cossura longocirrata														
Dorvillea sp.		100				25	50			260			87	150
Eteone longa														
Eunoe uniseriata														
Euchone analis														
Exogone gemmifera	300		100	1100		375	499	260	520	649			216	375
Fabricia sabella			100			25	50							
Glycinde sp.														
Gyptis sp.														
Harmothoe imbricata								130					43	75
Haploscoloplos elongatus (Orbiniidae)														
Lumbrineris sp.														
Maldanidae sp. 1														

DOCK SITE

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Nephtys ciliata														
Nephtys sp. 1								1039	520				520	520
Nephtys sp. 2										1299			433	750
Nephtys sp. 3														
Nereidae								130					43	75
Onuphis geophiliformis														
Owenia fusiformis														
Pectinaria sp.								130	520				216	270
Pholoe minuta	800	100	200	100		300	337	260					87	150
Phyllodoce groenlandica														
Pilargidae														
Polydora socialis									130				43	75
Praxillella														
Prionospio malmgreni	100					25	50	130					43	75
Prionospio sp. (filament gills)														
Prionospio sp. (large eyes)														
Potamilla sp.														
Scolelepis sp.														
Sphaerosyllis erinaceus														
Sphaerosyllis sp.														
Spio filicornis														
Spiophanes sp.								1948	1169	2987			2035	912
Spionidae sp. 1 (forked nose)								260	130	260			216	75
Spionidae sp. 2 (stubby nose)														
Spionidae sp. 3 (large eyes)														
Spionidae sp. 4 (black cheeks)								1299	1948	1558			1602	327
Sternaspis scutata														
Syllis adamantea														
Syllis sp.														
Syllidae sp. 2														
Syllidae sp. 3														
Tharyx secundus														
Travisia sp. 1														
Travisia sp. 2		300	700			250	332							
Archiannelida														
Dinophilidae														
Protodriloides sp.				11500		2875	5750							
Amphipoda														
Bateidae														
Caprella laeviuscula														
Corophium sp. 1														
Corophium sp. 2														
Gammaridae sp.														
Hyperiidae sp.														
Lysianassidae sp. 1								5325	6104	6883			6104	779
Lysianassidae sp. 2														
Marinogammarus sp.				600		150	300							
Mesogammaridae														
Oedicerotidae #1														
Oedicerotidae #2														
Photis sp.														
Phoxocephalidae								260	130	260			216	75
Stenothoidae														
Talitridae														
Unidentified amphipod sp. 2	200					50	100	390					130	225
Unidentified amphipod sp. 3														
Unidentified amphipod sp. 4														
Cumacea														
Unidentified cumacean														
Isopoda														
Asellota														
Gnorimosphaeroma oregonense		100				25	50			130			43	75
Idotea aculatea														
Tanaidacea														
Unidentified tanaids														
Mysidacea														
Unidentified mysids														
Caridea														
Crangon munitella														
Sclerocrangon alata														
Euphausiacea														
Unidentified euphausids														
Copepods														
Cyclopiod copepod														
Unidentified Calanoid sp.								260		130			130	130
Unidentified Harpacticoid sp.														

DOCK SITE

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Ostracod														
Unidentified ostracods														
Cirripedia														
Unidentified barnacles	3800	8100	4400	7400		5925	2141							
Paguroidea														
Pagarus sp.				400		100	200							
Brachyura														
Unidentified crab														
Unidentified zoea														
Arachnida														
Unidentified mite	200			300		125	150							
Unidentified Pseudoscorpionida		100				25	50							
Insecta														
Unidentified insect larvae	300	100		500		225	222							
Unidentified species														
Echinodermata														
Unidentified sea urchins														
Unidentified sand dollars														
Unidentified sea cucumbers														
Unidentified star fish														
Tunicata														
Unidentified tunicates														

Martin Marietta Environmental Center

Table B-6. Number of macrobenthic organisms per m^2 by species in samples collected from a reference area north of the proposed docking facility in Young Bay.

NORTHERN REFERENCE AREA

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Foraminifera														
Unidentified forams														
Cnidaria														
Unidentified anemones														
Platyhelminthes														
Acoela sp.	100			100		50	58							
Unidentified flatworms									130				32	65
Nematoda														
Unidentified nematodes	300	1300	400	17090		925	685							
Rhynchocoela														
Unidentified nemertean (red)			100	200		75	96	260	130	103			130	106
Unidentified nemertean (red w/white head)														
Phoronida														
Phoronopsis harmeri														
Chaetognatha														
Unidentified chaetognath														
Gastropoda														
Acmaea sp. (Limpets)														
Alvinia sp.														
Boreotrophon pacificus														
Cylichna sp.		300		200		125	150							
Lacuna variegata	300		500	100		225	222							
Littorina sitkana														
Littorina scutulata														
Moellaria sp.														
Natica sp.														
Nucella emarginata														
Odostomia sp.														
Polinices pallidus														
Unidentified nudibranchs														
Bivalvia														
Clinocardium ciliatum														
Lucinoma annulata														
Nuculana hamata														
Nucula tenuis														
Macoma balthica														
Macoma calcarea														
Macoma nasuta														
Macoma obliqua														
Macoma sp.														
Mya arenaria										130			32	65
Mya arenaria siphon								130		130	130		97	65
Mysella sp.	100	400	200	500		300	183							
Mytilus edulis											130		32	65
Pandora filosa								520	260	130	649		390	237
Panomya ampla											130		32	65
Protothaca staminia														
Psephidia lordi														
Yoldia myalis														
Oligochaeta														
Oligochaetes									390	260			162	195
Polychaeta														
Ampharetidae sp. 1								130			260		97	124
Ampharetidae sp. 2								649	520	260	649		520	184
Arabellidae								649	390				260	318
Aricidea jefreysii														
Armandia brevis														
Capitellidae(unidentified juvenile)														
Capitellidae (short)								17403	7143	7662	12468		1169	4798
Chaetopteridae														
Chaetozone setosa														
Chone sp.														
Cossura longocirrata									130				32	65
Dorvillea sp.														
Eteone longa														
Eunoe uriseriata										130			32	65
Euchone analis														
Exogone gemmifera			100			25	50		260	260	649		292	268
Fabricia sabella														
Glycinde sp.														
Gyptis sp.								130		130	260		130	106
Harmothoe imbricata								130			130		65	75
Haploscoloplos elongatus (Orbiniidae)														
Lumbrineris sp.														

NORTHERN REFERENCE AREA

	Intertidal							Subtidal						
	1	2	3	4	5	$\bar{X}$	SD	1	2	3	4	5	$\bar{X}$	SD
Nephtys ciliata														
Nephtys sp. 1									260	520			195	249
Nephtys sp. 2								520			260		195	249
Nephtys sp. 3														
Nereidae														
Onuphis geophiliformis														
Owenia fusiformis														
Pectinaria sp.								130	390	130	390		260	150
Pholoe minuta														
Phyllodoce groenlandica														
Pilargidae														
Polydora socialis									260				65	130
Praxillella sp.														
Prionospio malmgreni														
Prionospio sp. (filament gills)														
Prionospio sp. (large eyes)								520	130				16[illegible]	246
Potamilla sp.														
Scolelepis sp.														
Sphaerosyllis erinaceus														
Sphaerosyllis sp.														
Spio filicornis														
Spiophanes sp.		200				50	100	1169	390	909	2208		1169	765
Spionidae sp. 1 (forked nose)								260	130	260	390		260	106
Spionidae sp. 2 (stubby nose)														
Spionidae sp. 3 (large eyes)														
Spionidae sp. 4 (black cheeks)								3247	2857	2727	2078		2729	486
Sternaspis scutata		100	100			50	58							
Syllis adamantea														
Syllis sp.														
Syllidae sp. 2		100		200		75	96							
Syllidae sp. 3														
Tharyx secundus														
Travisia sp. 1														
Travisia sp. 2	900	1500	900	2600		1475	802				130		32	65
Archiannelida														
Dinophilidae		100				25	50							
Protodriloides sp.														
Amphipoda														
Bateidae														
Caprella laeviuscula														
Corophium sp. 1														
Corophium sp. 2														
Gammaridea sp.														
Hyperiidae sp.														
Lysianassidae sp. 1								3896	3377	2857	1688		2954	945
Lysianassidae sp. 2														
Marinogammarus sp.								130	130				65	75
Mesogammaridae														
Oedicerotidae sp. 1														
Oedicerotidae sp. 2														
Photis sp.														
Phoxocephalidae									130				32	65
Stenothoidae														
Talitridae														
Unidentified amphipod sp. 2								130					32	65
Unidentified amphipod sp. 3														
Unidentified amphipod sp. 4														
Cumacea														
Unidentified cumacean														
Isopoda														
Asellota														
Gnorimosphaeroma oregonense														
Idotea aculatea														
Tanaidacea														
Unidentified tanaids								130					32	65
Mysidacea														
Unidentified mysids														
Caridea														
Crangon munitella														
Sclerocrangon alata														
Euphausiacea														
Unidentified euphausids											130		32	65
Copepods														
Cyclopiod copepod														
Unidentified Calanoid sp.	200		200	200		150	100	260	130	390	260		260	106
Unidentified Harpacticoid sp.											130		32	65

NORTHERN REFERENCE AREA

	Intertidal							Subtidal						
	1	2	3	4	5	$\overline{X}$	SD	1	2	3	4	5	$\overline{X}$	SD
Ostracod														
Unidentified ostracods		100		100		50	58							
Cirripedia														
Unidentified barnacles		500		500		250	289							
Paguroidea														
Pagurus sp.														
Brachyura														
Unidentified crab														
Unidentified zoea														
Arachnida														
Unidentified mite														
Unidentified Pseudoscorpionida														
Insecta														
Unidentified insect larvae				300		75	150							
Unidentified species														
Echinodermata														
Unidentified sea urchins														
Unidentified sand dollars														
Unidentified sea cucumbers														
Unidentified star fish														
Tunicata														
Unidentified tunicates														

APPENDIX C

BIOGRAPHIES OF AUTHORS

A. FREDERICK HOLLAND
Scientist
Environmental Center

Education

B.S., Biology, The Citadel, 1964
M.S., Biology, University of South Carolina, 1972
Ph.D., Marine Science, University of South Carolina, 1974

Professional Background

Dr. Holland joined Martin Marietta's Environmental Center in 1974 as a Research Scientist. He has been responsible for designing, conducting, and coordinating studies to identify and quantify effects of perturbation on the structure and function of benthic communities. Dr. Holland has conducted extensive field research on organism-sediment relations and on factors affecting benthic community structure and population dynamics of benthic organisms. A special research interest is determining the importance of physical and biological factors in controlling benthic community structure and function by studying effects of these factors on population dynamics of dominant species. His present research efforts have been in the area of benthic-pelagic coupling and long-term variation in benthic communities. He is presently conducting studies to evaluate changes in benthic communities due to salinity, perturbation, and organic enrichment, and to describe long-term trends in the abundance of major benthic species. These studies involve intensive investigation and characterization of the population dynamics of representative benthic species. He has studied important aspects of the population dynamics, energetics biogeography, and systematics of ecologically important invertebrate species.

MARTHA H. HIEGEL
R&D Specialist
Environmental Center

Education

B.S., Zoology, Louisiana State University, 1969
M.S., Zoology, Louisiana State University, 1971

Professional Background

Ms. Martha H. Hiegel has been a technical assistant on benthic field programs since 1975. She is a recognized authority on the identification of benthic invertebrates and on methods of collecting and processing of benthic samples. She is presently responsible for ensuring that benthic samples collected by EC's ongoing benthic programs are processed in a timely manner. Ms. Hiegel's experience with the mechanics of benthic field projects has provided her with a broad background in the general area of benthic ecology. She has been responsible for collecting and processing sediment samples; has used a broad variety of benthic sampling devices and processing methods; has participated in field experiments on predator exclusion, organic enrichment, and recolonization; has collected and processed ATP samples to estimate microbenthic standing stocks; and has processed meiobenthic and macrobenthic samples. She is a recognized biological illustrator who has published illustrations of benthic organisms in a number of books and journals. Ms. Hiegel has also conducted studies on the population dynamics of several bivalves.

WILLIAM A. RICHKUS
Senior Scientist and Technical Director
Environmental Center

Education

B.S., Zoology, University of Rhode Island, 1966
M.S., Oceanography, University of California (San Diego)
Scripps Institute of Oceanography, 1968
Ph.D., Oceanography, Graduate School of Oceanography, University of Rhode Island, 1974

Professional Background

Dr. Richkus has been a staff member of Martin Marietta's Environmental Center since June 1974, participating in studies aimed at identifying and quantifying the effects of power plant operations on fish stocks in the Chesapeake Bay and its tributaries. He has also participated in assessments of impacts of various Corporate facilities. He has prepared and assisted in the preparation of numerous documents for state and federal agencies, technical audiences, and the general public.

Dr. Richkus has recently served as program manager and co-principal investigator on a Maryland Coastal Resources Division project to evaluate the suitability and applicability of fisheries population and yield models for the management of Maryland tidewater fisheries. He is also currently directing field and laboratory work designed to assess levels of heavy metals in the tissues of various freshwater and marine biota.

Dr. Richkus currently directs studies funded by the Maryland Department of Natural Resources to assess environmental impacts of the Conowingo hydroelectric facility on the Susquehanna River. Ongoing studies are aimed at assessing the effects of the facility on water quality, aquatic biota, and commercial and recreational fisheries resources, and possible mitigation measures necessary to alleviate measured impacts. Dr. Richkus also currently serves as technical advisor and expert witness for the State of Maryland in ongoing FERC proceedings relating to restoration of anadromous fish runs in the Susquehanna River drainage. In this role, he has assisted all other intervening parties in preparation of the case, including U.S. Fish and Wildlife Service, Susquehanna River Basin Commission, and other state and citizens groups.

MARTIN MARIETTA

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