BASELINE STUDIES AND EVALUATION OF THE PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS OF NEARSHORE DREDGE SPOIL DISPOSAL, PEARL HARBOR, HAWAII

PART B

IMMEDIATE EFFECTS OF DUMPING: MONITORING STUDIES

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TABLE OF CONTENTS

Summary of Findings

The collection and analysis of samples taken during and immediately following the disposal of dredge spoil, 2½ miles south of Pearl Harbor, Honolulu, Hawaii, indicate minimal environmental impact and modification to the water column, biota, and geology of the dredge spoil disposal site. Specific findings are summarized as follows:

<u>Geology and Physical Oceanography</u>

1. Current Measurements

Continuous current measurements over a period of 30 days have been obtained for 2 meters located at depths of 570' (172 m) and 1175' (356 m), although the higher meter obtained only current speed data. An 8-day current record was obtained for a single meter at 165' (50 m). Computer analysis of the data obtained has shown strong variable bottom currents with peak values of up to 35 cm/sec to the west and 30 cm/sec to the south, with a large high-frequency, non-tidal constituent, as well as some tidal influence.

2. Bottom Samples

Thirty-three bottom samples were obtained within the study site and near by contiguous area for X-ray or grain-size analysis. X-ray diffraction analysis of the sediment samples indicates widespread dispersal of spoil. Coarse-grained sediments remained within ½ mile of the specific dump site (21°15.9'N; 157°56.7'W). Sediment grain size analysis indicates only minor deposition of fine-grained spoil within the site.

3. Geologic Features

Fathometer traces indicate a nearly continuous flat sea floor in the immediate vicinity of the disposal site. Photo reconnaissance confirmed evidence indicating deposition of coarse rather than fine material. This agrees well with computer predictions.

The lack of fine-grained sediment on the bottom, which is shown by grain size analysis, coring attempts and by bottom photography, supports the computer prediction that the coarse material will be deposited immediately below the point of release, while the fine-grained spoil will be removed from the area via moderate to strong bottom currents which exhibit a net flow to the southwest. The mineralogy of the bottom samples provides further confirmation.

Water Chemistry

Suspended solids and turbidity were the most useful parameters for tracing the horizontal and vertical movement of the plume. Aside from high concentrations observed in the surface plume, an accumulation of the fine spoil was noted near the top of the pycnocline. Higher nutrient concentrations (TKN and TP) and metals concentrations (associated with sediments) are restricted to the surface plume and dissipate with time. Based on the distribution of heavy metals the majority of the spoil was deposited within a ½ mile radius of the disposal site. Spoil material from the "Harding" was generally low in metals and pesticides. Shrimp collected from the dump site 45 days after disposal operations had ceased showed no appreciable difference in heavy metal body burdens as compared to shrimp collected from a site approximately 2 miles west.

Zooplankton

Ten zooplankton tows were taken approximately one month after disposal of spoil began. Samples contained large volumes of foreign non-dredge-spoil material. Flow of sewage into the disposal site during kona weather from the recently opened Sand Island sewage outfall is assumed to be the source of material.

Zooplankton was three times as abundant in the disposal area during dumping as compared with the baseline studies. The community structure showed a modest change: copepods made up a smaller percentage of the total community and larvaceans were more abundant. The effects of land runoff including sewage disposal are concluded to be of greater importance to the zooplankton populations than either seasonal variation or dredge spoil disposal.

There was no difference in the appearance of the gut contents or gills between the euphausiids taken during Part A and B.

Benthic Biology

Large tracer species (>64 mm) were taken in core and grab samples within a ½ mile radius of the specific dump site. Small tracer species (<2 mm) drifted throughout the disposal site area as far as the base of Barbers Point ledge but not on the ledge. Sampling stations south and east of the specific dump site were relatively free of spoil deposits. The presence of spoil tracer species at Stations M9, J2 and P11 probably represents dredge spoil from previous (1959-74) disposal operations.

Fisheries

There was no evidence that dredge spoil disposal had deleterious effects on the fish or shrimp. Shrimp were found in substantially higher numbers during and after dredge spoil disposal than during the baseline survey. The fish catch statistics were inconclusive as to the possible influence of dredge spoil disposal on the commercial fisheries. Some species showed an increase in catch while others declined.

Recommendation

The results of the Part A and Part B studies have indicated no apparent significant adverse environmental effects associated with the disposal of dredge spoil at the designated dump site. We recommend continued dredge spoil disposal at the specifically designated disposal site, 21°15.9'N, 156°56.7'W.

I. INTRODUCTION

The environmentally acceptable location for the disposal of dredge spoil is a matter of continuing concern particularly by those faced with the responsibility for maintenance of harbors, marinas, canals, and protected coastal embayments. The Corps of Engineers' nationwide Dredged Material Research Program (DMRP) is an example of the effort that has been, and continues to be provided at the national level to address the problems of dredge spoil disposal. Hawaii's unique geographical position and geological structure do not lend themselves readily to extrapolation of environmental considerations addressed and observed in many of these mainland dredge spoil disposal site studies. For the most part, disposal of sediments along the continental margins of the mainland involves disposal in shallow waters on the continental shelf, or at most the somewhat deeper continental borderland found off the Pacific coast. In either case, transportation time and the attendant costs necessitate disposal within a few miles off shore, at depths generally less than 75 meters and frequently depths less than 30 meters.

In contrast the State of Hawaii, rising as it does abruptly from the deep sea floor, is characterized by exceedingly deep water within a few miles of most of the shoreline. Environmental considerations for the selection and evaluation of suitable off shore dredge spoil disposal sites must therefore be considered in terms of deep water, >400 meters, and oceanic conditions.

The present on-going study represents a major effort to evaluate the essentially unique environmental considerations required for the safe disposal of dredge spoil in deep, near shore, coastal waters. Part A of this study involved the collection of certain baseline data and the selection of an environmentally acceptable disposal site approximately 2½ nautical miles due south of Pearl Harbor, Hawaii. The present report presents the results of the second part (B) of the project which addresses the actual dumping operation and includes monitoring of the distribution of the spoil in the water column, on the bottom, and its immediate effects on the biota.

II. Description of Area and Dredging Operations

The dredge spoil disposal site lies off the southern coast of Oahu, Hawaii, in a crescent-shaped area beginning at latitude 21°16.8'N, longitude 157°56.7'W, thence on a line to latitude 21°15.9'N, longitude 157°56.1'W, thence on an arc to the right with a radius of 2 1/2 nautical miles to latitude 21°15.9'N, longitude 157°59.0'W, thence on a line to latitude 21°16.8'N, longitude 157°58.5'W, thence on an arc to the left with a radius of 1 1/2 nautical miles to the point of beginning (Fig. 1). The origin of the radii of the two arcs is the approximate location of Pearl Harbor Entrance Channel Buoy No. 1. The area of this site is 3.54 $mi.^2$ (898 ha). The bottom slopes gently to the southeast, from about 160 fm at the northwest corner to about 240 fm at the southeast corner.

The results of the data obtained during the Part A studies of this project led to the recommendation that all disposal during the Part B studies take place in the southeast sector of the disposal area at the specific coordinates of 21°15.9'N, 157°56.7'W.

Sampling has been conducted throughout the entire disposal site; however, efforts have been concentrated in the area of the recommended specific disposal site coordinates.

The dredging operations performed during the Part B studies were conducted by the Army Corps of Engineers Hopper dredge Harding. Dredging operations were begun on April 11, 1977 and continued on a 24 hour schedule until May 31, 1977 with the exception of approximately 2 days of down time every 14 days for refueling and maintenance. A total of 761,354 cubic yards of material was removed from the common use channels and turning basin areas of Pearl Harbor and subsequently dumped in the disposal area. With the exception of approximately 12000 cubic yards of material dumped from 1500 on May 18, 1977 to 0900 May 19, 1977 all material (∿750,000 cubic yards) was dumped at or within a 1000 foot radius of the specifically designated disposal site at 21°15.9'N, 157°56.7'W. The ∿12000 cubic yards dumped on May 18 and 19 was dumped at 21°16.5'N 157°56.7'W so as not to conflict with shrimp trapping at the regular disposal site.

III. GEOLOGY AND PHYSICAL OCEANOGRAPHY

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A. Objectives

The purpose of this study is to observe the immediate effects of spoil disposal in terms of the extent of spoil deposition in and around the disposal site, the behavior of the spoil during disposal, and the physical factors governing this distribution and behavior. More specifically, the objectives are as follows:

1. Measure currents at near surface, thermocline, and near bottom depths.
2. Collect bottom samples to determine the extent of spoil deposition in and around the site.
3. Compare the sediments in the hopper dredge prior to disposal with those recovered on the bottom to estimate the quantity and composition of material going into suspension and potentially able to leave the disposal area.
4. Monitor the spoil acoustically during disposal to observe the descent of the plume.
5. Determine the immediate changes in the geological features of the site and adjacent areas.
6. Compare field observations with computer predictions of spoil behavior upon disposal.

B. Methods

1. Current Measurements

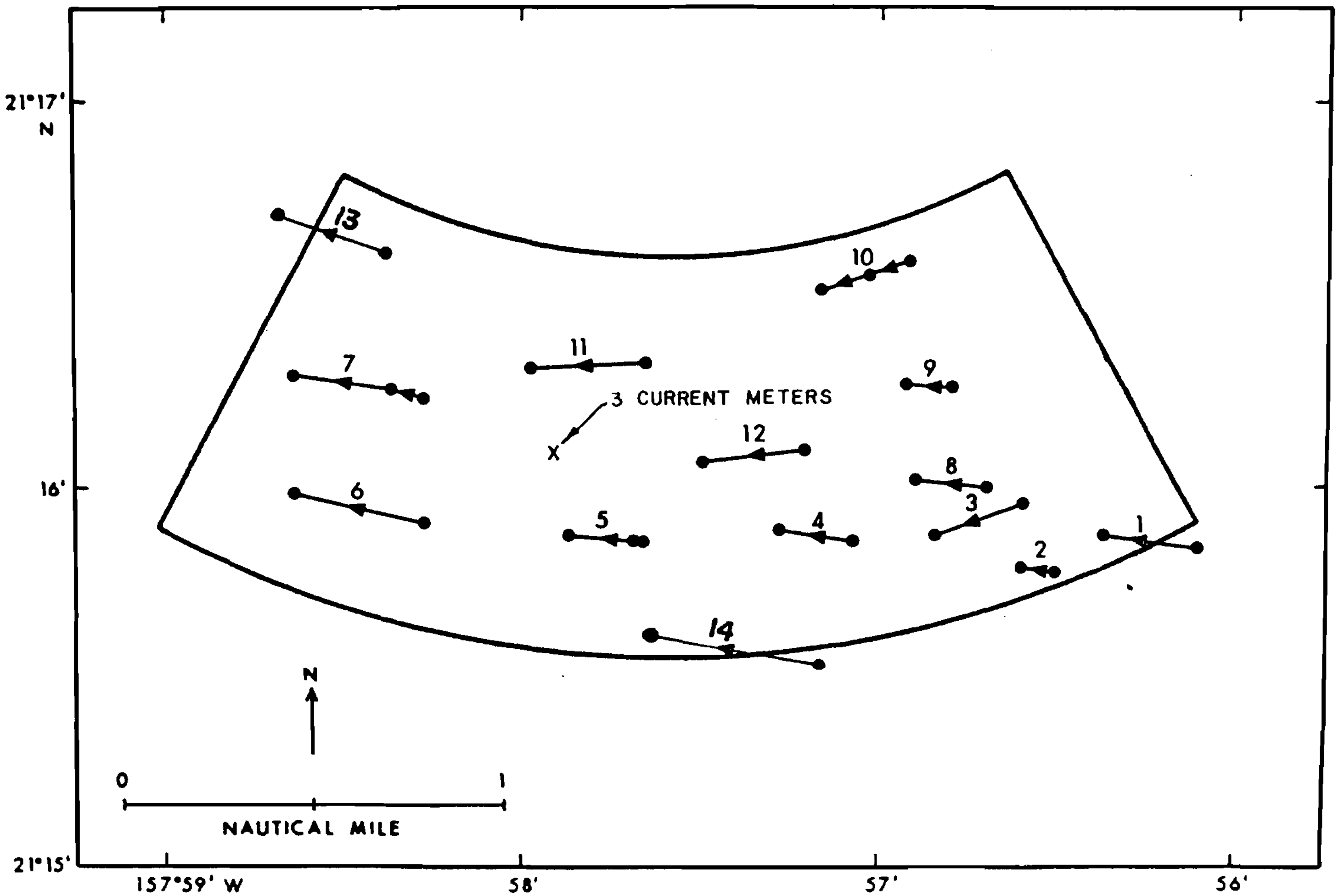
An array of current meters was deployed on May 2, 1977, at 21°16.1'N, 157° 57.9'W. The three meters comprising the vertical array are converted Geodyne current meters which employ Savonius rotors, vanes, and internal magnetic compasses to measure current. Current data are recorded internally on magnetic tape cassettes. The sampling interval on the shallowest meter (CM 332) was one minute, and was two minutes for the deeper pair (CM 156 and CM 459). The depths of the meters were as follows:

CM 332 - 50 meters (165 ft)
CM 156 - 172 m (570 ft)
CM 459 - 356 m (1175 ft)

Total water depth - 364 m (1200 ft)

The location of the current meters is shown on Figure III-1.

Figure III-1. Location of current meters and color photo trawls.



2. Bottom samples

Three series of grab samples were taken on 4/22/77 ("M" series), 5/18/77 ("J" series), and 5/31-6/1/77 ("P" series). The first two sets were taken to determine deposition of spoil for intermediate amounts of spoil dumped. The final set was to find the total extent of deposition. All samples were taken with a Petersen grab sampler. Locations were determined using visual bearings and radar ranges to objects onshore, and are accurate to about 150 meters.

Coring was attempted in order to obtain a vertical dimension of the deposited spoil. A variety of coring devices was tried with almost no success, due to the coarseness of the bottom sediments. See the Results section of this report for further details.

Six attempts each with a gravity corer and a piston corer yielded one usable piston core, taken on 6/14/77. Navigation was as before. Locations of core and grab samples are shown on Figure III-2. A box corer was also tried unsuccessfully.

3. Sediment Comparison

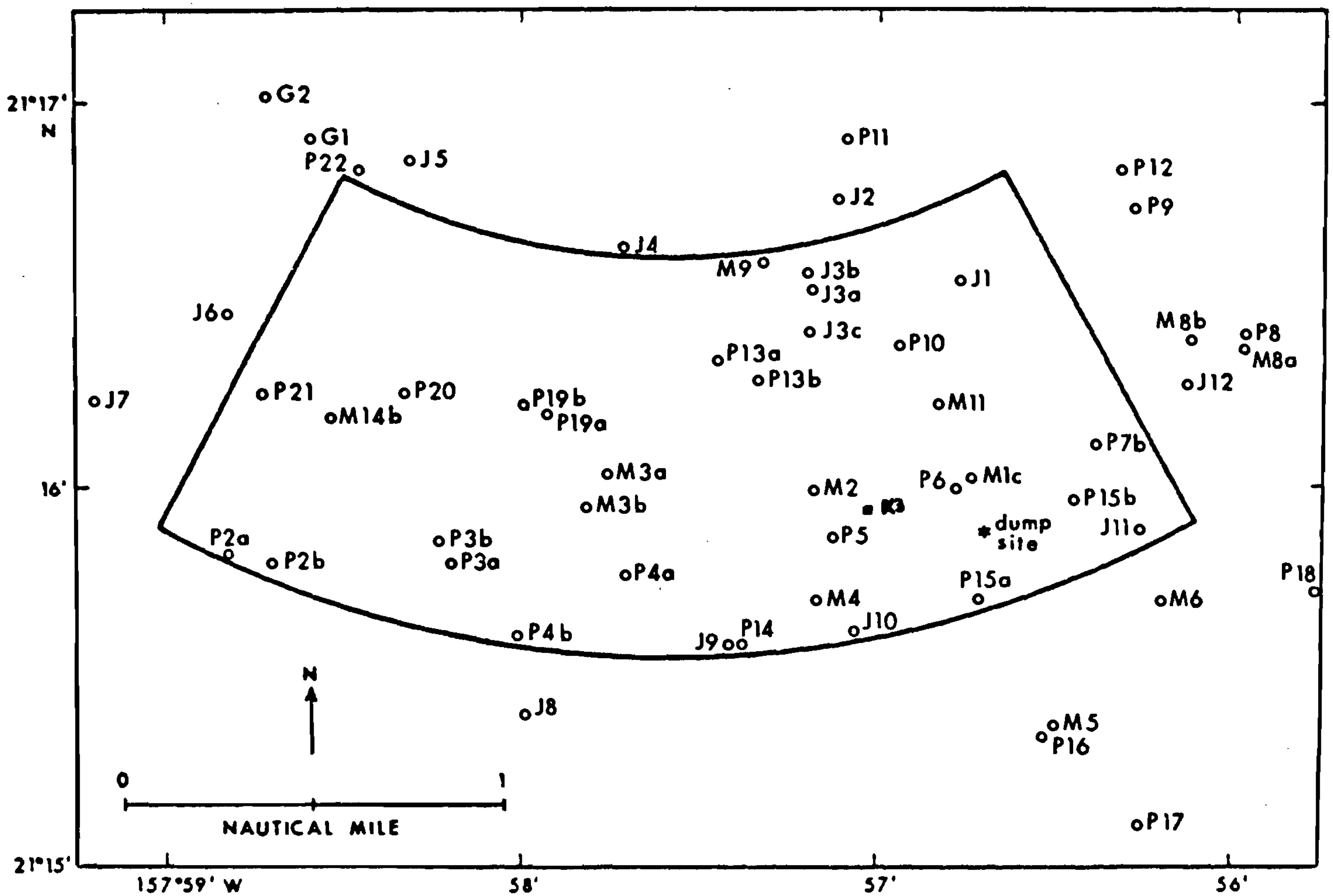
Sediment samples were analyzed for mineralogy using a Phillips-Norelco diffractometer system as in Part A. In the 50% progress report for this study, it was suggested that the large carbonate (calcite and aragonite) fraction might be masking the diffraction peaks of less abundant minerals present. Subsequent close examination of these diffraction records have resolved identification problems. Resolution of mineral proportions is good to about 1 percent.

Grain size analysis of the bottom samples was carried out either by dry sieving, using a Ro-Tap machine for 15 minutes per sample, or by wet sieving. In both cases, sieve sizes ranging from -1.5 Ø to 4.5 Ø were used. For analysis of the fraction finer than 4.5 Ø diameters, an optical extinction centrifuge system was employed to obtain a breakdown of the 5.0 Ø to 9.0 Ø range.

4. Acoustic Monitoring

A Benmar 50 kHz "fish-finder" echo sounder aboard the R/V Machias was used in attempts to follow the movement of spoil subsequent to release from the Harding's hoppers. It was only partly successful because of the limited size of the paper chart recorder, which required a series of different scales to

Figure III-2. Location of grab samples taken on April 22, 1977 (M), May 18, 1977 (J), and May 31-June 1, 1977 (P), core sample taken on June 14, 1977 (K).



display different depth ranges. This therefore necessitated constant switching from one depth scale to another and allowed us only to obtain fragmentary records. See the Results section for further discussion.

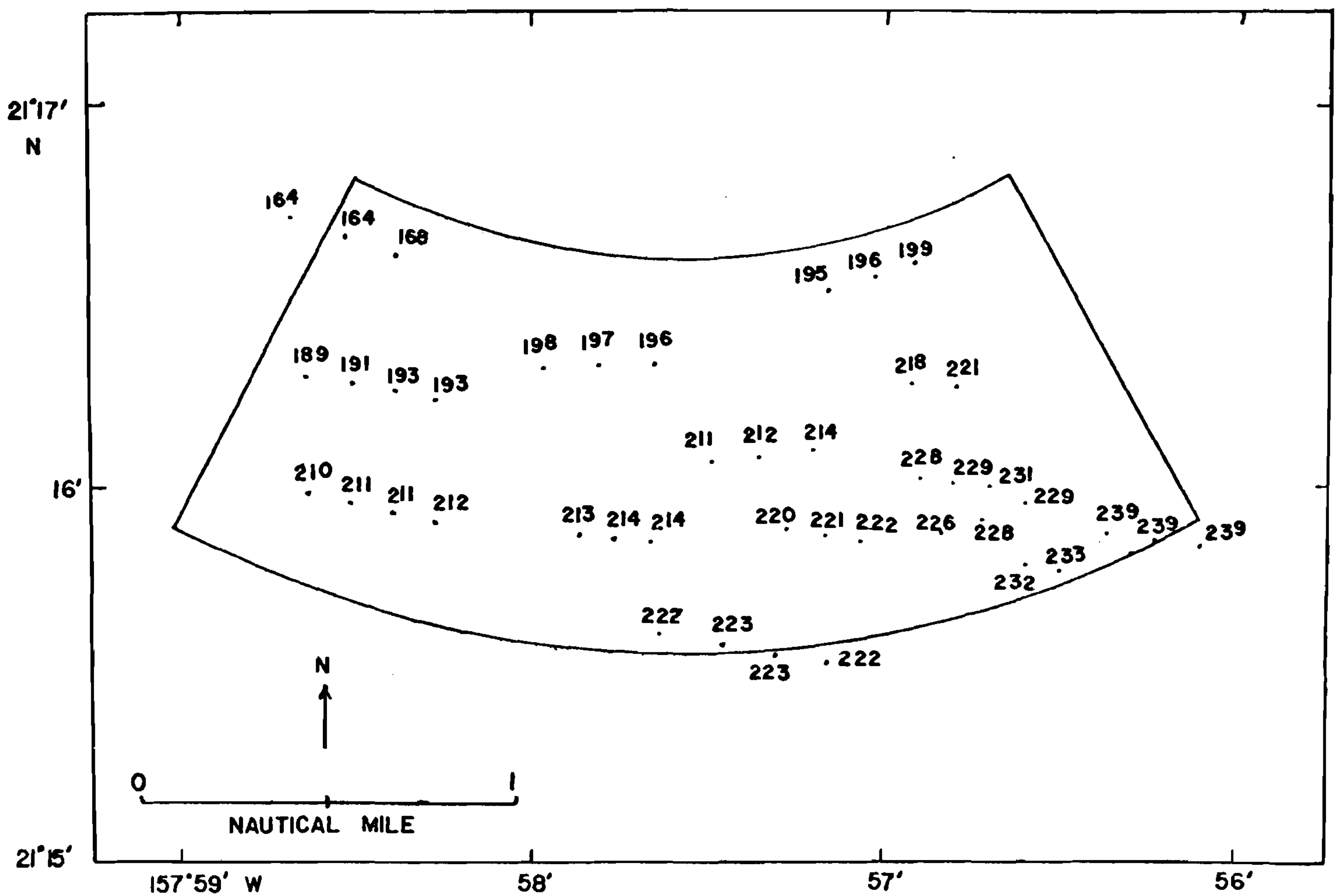
5. Determination of Geological Changes

Echo sounding data and a series of photographs were obtained on 14-15 June 1977 and 19 July 1977 respectively. Navigation was as before, using radar ranges and visual bearings. Bathymetry is presented in Figure III-3. For comparison, Part A bathymetry is shown in Figure III-4. Bottom photographs were taken along 14 lines within the disposal area (Figure III-1). A series of bottom photographs was obtained in an attempt to trace the horizontal distribution of the spoil and to estimate any changes in the geologic features in the immediate vicinity of the specified dump site as compared with the pictures taken in Part A. The camera used was a standard 35 mm E.G.&G. Company 35 mm underwater camera with an accompanying strobe unit similar to that used during the Part A studies. Modification of the method of mounting the camera, i.e., on a tripod rather than a sled, was predicated on available equipment and costs. Photographs were taken on 16 June and 19 July 1977. The camera, attached to a steel tripod, was lowered to within a few meters of the bottom as determined acoustically and allowed to drift for five minutes over the designated sampling site. The camera was then raised to the surface and shut off for transit to the next location where it was again activated and lowered. The photos obtained are discussed in the Results section below.

6. Comparison of Field Results and Computer Predictions

The Koh-Chang/Tetra Tech computer program has been run by the Corps of Engineers' Waterways Experiment Station (Johnson, 1977), in connection with the Corps' study of their dredge spoil disposal site, Honolulu site #3, adjacent to the site of this study. WES had agreed to run the program for our site also, but the results of their calculations for the Corps led to the conclusion that the Navy and Corps sites were so similar that such an additional run was not necessary, and instead WES supplied us with a copy of the results for Honolulu site #3 (Johnson, 1977). During Part A of this study we attempted to obtain and run the Koh-Chang computer model with little success. A poor quality reproduction of the source-deck listing, combined with difficulties in converting the code from CDC to IBM Fortran, prevented successful use of the

Figure III-3. Bathymetry determined after the 1977 dredge spoil disposal. Soundings in fathoms.



program. More importantly, the Corps of Engineers informed us (Johnson, personal communication) that there were so many bugs in the original version that we ought not pursue the idea further. We have requested a copy of the program from WES when their corrections are completed, but to date it has not arrived.

C. Results

1. Currents

Plots of east-west and north-south current components are shown in Figures III-5, III-6, and III-7 for CM 332 and CM 459. The rotor of CM 332 stopped turning after about eight days, probably a result of biological fouling, so there are only eight days of good data for CM 332. CM 156 and CM 459 operated for approximately 30 days. During reduction of the current data from CM 156, it was found that its vane-direction sensor had been malfunctioning. The direction information is, therefore, suspect. Further work is in progress in an attempt to salvage or reconstruct the current information from this intermediate depth meter, but at this time only the rotor can be assumed to have operated successfully. The scalar current speed only is shown in Figure III-8. A summary of current data retrieved is shown in Table III-1.

Removal of the four principal solar and lunar harmonic tidal constituents (M2, S2, K1, and O1) indicated that currents are not principally in response to the direct tides, but have relatively large (>50%) non-tidal components, or perhaps components of near-tidal frequency that are caused by tidal forces (internal tidal currents). There is a marked 12.4 hour, or M2 tidal, periodicity, as was expected.

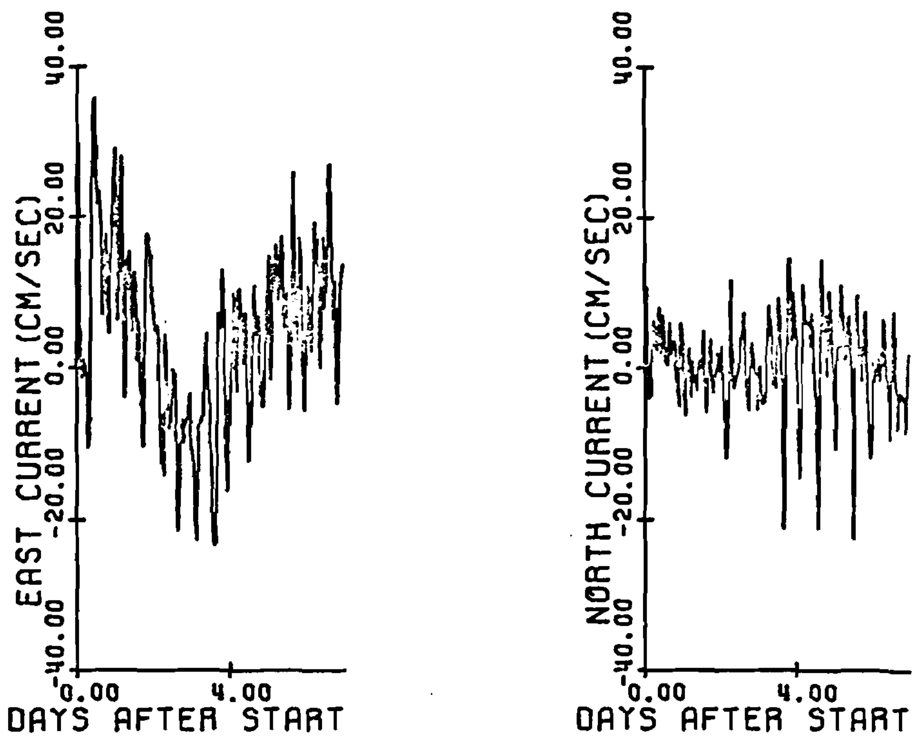
The directional components plotted in Figures III-5, III-6, and III-7 show a strong east-west current flowing, particularly near the bottom. Maximum current speeds at the deep and shallow meters were 40 cm/sec and 35 cm/sec (east-west component) and 30 cm/sec and 20 cm/sec (north-south component). A table of computed mean values for the east-west and north-south current components for each meter follows (Table III-2).

Frequency spectra from the east-west component of CM 332 and CM 459 are shown in Figures III-9 and III-10. The frequency spectra for meters CM 332 and 459 were high-pass filtered to remove frequencies of less than about 2 cycles/ day (12 hour period). The filtered series were then used to reconstruct current components (east-west only) to exhibit the high frequency portion of the currents. The reconstructed series are shown in Figures III-11 and III-12.

FIGURE III-5: DIRECTIONAL COMPONENTS

CURRENT METER CM-332

East-west and north-south current vector components are shown for current meter CM 332 (depth = 50 meters). Positive indicates east and negative indicates west for the east-west plot. Positive indicates north and negative indicates south in the north-south plot. The net flow, or average current, for the eight days is 4.3 cm/sec to the east, and 3.3 cm/sec to the south.



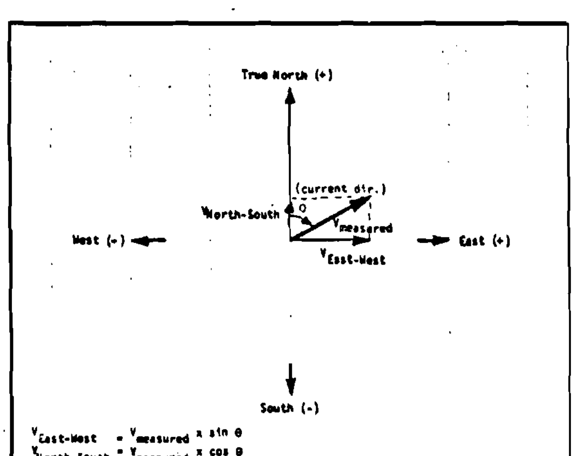


FIGURE III-6. EAST-WEST COMPONENT-
CURRENT METER CM-459

The east-west current vector component for current meter CM 459 (depth = 356 m) is shown. The sign convention is the same as for Figure III-5. The net flow is 7.9 cm/sec to the west.

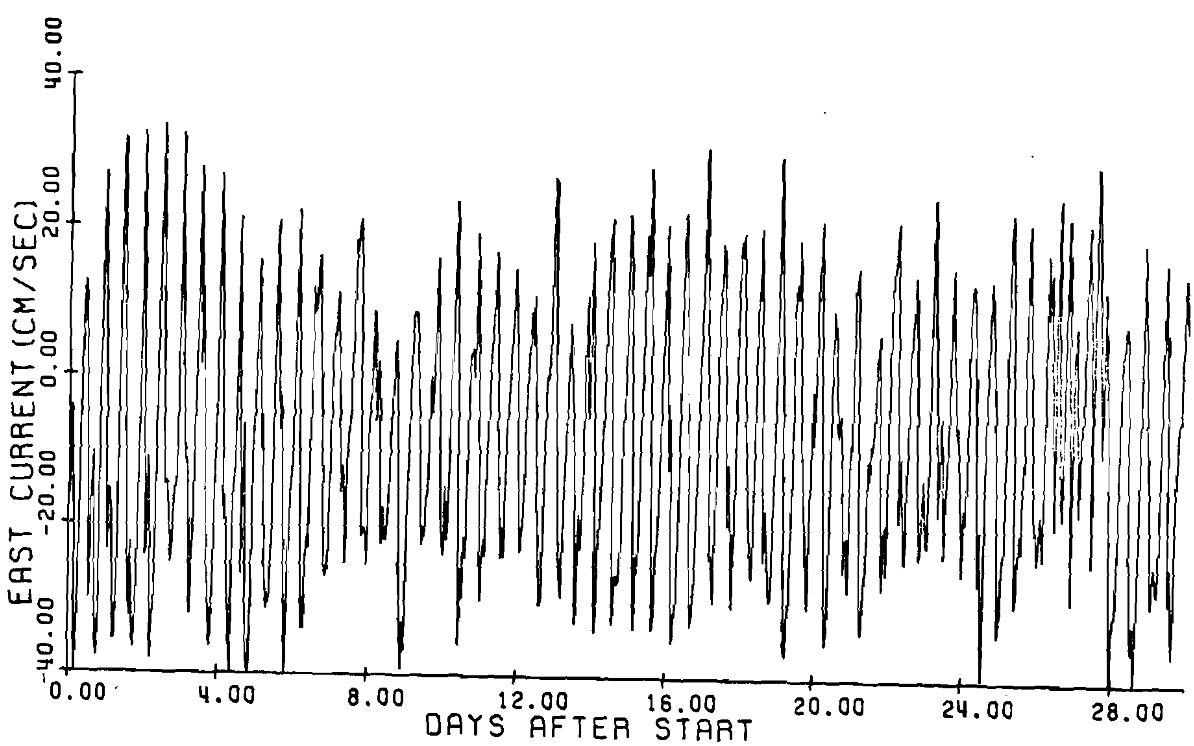


FIGURE III-7. NORTH-SOUTH COMPONENT-
CURRENT METER CM-459

The north-south current vector component for current meter CM 459 (depth = 356 m) is shown. See Figure III-5 for sign convention. The net flow is 3.7 cm/sec to the south.

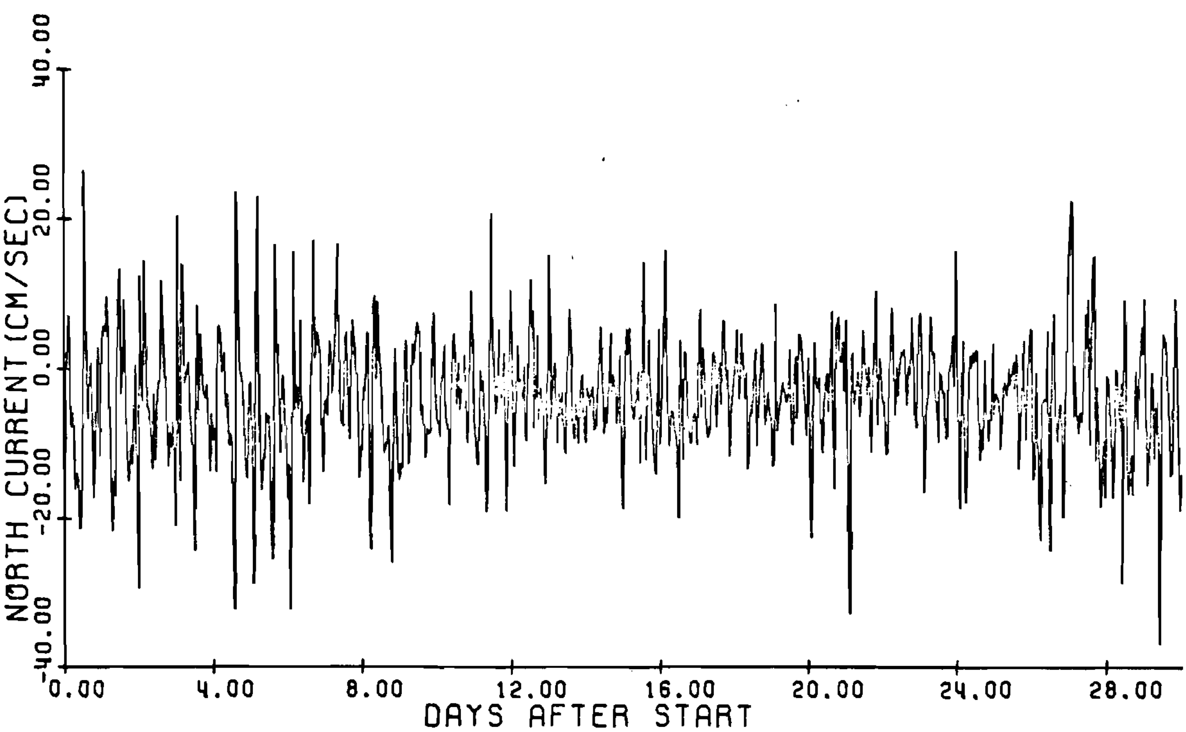


FIGURE III-8. DIRECTIONLESS CURRENT SPEED

CM-156

Current speed (scalar) measured by current meter CM 156 (depth = 172 meters) is plotted versus time. Since no direction can be shown, there is no sign convention.

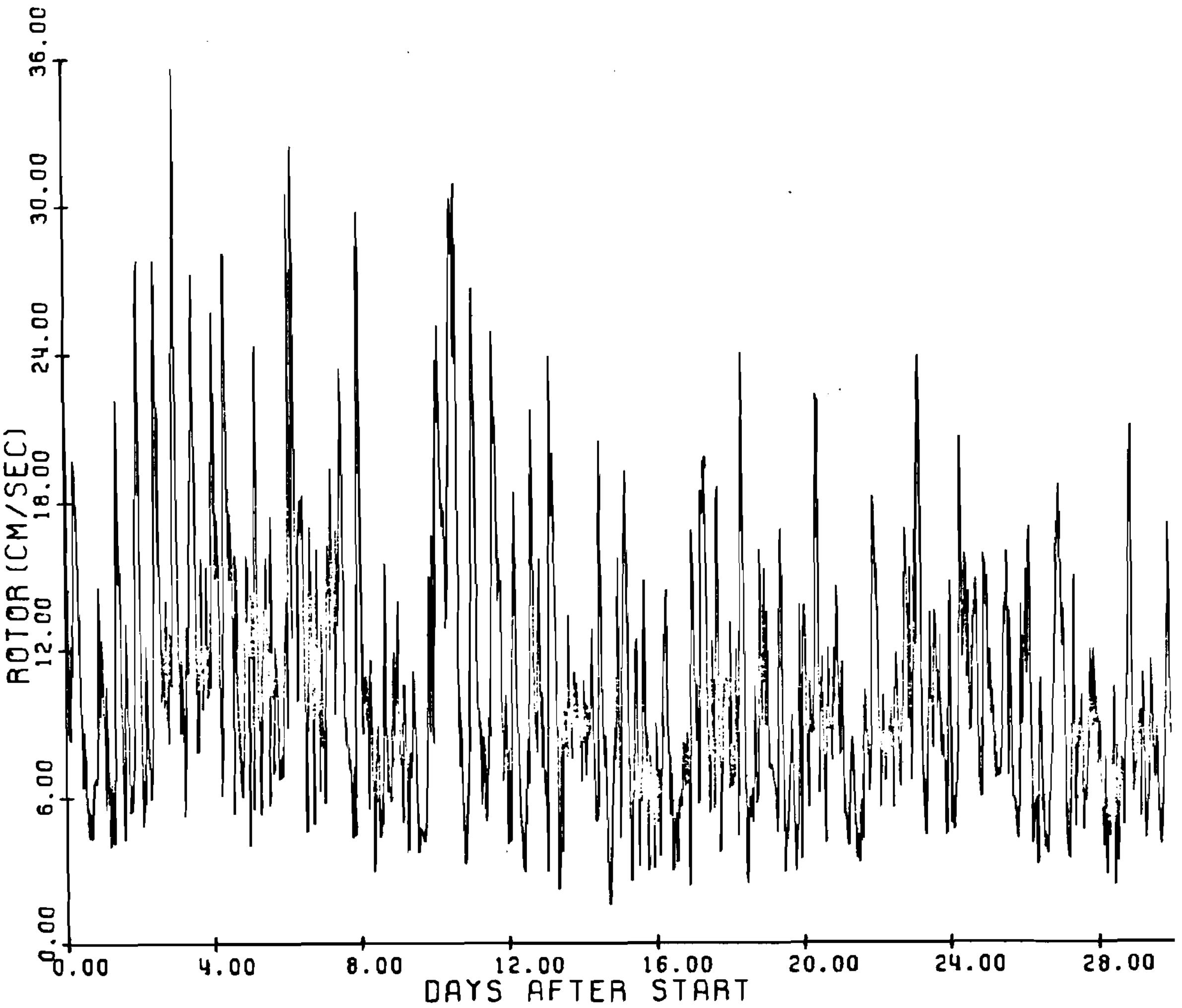


Table III-1. Summary of current data retrieval, abstracted from text. See Figure III-1 for the location of the current meter array.

Current meter	Depth	Dates deployed	Length of good data	Type of good data
CM 332	50 m.	5/2-6/1/77	8 days	speed & direction
CM 156	172 m.	5/2-6/1/77	30 days	speed
CM 459	356 m.*	5/2-6/1/77	30 days	speed & direction

*Total water depth = 363 m.

Table III-2. Mean values of directional current components.

	mean current (cm/sec) E-W	mean current (cm/sec) N-S
CM 332	4.3 E	3.3 S
CM 459	7.9 W	3.7 S

(Note: one knot is about 50 cm/sec.)

FIGURE III-9. FREQUENCY SPECTRUM,
CM-332

Frequency spectrum for the east-west current vector component for current meter CM 332 (depth = 50 m.). The dominant frequency is marked M2, i.e. the lunar semi-diurnal frequency which has a period of 12.4 hours, or frequency of 1.94 cycles/day. The energy is a measure of the strength of that frequency's input, and is defined as the sum of the squared Fourier coefficients for the time series.

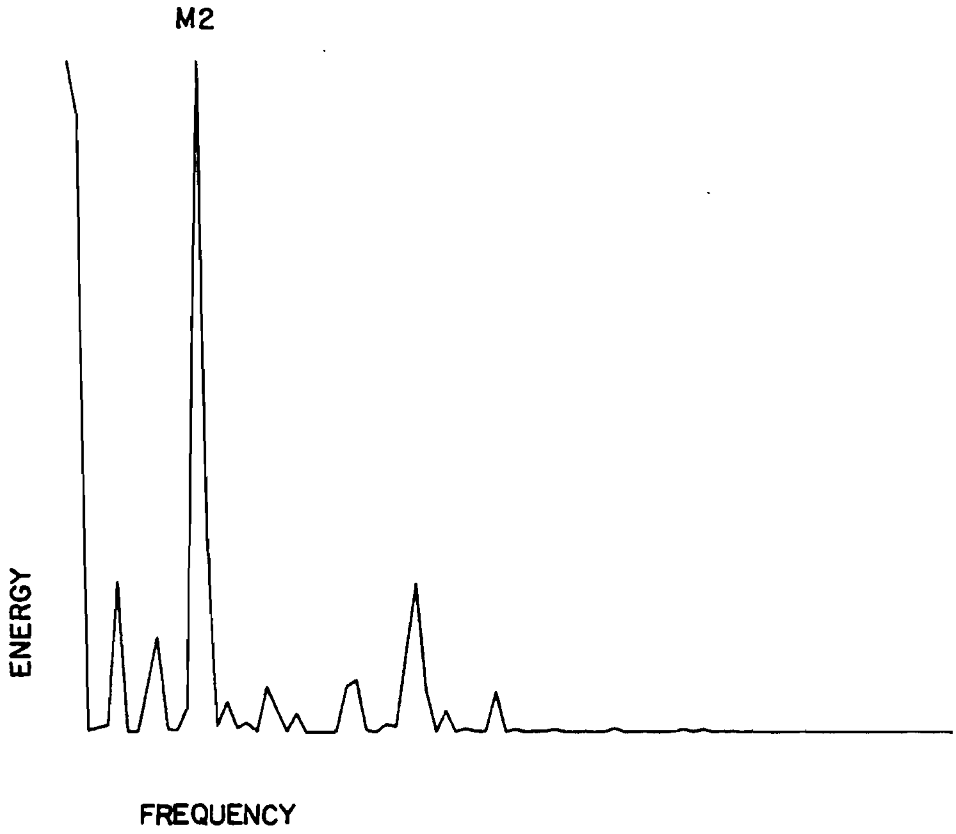


FIGURE III-10. FREQUENCY SPECTRUM,
CM-459

Frequency spectrum for the east-west current vector component for current meter CM 459 (depth = 356 meters). Dominant frequency is at 1.94 cycles per day, or a 12.4 period. Axes are the same as in Figure III-9.

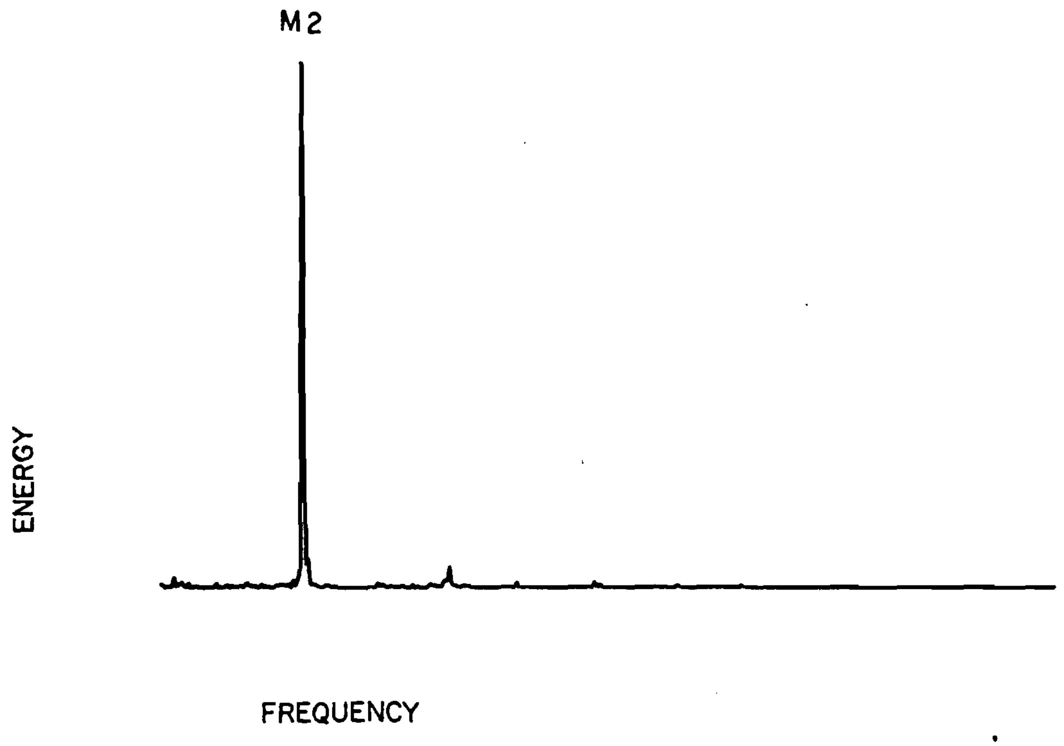


FIGURE III-11. HIGH-PASS FILTERED CURRENT, CM-332

High-pass filtered east-west current vector component for CM 332, i.e., all frequencies less than 1.94 cycles/day (or periods greater than 12.4 hours) have been removed from the spectrum, and the remaining high frequency current input has been reconstructed to form a time series of current data excluding tidal influence.

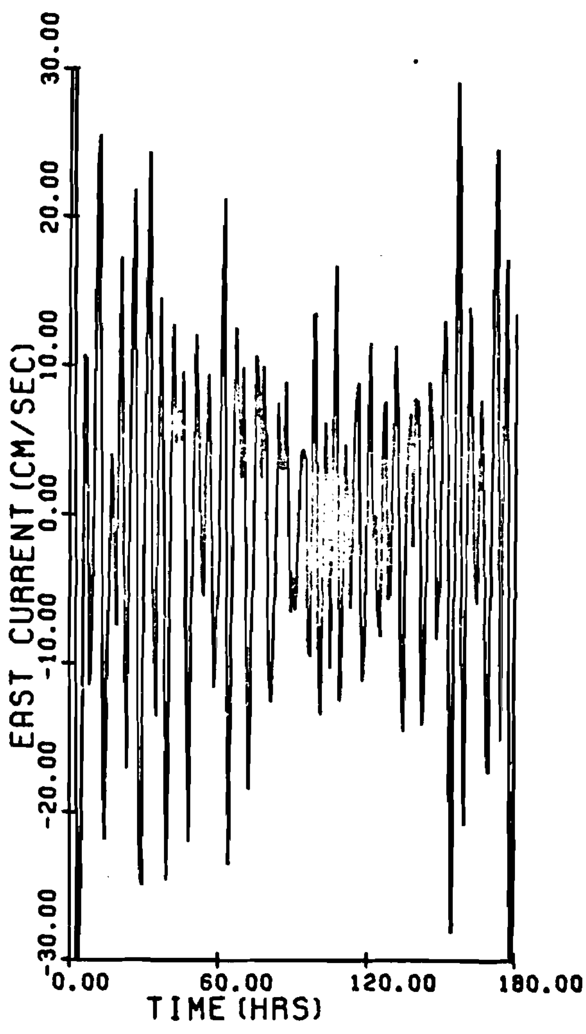
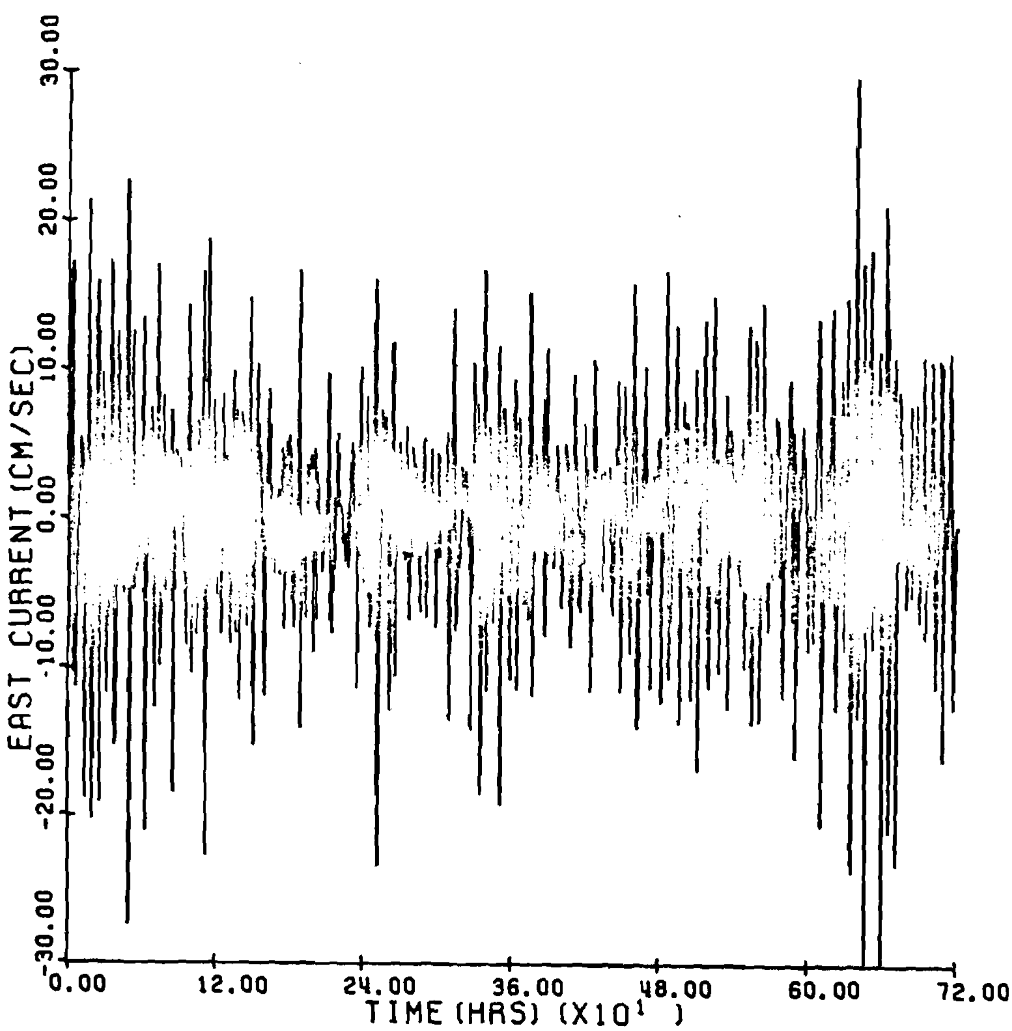


FIGURE III-12. HIGH-PASS FILTERED CURRENT, CM-459

High-pass filtered east-west vector component for CM 459, i.e., the high frequency (non-tidal) current constituent of the currents measured near the bottom.



2. Bottom Samples

A total of 40 bottom samples was obtained, of which 33 samples were examined for geological purposes. Mineral content of the samples analyzed is shown in Tables III-3, III-4, and III-5. Samples M7b, P9, and P14 were so small that they were examined only for biological content. Samples M3, J1, and P17 were coarse shell and coral rubble, and were not examined for x-ray mineralogy or sediment texture.

In the Part B samples, small amounts (<10%) of plagioclase are not considered diagnostic of spoil presence, and the same is true for quartz. A high percentage, as compared to the Part A samples, of plagioclase, chlorite, or halloysite, a pseudomorph for kaolinite, seem to indicate a sufficient change in mineralogy to warrant spoil identification.

The piston core K3 measured 14 cm in total length, and consisted of unstratified carbonate sand except for a thin layer of about 3 mm of silty material at the surface. It is suspected that this is simply silt stirred up by the piston in the core barrel to form the thin top layers.

The mineralogy of the upper and lower layers of core K3 is included in Figure III-13. A sketch of the core is also shown in Figure III-13.

3. Sediment Comparison

Compared with the Part A sediments at the disposal site, which were 90 to 100% carbonate minerals, with a ratio of aragonite to calcite of 3 or 4 to 1, the sediments of Pearl Harbor should be easily distinguishable. The Pearl Harbor sediments, though containing from one-third to as much as two-thirds carbonates, also contain appreciable amounts of the basaltic suite of minerals (plagioclase, augite, magnetite, olivine) or secondary minerals produced by the weathering of basalt (hematite, kaolinite, montmorillonite, gibbsite).

The results of x-ray diffraction analysis of the grab samples appear in Tables III-3, III-4, and III-5.

In the M series of samples, using the above criteria for spoil identification, samples M1c, M5, M6, and M9 contain spoil; M2, M4, M11, and M14b do not.

In the J samples, J2 and J4 contain spoil; J3c, J5, J6, J7, J8, J9, J10, and J11 do not.

Table III-3. X-ray mineralogy of grab samples taken April 26, 1977. Copper K-alpha radiation. (weight percentages)

	Sample							
Mineral	M1c	M2	M4	M5	M6	M9	M11	M14b
calcite	31.5	32.2	29.6	39.6	31.2	13.7	29.3	25.4
aragonite	63.9	66.1	67.5	56.1	63.6	40.6	68.8	70.9
plagioclase	-	-	2.9	-	-	1.7	1.9	3.7
chlorite	-	-	-	4.3	-	-	-	-
halloysite	4.6	-	-	-	5.2	1.5	-	-
quartz	-	1.7	-	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table III-4. X-ray mineralogy of May 18, 1977 grab samples.
Copper K-alpha radiation. (weight percentages)

	Sample									
Mineral	J2	J3c	J4	J5	J6	J7	J8	J9	J10	J11
calcite	23.4	29.7	19.2	21.0	23.5	40.9	37.1	26.6	36.1	37.6
aragonite	73.6	70.3	73.7	79.0	76.5	59.1	62.9	70.6	63.9	62.4
plagioclase	-	-	-	-	-	-	-	2.8	-	-
halloysite	3.0	-	4.3	-	-	-		-	-	-
quartz	-	-	2.8	-	-	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table III-5. X-ray mineralogy of grab samples taken May 31-June 1, 1977. Copper K-alpha radiation. (weight percentages)

	Sample													
Mineral	P4b	P5	P6	P7b	P10	P11	P12	P13a	P15a	P16	P18	P20	P21	P22
calcite	28.2	35.7	19.2	42.4	24.2	18.5	32.6	35.5	32.2	33.2	33.3	20.8	30.6	20.1
aragonite	66.2	59.7	67.2	57.6	57.8	61.1	67.4	62.0	67.8	66.8	66.7	70.7	69.4	79.9
plagioclase	-	-	4.3	-	8.0	11.0	-	2.5	-	-	-	-	-	-
halloysite	5.6	4.6	9.3	-	-	9.4	-	-	-	-	-	6.5	-	-
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

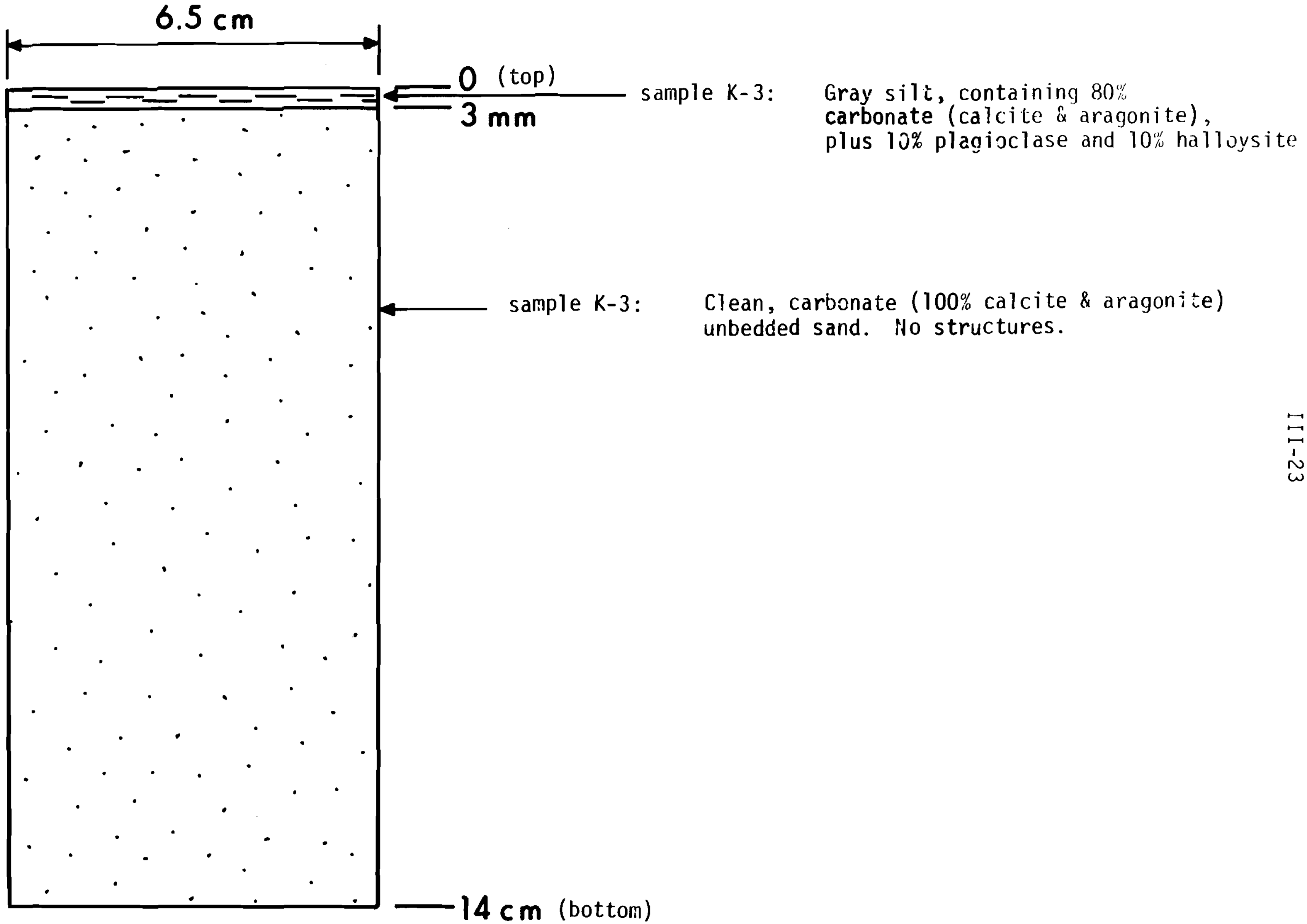


Figure III-13. Description of piston core K3.

In the P samples, P4b, P5, P6, P11, and P20 contain spoil; P7b, P10, P12, P13a, P15a, P16, P18, P21, and P22 do not. A summary of spoil identification on the basis of mineralogy is shown in Tables III-6a, b, and c.

The results of sediment grain size analysis are presented in Tables III-7, III-8 and III-9. As with the samples collected prior to dumping, these samples exhibited no clay size fraction even though considerable amounts of clay-sized material were dumped. In some samples an increase in the silt fraction can be discerned, when compared with the Part A samples, but usually only a percentage point or two at most. An increase in the gravel fraction was sometimes noted. Generally, the distribution of grain sizes, with the exception of the -1.5 ∅, or coarsest portion, peaked in the medium to fine sand sizes, 2.0 ∅ to 3.5 ∅. This was generally true for the Part A samples, although they peaked at a bit coarser interval approximately 1.5 to 2.5 ∅. The distribution of sediment in the sand and silt sizes is broader in the Part B samples and more peaked in the Part A samples.

4. Acoustic Monitoring

Direct acoustic monitoring of the spoil during disposal was attempted for two dumps on 4/26/77. The R/V Machias was positioned about 100 meters astern of the dredge Harding and the spoil was tracked visually and acoustically as it was dumped. Several passes across the general area of the dump site and through the surface plume were made while attempting to a) determine the settling speed of the plume, b) determine the time of impact on the bottom and c) if possible, estimate the extent of sediment deposition.

The acoustic monitoring was hampered for the initial five minutes of each dump because something, probably air bubbles, blanked out all returns on the fathometer. After this, a faint trace on the fathometer indicated a descent of reflective material to a depth of 225 fathoms in 25 minutes (average speed of descent, 27 cm/sec) for the first dump and 16 minutes to reach 230 fathoms (44 cm/sec average speed) for the second dump. These speeds can be considered approximate at best, for the fathometer traces were very faint and definitely subjective in interpretation. The 25 minute interval noted in the first instance may be excessive. It was necessary to maneuver for 6-7 minutes due to wind drift before picking up the plume's return again, where it could be seen as a continuous trace down to close to the bottom.

Table III-6a. Spoil identification in April 26, 1977 grab samples, based on x-ray mineralogy.

Sample	Spoil	No Spoil
M1c	✓	
M2		✓
M4		✓
M5	✓	
M6	✓	
M9	✓	
M11		✓
M14b		✓

Table III-6b. Spoil identification in May 18, 1977 grab samples, based on x-ray mineralogy.

Sample	Spoil	No Spoil
J2	✓	
J3c		✓
J4	✓	
J5		✓
J6		✓
J7		✓
J8		✓
J9		✓
J10		✓
J11		✓

Table III-6c. Spoil identification in May 31-June 1, 1977 grab samples, based on x-ray mineralogy.

Sample	Spoil	No Spoil
P4b	✓	
P5	✓	
P6	✓	
P7b		✓
P10		✓
P11	✓	
P12		✓
P13a		✓
P15a		✓
P16		✓
P18		✓
P20	✓	
P21		✓
P22		✓

Table III-7. Grain size analysis of April 26, 1977 samples (weight percentages)

Type	Phi	mm	M1c	M2	M4	M5	M6	M9	M11	M14b
gravel	-1.5	2.83	19.55	12.27	2.99	.14	4.19	24.02	9.14	6.95
———	-1.0	2.00	5.98	3.57	2.65	.89	2.80	3.01	1.54	3.07
	-0.5	1.41	5.16	2.87	2.22	1.10	2.83	2.79	.92	2.85
	0.0	1.00	3.76	1.84	1.25	1.42	1.93	.87	.16	3.56
	0.5	.71	7.32	4.64	3.29	6.66	5.29	4.38	2.28	3.73
	1.0	.50	7.82	6.01	5.34	14.47	6.94	4.65	4.41	3.99
sand	1.5	.35	10.82	11.09	11.31	32.09	12.64	7.74	11.94	7.13
	2.0	.25	10.98	13.93	16.81	28.57	17.76	10.73	14.12	11.05
	2.5	.177	9.55	15.20	21.71	8.51	13.57	15.33	11.78	19.34
	3.0	.125	7.53	11.87	15.18	3.24	6.38	16.28	15.21	19.24
	3.5	.088	5.43	8.97	9.10	2.23	15.85	6.16	12.82	13.67
———	4.0	.0625	2.02	3.38	4.17	.27	4.53	2.03	4.98	2.92
	4.5	.044	1.86	1.87	2.20	.19	2.55	1.04	4.78	1.44
	5.0	.031	.01	.02	.01	.18	.04	.28	.04	.31
	5.5	.022	.01	.01	0.0	.05	.06	.56	.05	.57
silt	6.0	.0156	.21	.06	.56	-	1.89	.14	.24	.19
	6.5	.011	.92	.86	1.18	-	.70	-	2.15	-
	7.0	.0078	.54	.86	.03	-	.05	-	2.00	-
	7.5	.0055	.51	.52	-	-	0.0	-	1.41	-
———	8.0	.0039	.03	.16	-	-	-	-	.03	-
	8.5	.0028	-	-	-	-	-	-	-	-
	9.0	.002	-	-	-	-	-	-	-	-
Total:			100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
mean ø:			-0.46	1.87	2.09	1.32	1.79	-0.37	2.44	2.01
S.D.:			0.97	0.93	0.70	0.39	0.79	0.95	0.96	0.79
skewness			0.20	-0.02	-0.20	-0.04	-0.09	-0.16	-0.01	-0.42
kurtosis			-0.02	0.33	1.39	2.40	0.41	-1.2	0.76	0.03

Table III-8. Grain size analysis
of May 18, 1977 samples
(weight percentages)

Type	ø	mm	J2	J3c	J4	J5	J6	J7	J8	J9	J10	J11
gravel	-1.5	2.83	1.54	31.81	19.25	9.88	30.31	14.74	14.52	8.98	8.15	23.16
	-1.0	2.0	1.47	3.86	4.94	2.34	6.93	8.26	4.09	1.96	3.20	8.13
	-0.5	1.41	1.97	3.16	3.51	2.66	3.91	10.82	4.55	2.23	2.46	6.50
	0.0	1.0	.28	1.68	3.15	1.96	3.14	11.89	5.12	4.31	4.68	10.20
	0.5	.71	5.06	3.65	6.34	6.19	7.37	17.28	7.74	3.27	5.95	8.35
	1.0	.5	7.47	4.73	8.92	6.46	6.32	11.85	9.92	4.04	10.22	7.91
sand	1.5	.35	12.80	6.84	12.66	8.07	7.42	7.13	15.25	8.65	20.35	9.39
	2.0	.25	15.16	9.64	14.16	9.89	8.90	4.91	12.04	14.88	21.92	7.71
	2.5	.177	14.68	11.82	11.31	13.92	11.27	5.64	8.10	16.98	13.10	4.84
	3.0	.125	22.61	11.27	7.96	18.81	4.91	4.80	6.81	17.31	6.33	7.00
	3.5	.088	6.74	4.02	4.03	6.93	8.05	1.52	6.09	5.44	1.83	2.71
	4.0	.0625	3.31	2.29	1.08	4.26	.41	.33	2.35	4.99	.83	1.49
	4.5	.044	2.95	1.82	1.21	4.02	.35	.29	1.41	3.78	.50	1.29
	5.0	.031	.08	.06	.06	.12	-	.22	.05	.10	.01	.04
	5.5	.022	.42	.22	.15	.16	.08	.26	.83	.78	.01	.03
silt	6.0	.0156	1.12	.72	.36	.58	.22	.05	.71	.92	.07	.02
	6.5	.011	1.67	1.38	.51	1.89	.36	-	.41	1.06	.19	.45
	7.0	.0078	.62	.63	.26	1.29	.05	-	.01	.33	.11	.50
	7.5	.0055	.06	.38	.13	.58	-	-	-	.01	.07	.27
	8.0	.0039	-	.01	-	-	-	-	-	-	.01	.01
	8.5	.0028	-	-	-	-	-	-	-	-	-	-
clay	9.0	.002	-	-	-	-	-	-	-	-	-	-
Total:			100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mean:			2.42	-.50	-.45	2.27	-.68	.22	1.11	2.26	1.44	-.71
S.D.:			.71	1.09	.89	.96	.94	.71	.87	.87	.68	.91
Skewness:			.12	.19	.05	0.0	.14	.28	.06	-.16	-.20	-.37
Kurtosis:			1.65	-.60	-.27	.24	-1.04	-.03	-.32	0.20	.87	.39

Table III-9. Grain size analysis of May 31-June 1, 1977 samples
(weight percentages)

Type	Ø	mm	P4b	P5	P6	P7b	P10	P11	P12	P13a	P15a	P16	P18	P20	P21	P22
gravel	-1.5	2.83	3.24	33.21	52.38	18.68	45.78	43.05	.06	5.76	11.45	.53	1.28	5.20	10.24	9.92
	-1.0	2.0	2.28	6.66	6.82	3.55	1.63	9.68	.76	7.64	4.16	1.05	2.46	2.28	4.26	1.41
	-0.5	1.41	1.91	2.49	5.74	3.55	4.49	6.61	1.03	19.07	4.24	1.87	3.18	2.40	5.41	1.27
	0.0	1.0	1.60	.49	3.27	3.55	1.88	6.77	1.77	13.19	3.19	2.86	2.61	2.22	4.93	.52
	0.5	.71	3.38	3.77	7.45	10.07	2.13	4.22	4.13	3.39	7.40	9.28	4.67	7.65	8.18	4.48
	1.0	.5	3.86	4.92	4.74	12.99	2.25	2.78	4.95	4.01	8.27	13.88	5.05	9.41	5.94	5.01
sand	1.5	.35	8.06	10.56	3.87	14.07	4.96	2.58	6.72	7.98	10.72	18.12	9.61	14.96	6.06	7.72
	2.0	.25	19.28	14.82	2.58	15.39	5.65	2.37	8.15	11.11	11.04	17.17	14.58	16.55	7.08	11.86
	2.5	.177	21.96	11.23	1.64	4.43	4.51	1.93	11.60	13.63	10.67	16.56	12.31	17.52	8.77	17.09
	3.0	.125	15.23	8.48	7.66	9.50	3.72	7.29	10.55	8.48	13.64	12.78	11.49	10.16	13.33	22.74
	3.5	.088	10.14	1.24	1.72	1.77	3.05	1.95	27.16	3.44	5.36	3.36	18.44	10.26	6.65	6.91
	4.0	.0625	5.16	.52	.59	.91	1.95	1.67	9.09	1.30	3.50	1.41	5.93	.61	5.76	4.17
	4.5	.044	2.40	.45	.71	.68	1.63	7.28	7.30	1.00	3.52	.72	3.91	.35	9.35	3.58
	5.0	.031	.02	.02	.02	.05	1.32	.11	.05	-	.06	.06	.15	.23	.19	.02
	5.5	.022	.53	.17	.03	.48	.87	.08	.04	-	.41	.20	.10	.20	.38	.19
	6.0	.0156	.44	.56	.09	.23	1.62	.25	.20	-	.83	.08	.18	-	.70	.68
silt	6.5	.011	.43	.30	.21	.11	2.34	.37	1.65	-	1.04	.06	1.69	-	1.55	1.50
	7.0	.0078	.06	.10	.25	.01	2.53	.42	2.00	-	.36	-	1.27	-	.92	.77
	7.5	.0055	-	-	.24	-	4.84	.43	1.84	-	.15	-	.97	-	.32	.17
	8.0	.0039	-	-	-	-	2.86	.17	.97	-	-	-	.10	-	-	-
	8.5	.0028	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	9.0	.002	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total:			100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mean:			2.12	-.68	-1.12	-.53	-.45	-.89	3.02	-.02	2.05	1.40	2.73	1.87	2.19	2.33
S.D.:			.69	.94	.88	.80	1.56	1.10	.81	.78	.93	.53	.83	.67	1.04	.88
Skewness:			-.33	.11	.7	-.01	.45	.58	.25	.08	.03	-.04	.11	-.34	.03	-.18
Kurtosis:			1.32	-.97	1.45	-.46	-.51	.27	1.30	1.24	-.21	.60	1.00	.25	-.64	.66

At no time did we observe what could be considered an "impact" upon the bottom. Rather, the plume's descent seemed to reach to within 20-30 fathoms of the bottom and then hover there. Further, no deposition of sediment could be perceived. However, since the sand and gravel content of the sediment was probably only a quarter or less of the total bulk of spoil, and the material most likely to be deposited immediately, this is not surprising.

A concentration of reflective material was observed at 120 fathoms 16 minutes after the second dump, then later at 160 fathoms 22 minutes after the dump. It fell at a speed of 22 cm/sec to 120 fathoms and at 20 cm/sec from there to 160 fathoms.

In terms of areal extent, the surface plume was about 100-150 meters in diameter soon after the dump. It did not enlarge appreciably afterwards.

Monitoring by fathometer of the subsurface reflector showed that it did not seem to spread much beyond the dimensions of the surface slick. This observation could be a spurious impression resulting from selective reflectivity of the central, and probably densest, part of the plume.

5. Geological Features

In the 50% progress report mention was made of minor topographic irregularities referred to as "clumps" seen once or twice in the fathometer records. Upon re-examination of these records, only one really seems to exist. No more were noted in subsequent work. Although it was speculated that this feature, about 45 ft (14 m) high by 100 ft (31 m) feet wide, might represent accumulated dredged material, it seems unlikely. Assuming a roughly conical shape these dimensions would result in a volume of about 4300 cubic yards. Since the coarse fraction of the spoil was small, numerous loads would have had to land on to f each other, an unlikely occurrence. Instead, it seems more probable that is simply a bottom feature not found in the original sounding work.

Bottom photographs were taken at numerous sites throughout the area. Representative examples are reproduced in the attached set of photos. A series of two 100-foot rolls was taken using color film. An exposure rate of one picture every 10 seconds was used in both cases. Four of the 14 photo tows (#2, #5, #12, #14) obtained pictures only of the water column. The remaining 10 photos tows provided information on benthic fauna (covered in Section VI) but because of their distance off the bottom they were of limited value as far as estimating changes in the geological features. Photograph track #1 shows current-rippled sand and man-made debris. Line #3 shows evidence of dredge spoil (debris). Line #4 shows sand and silt, but no current ripples. Current ripples and exposed reef flat can be seen in line #6. Sand and rubble appear in line #7 photos. Line #8 photos show reef flat with sand patches. In line #9, rubble, sand, debris and hard bottom can be seen. Sand and rubble can be seen in line #10 photos. Sand, but with no current ripples, can be seen in lines #11 and #13. (Figures III-14-23.) Further discussion may be found in the Benthic Biology section (Chave). A summary of the bottom photography appears in Table III-10.

Bathymetry is plotted on Figure III-3. As before, the terrain is flat and featureless, with almost no topographic relief, indicating little or no change due to the dredge spoil disposal. No significant shoaling has occurred. Soundings are accurate to 1 fathom, and positions to 150 meters.

6. Field-Computer Comparison

Information regarding the Corps of Engineers' disposal site Honolulu #3 has been supplied to us by the Waterways Experiment Station (WES). Their conclusion was that for a similar dump in their site adjacent to our study area, all of the sand and gravel would be deposited immediately beneath the dumping point while the silt and clay sizes would descend to a depth of 800-1200 ft. (242-364 meters) and stay there, becoming subject to diffusion and currents. Thereafter, the silt and clay would be entirely removed from the area by currents. Initial field examination of grab samples seemed to indicate that silt and clay were showing up on the bottom, contrary to the prediction of the computer. It was hypothesized that sufficient cohesion amongst the fines permitted them to fall as larger diameter material, at correspondingly higher speeds, allowing the deposition to occur. Subsequent laboratory analysis, however, reveals only minor increases; if at all, in the amount of silt in the bottom samples, and no discernable clay fraction. If anything coarser material seems to be deposited, in the form of eroded coral rubble and broken shell debris.

It seems, therefore, that the Koh/Chang computer predictions are correct. What silt does reach the bottom probably was cohesive enough to fall with the gravel. Most of it, comprising 2/3 to 3/4 of the sediments dumped, has gone

Figure III-14

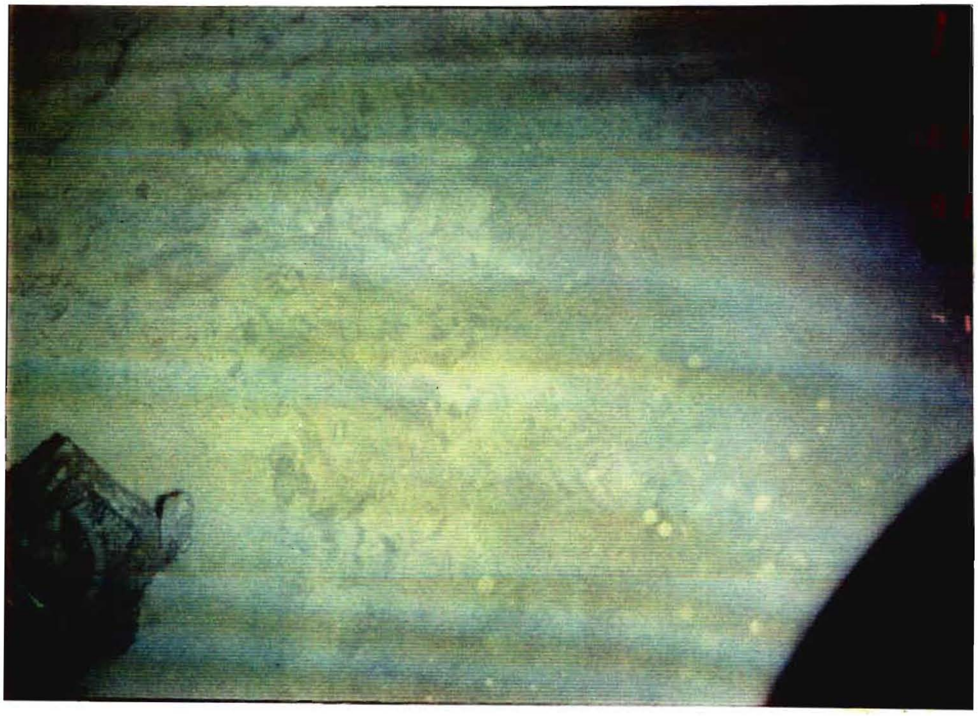


Photo line 1(6) Sand with ripples and debris.

Figure III-15

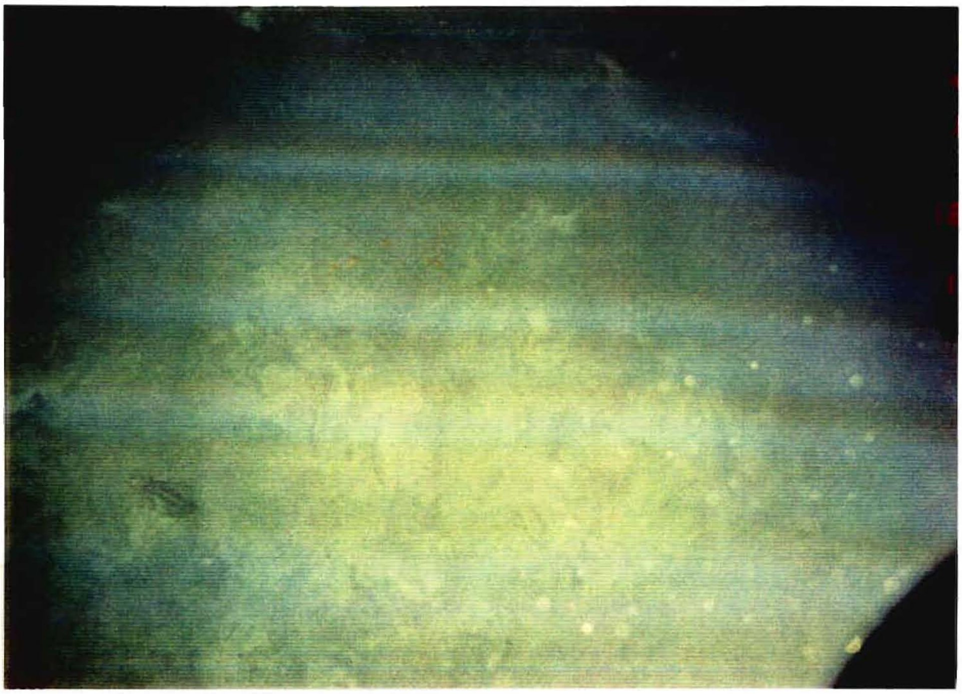


Photo line 1(21) The squid Notodarus on sand, lower left corner.

Figure III-16

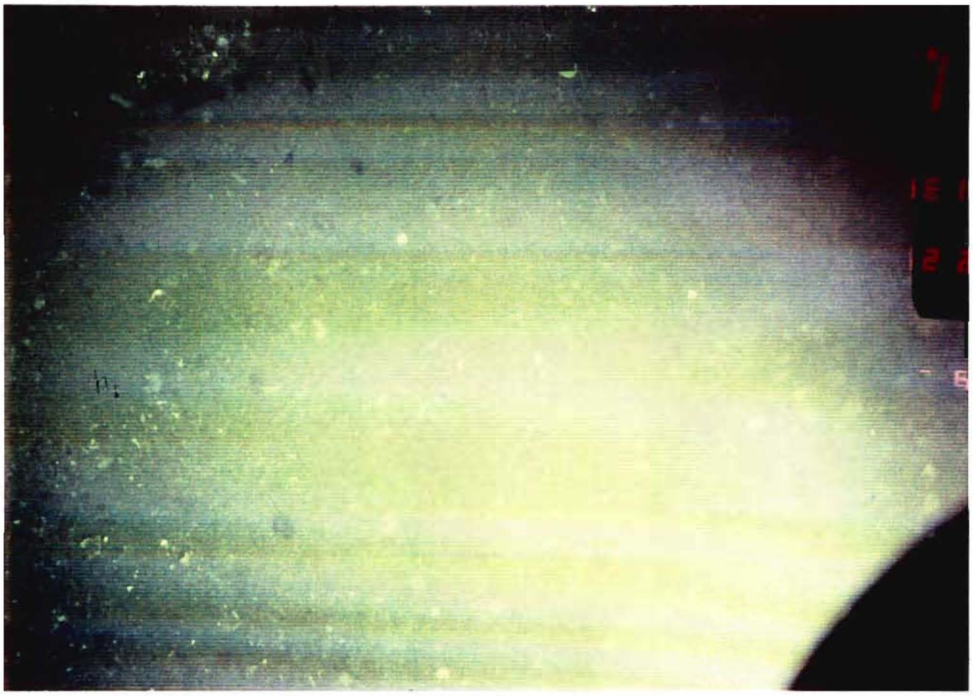


Photo line 3(18), Dredge Spoil.
Identifiable large tracer species, shell and coral rubble.

Figure III-17

Photo line 4(18), Sand and dredge spoil.

Figure III-18

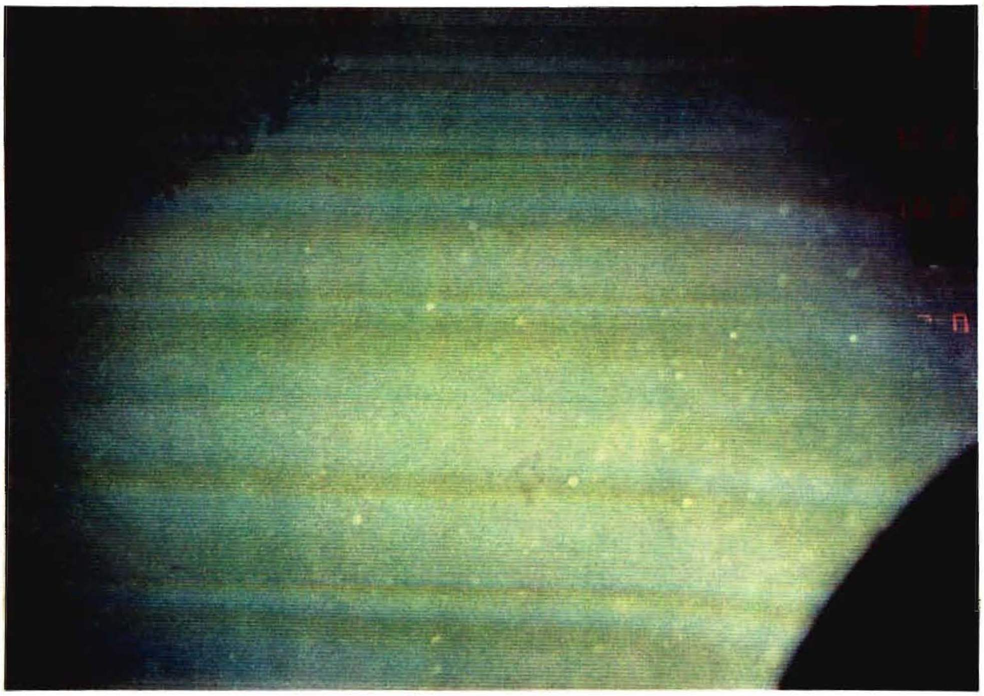


Photo line 6(38), Sand and hard substrate.

Figure III-19

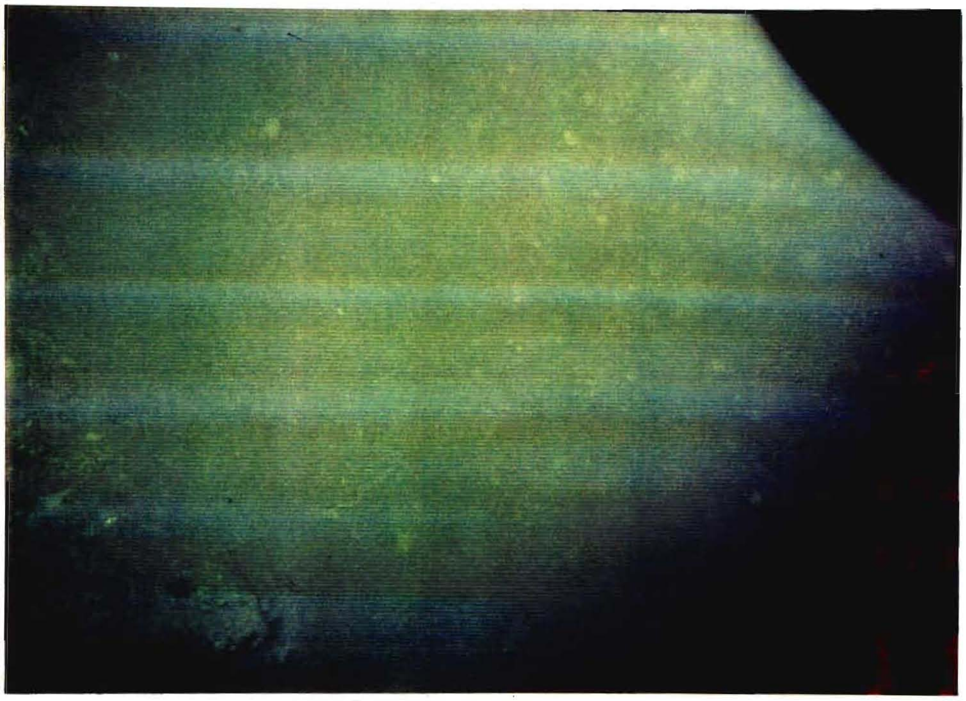


Photo line 8(32), Dredge spoil and hard substrate.

Figure III-20

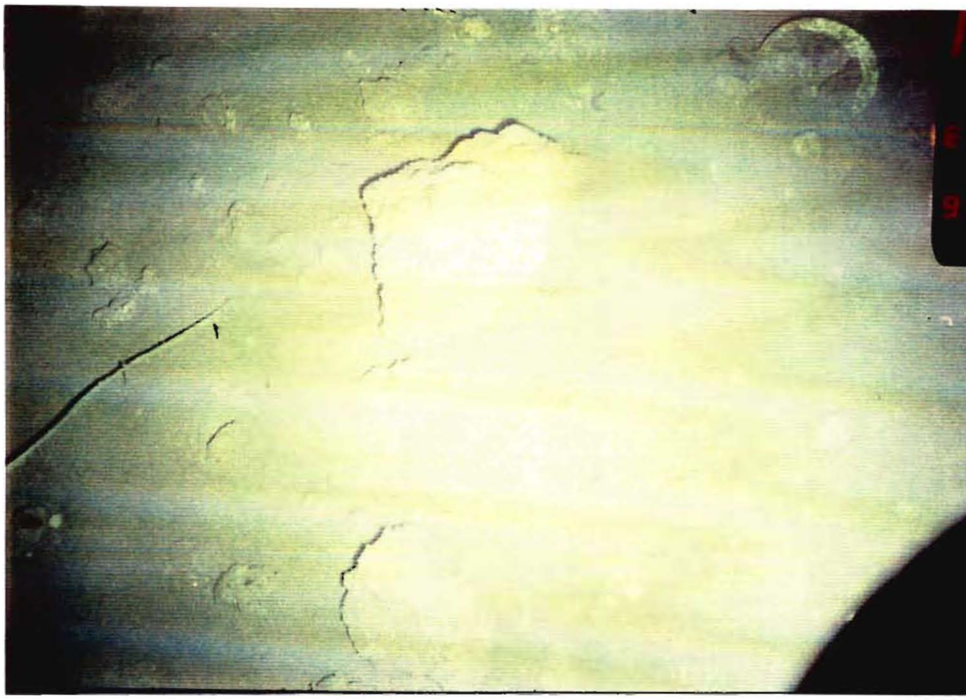


Photo line 9 (36), Heterocarpus on sand with rubble and debris. Note the reflection of the strobe off the lens of the eye.

Figure III-21

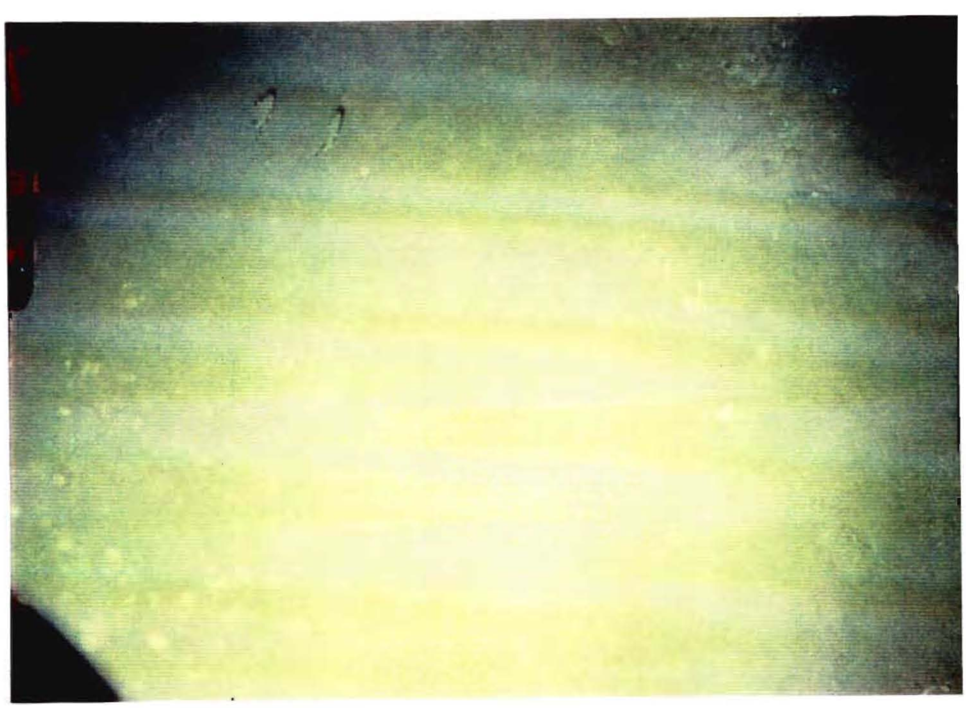


Photo line 10(15), Polymixia on sand.

Figure III-22

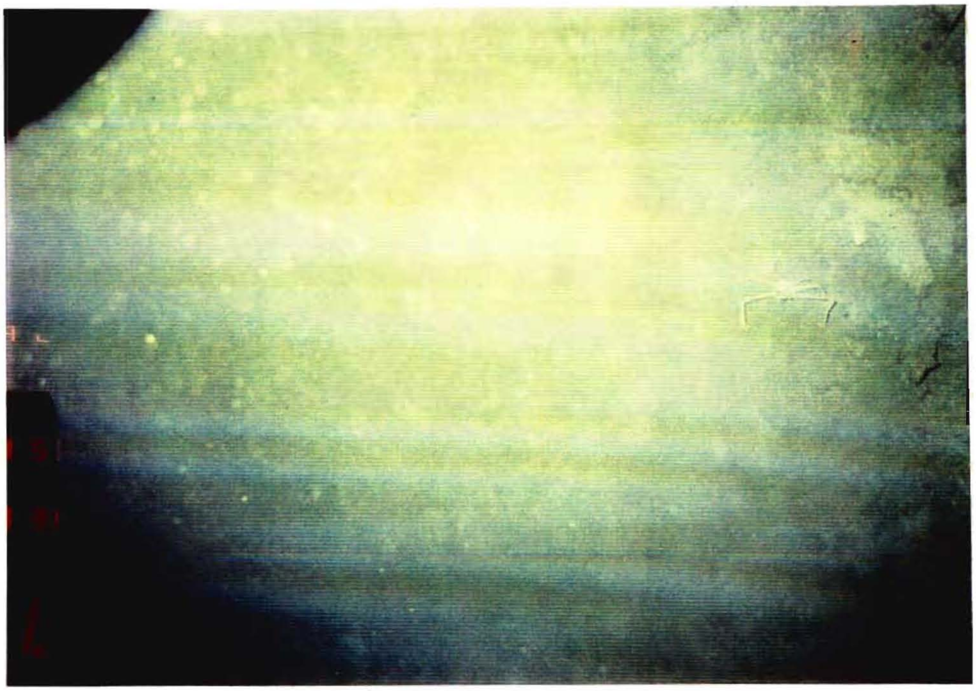


Photo line 10(20), _Randallia_ on sand.

Figure III-23

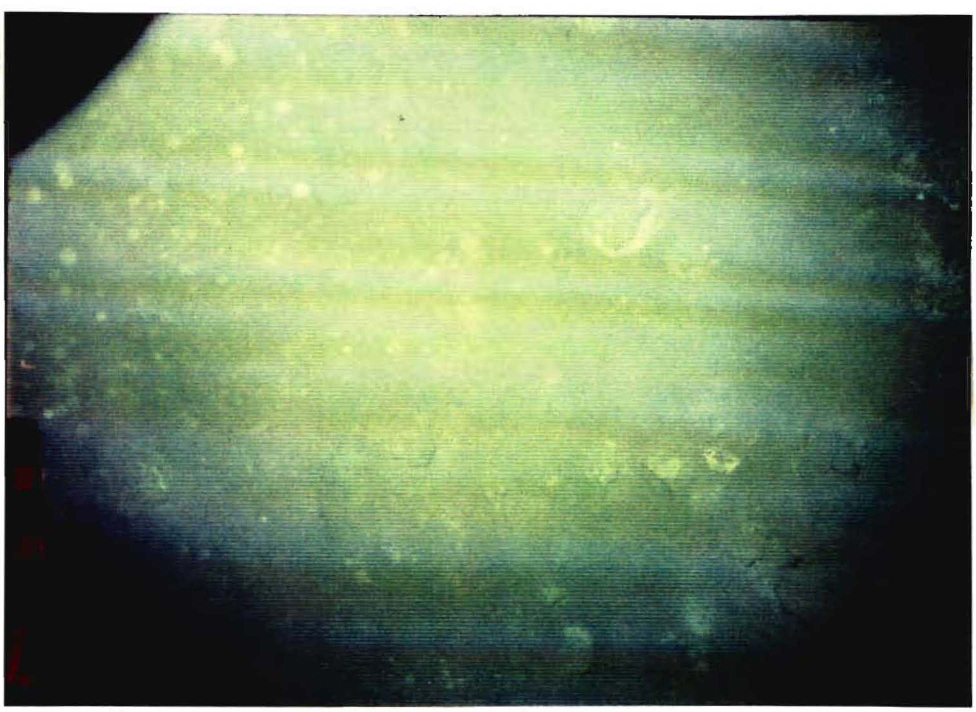


Photo line 10(37), _Cyrtomya_ on sand and rubble.

Table III-10. Summary of bottom photography. See Fig. III-1 for photo trawl locations.

Photo trawl	Remarks
1	rippled sand and man-made debris
2	no photos
3	man-made debris, rubble
4	sand and silt, no current ripples
5	no photos
6	current rippled sand and reef flat
7	sand and rubble
8	reef flat with sand patches
9	rubble, sand, reef-flat, man-made debris
10	sand and rubble
11	sand (no ripples)
12	no photos
13	sand (no ripples)
14	no photos

into suspension or has been so widely distributed over the bottom that its presence is barely discernible. Bottom photography seems to confirm the above, indicating rubble and unsorted debris, as well as man-made refuse, and correspondingly less flat or ripple-marked sands. This last observation might, however, be a result of inadvertent biasing due to the location of the photo tracks. Only photos from tracks 1, 3, 4, and 6 were obtained from the general area of the photo trawl conducted in Part A.

D. Conclusion and Discussion

Coarse-grained dredge spoil is being deposited within the study area, while finer-grained spoil is being deposited only in small quantities. Most of the fines appear to be settling slowly enough to allow their removal by current action.

Spoil behavior upon release in the ocean seems to follow computer simulations reasonably well. Rapid convective descent by a plume that does not increase much in lateral dimension is predicted and observed. The computer simulations predict that at about 1000' (300m) depth, this descent collapses, the sand and gravel falling on down to the bottom, and the silt and clay sized materials spreading out into a suspended cloud that is then subject primarily to the currents in the area, and thereby carried completely away. Field work shows this latter prediction to be correct, although a small amount of fines do appear in samples from the bottom. It is likely that spoil that gets directly to the bottom does so almost directly beneath the point of release, whereas that which goes into suspension is either removed entirely by currents, or some of it spreads thinly over a wide area. It should be noted that very little spoil remains at or near the surface, and that none seems to be carried ashore, whatever the winds. The spoil's initial rapid descent carries it below the depth of water affected by wind.

From the current data, especially the results from the meter near the bottom, it appears that the net drift is south and west, in which case one would expect the fine grained spoil to leave the area. The currents at higher levels seem to be of less importance regarding the spoil's descent because the rapid convective descent penetrates below the influence of shallow currents, such as wind-driven surface drift, or currents in the mixed layer or upper thermocline. This is supported by evidence (see water chemistry section) of a turbidity increase beginning in mid-water depths and going on down to the bottom. Also, biological work (see plankton section) indicates the water column remains fairly clean down to 150 to 200 meters, but in that case, the evidence is clouded by the possible presence of sewage from the Sand Island outfall.

Photography seems to bear out the conclusion that coarse rubble is the main constituent of deposited spoil. In the Part A photos, nearly half the area seen exhibited sand ripples, but ripples are seen less often in the Part B photos. However, much rubble was seen in the Part A photos, so that the amount of rubble seen in the B photos may simply represent no change in the bottom sediments.

Remembering that the average grain size breakdown of Pearl Harbor sediments is about 24% by weight sand and gravel, and about 76% by weight silt and clay, (Youngberg, 1973) it can reasonably be expected that the entire 24% sand and gravel portion and only a small part of the silt-clay portion (say 5%, representing about 4% of the total) would be deposited. This means only about 28% of the total volume of spoil dumped or about 210,000 cubic yards, would be deposited in the immediate area.

This relatively small volume (compared to the amount dumped) to be expected on the bottom agrees with the observations that: significant shoaling has not occurred; that sand, sand-ripples, and coarse rubble still exist on the bottom; and that little or no silt-clay material is found on the bottom.

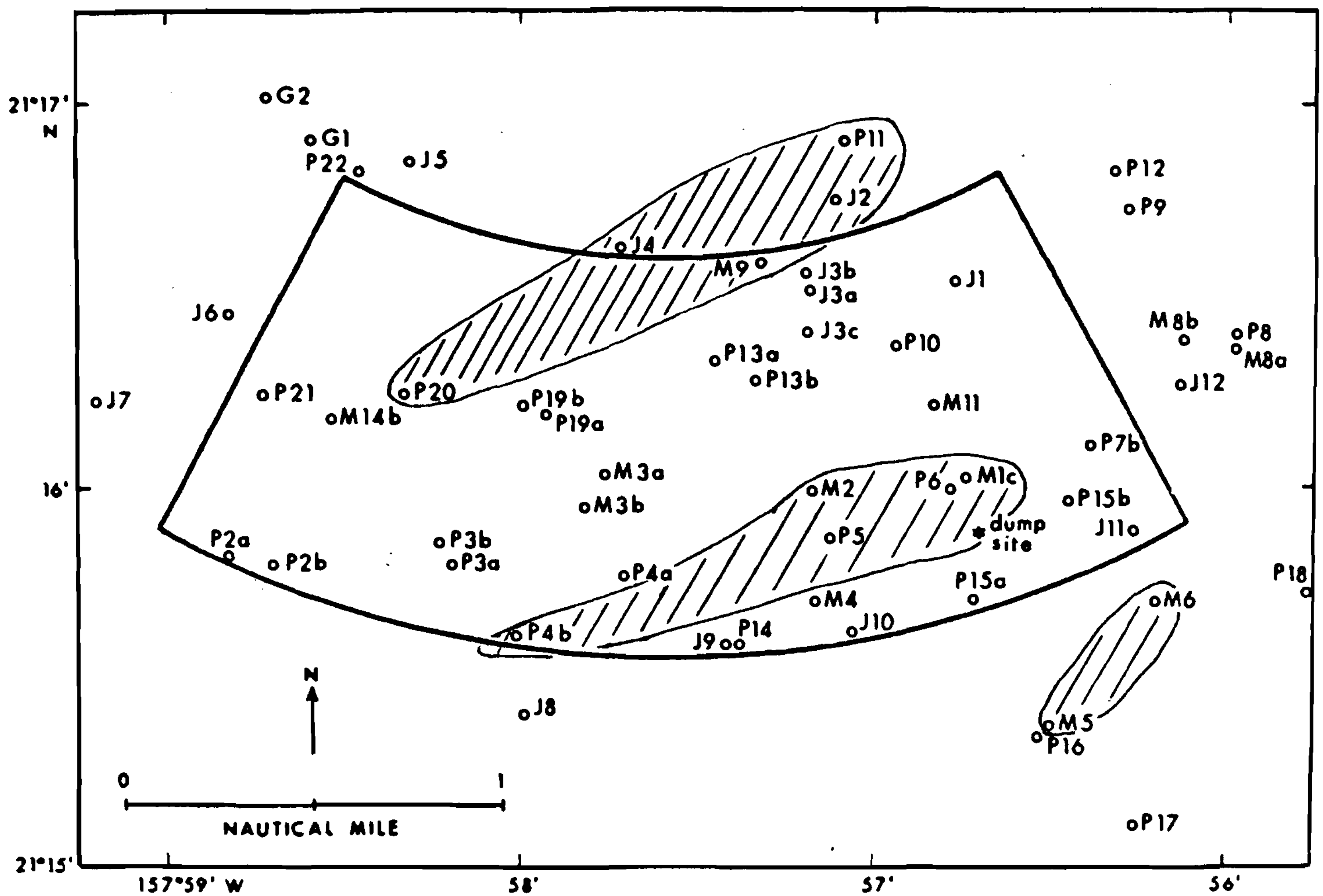
Based upon our data including mineralogy, grain size analysis, bottom photography, and unsuccessful attempts at coring, it can be safely concluded that little, if any, fines are being deposited at the dump site, while the sand and gravel dumped are reaching the bottom. This is predicted theoretically. To pursue the point, let us assume a bottom current equal to the net bottom current observed (10 cm/sec) and allow it to oscillate so as to spread spoil in all directions equally. Further, using the average grain size distribution for Pearl Harbor sediments, 25% will be coarse (sand and gravel) while 75% will be silt and clay. Let us assume all 75% is coarse silt, having a fall velocity (according to Stokes' Law) settling through still water at 0.3 cm/sec. If this material falls through 364 meters of water, it would take 34 hours to reach bottom, and would be dispersed radially at a rate of 10 cm/sec by currents. We might expect a conical pile on the bottom roughly 12 kilometers in radius. Since a total volume of about 750,000 cubic yards of spoil was dumped, about 560,000 (75%) cubic yards were silt-sized or finer. Depositing this volume in a conical pile with a radius of 12 kilometers would result in a maximum thickness (at the apex of the cone) of 1.2 cm (½ inch). Therefore, even if all of the fine-grained spoil were actually deposited (and much of the spoil was finer and would, therefore. disperse more widely), the amount would be nearly impossible to detect by visual or acoustic means.

Based upon mineral content, much of the non-carbonate Pearl Harbor sediments seem to be leaving the area, while the coarser, (probably carbonate) fraction is deposited. The carbonates from Pearl Harbor are not likely to be easily distinguishable. For that matter, considering that nearly 4,000,000 cubic yards of mostly silty-clay spoil have been dumped just inshore of the study area between 1959 and 1974, nothing much besides carbonate sands and rubble remains on the bottom.

It might also be argued that the present sediments (Part A) found in the study area prior to the 1977 disposal operations are no more than the residue of previously dumped Pearl Harbor dredgings. As already pointed out, it would be difficult to differentiate, on the basis of mineralogy, grain size, or bottom photography, between new and old dredge spoil, particularly after bottom currents have re-worked the spoil deposits and selectively removed the silt and clay sized, non-carbonate portion.

Our field investigations of the area during and immediately after disposal operations have turned up mineralogical differences in the bottom sediment. In Figure III-24, the stations showing dredge spoil presence (based on mineralogy). have been indicated, and the pattern of deposition is obvious. Spoil deposition has occurred at the two sites of disposal (near sample J2 and at the main dump site in the south-east corner). The observed pattern is skewed to the southwest, which agrees well with the observed net bottom currents. The occurrence of dredge spoil indicators in samples M5 and M6 has no obvious explanation. Perhaps the dredge dumped accidentally at these sites. Alternatively, these sites were not sampled during Part A, and might have had the present mineralogy. It should be remembered that dredge spoil presence is based upon a change in mineralogy, generally by the appearance of non-carbonate minerals. This is clearly the case in samples P4b, P5, P6, M9, M2, and P20.

Figure III-24. Dredge spoil presence in bottom samples, based on mineralogy. Note the apparent smearing out in a southwesterly direction from the inshore (temporary) dump site near J2 and from the designated dump site.



In the future, the coarse nature of sediment deposited in the area should dictate the acquisition of bottom samples using grab samplers, and not core samplers. Further work monitoring spoil behavior by acoustical means may, with different equipment, prove valuable.

E. Summary

Spoil disposal off Pearl Harbor has had no deleterious effect in a geological sense. Spoil has been deposited both in and around the area, though not in a copious or uniform manner. The coarseness of the bottom sediments indicate that coarse material is being deposited within the area in greater quantity than is fine material. Computer modeling using the Koh/Chang computer simulation model has accurately predicted the behavior of the spoil in the water column and the short-term fate of the sediment. That is, after rapid convective descent to about 1000 feet depth, the sediment plume collapses to form a diffusing cloud of silt and clay which moves out of the area via the prevailing currents, while the sand and gravel lands on the bottom at about the point beneath release. Tidally varying bottom currents with peak values of up to 35 cm/sec to the west and 30 cm/sec to the south, and mean velocities westward and southward seem responsible for the removal of fine grain sediments from the area.

F. Reference

Johnson, B.H., 1977. "Numerical Model Results of Dredge Material Disposal at Ten Proposed Ocean Disposal sites in the Hawaiian Islands." Misc. Paper H-77-6, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.

IV. WATER CHEMISTRY

by

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A. Objectives

In order to evaluate the immediate environmental impacts of the ocean disposal of sediment from a Pearl Harbor dredging project, water quality measurements were performed on samples collected during actual disposal operations and compared to a set of baseline conditions measured in September 1976 (Char and Chave, 1977). Water quality parameters measured during the present phase of investigations were essentially the same as those analyzed during the initial baseline data collection phase. These included measurements of temperature, salinity, dissolved oxygen, pH, suspended solids, turbidity, total Kjeldahl nitrogen, total phosphorus, and heavy metals, at the surface and selected depths.

In addition to these receiving water quality parameters, baseline sediment samples collected at the disposal site in September 1976 and sediment samples collected during the present study were assayed for heavy metals in an effort to trace the dispersal of spoil material. Samples of spoil material were also collected from the U.S. Army Corps of Engineers hopper dredge Chester Harding and characterized for heavy metals, pesticides, and solids content. Shrimp samples collected from the study site were also examined for heavy metals.

In summary, the specific objectives accomplished in this study included:

1. Receiving water surveys.
    a. Part 1: A general site survey to determine the distribution of water properties in the vicinity of the disposal site;
    b. Part 2: A description of plume settling behavior based on water quality observations;
    c. Part 3: A follow-up site survey immediately after dumping had ceased;
2. Characterization of spoil material for heavy metals, pesticides, and solids content;
3. Tracing the dispersal of spoil using the sediment metals content as a label;
4. Determining the heavy metal body burdens of shrimp collected from the disposal site.

B. Methods and Procedures

1. Sampling Stations, Depths, and Dates

a. Receiving Water Stations

Stations 1, 2, 3, and 4 were established in the eastern half of the initial study area, with Station 2 being located at the designated Pearl Harbor dredge spoil disposal site (Figure IV-1):

Station 1	coordinates:	21° 15.9' N, 157° 57.8' W
	depth:	384 m (210 fm)
Station 2	coordinates:	21° 15.9' N, 157° 56.7' W
	depth:	421 m (230 fm)
Station 3	coordinates:	21° 16.3' N, 157° 56.1' W
	depth:	393 m (215 fm)
Station 4	coordinates:	21° 16.6' N, 157° 57.3' W
	depth:	335 m (183 fm)

Typical depths for the mixed surface layer during the period of this study (April to May) are approximately 120 to 125 meters (Bathen, 1970), and correspond to the annual maximum depth of the surface layer in waters off the Hawaiian Islands. Therefore, depths sampled included the following locations in the water column:

1) Surface, just below interference from surface waves, 0 m (0 fm);
2) Middle of the mixed surface layer, 50 m (30 fm);
3) Bottom of the surface layer, 100 m (55 fm);
4) Top of the thermocline, 150 m (80 fm);
5) Middle of the thermocline, 200 m (110 fm);
6) As near to the bottom as feasible, 300-400 m (165-220 fm).

Hydrocasts at Station 2 when there was no visible plume present from disposal operations were designated as "2A", while "2B" was used to describe sampling in the plume shortly after dumping.

Receiving water sampling was completed in accordance with the following schedule:

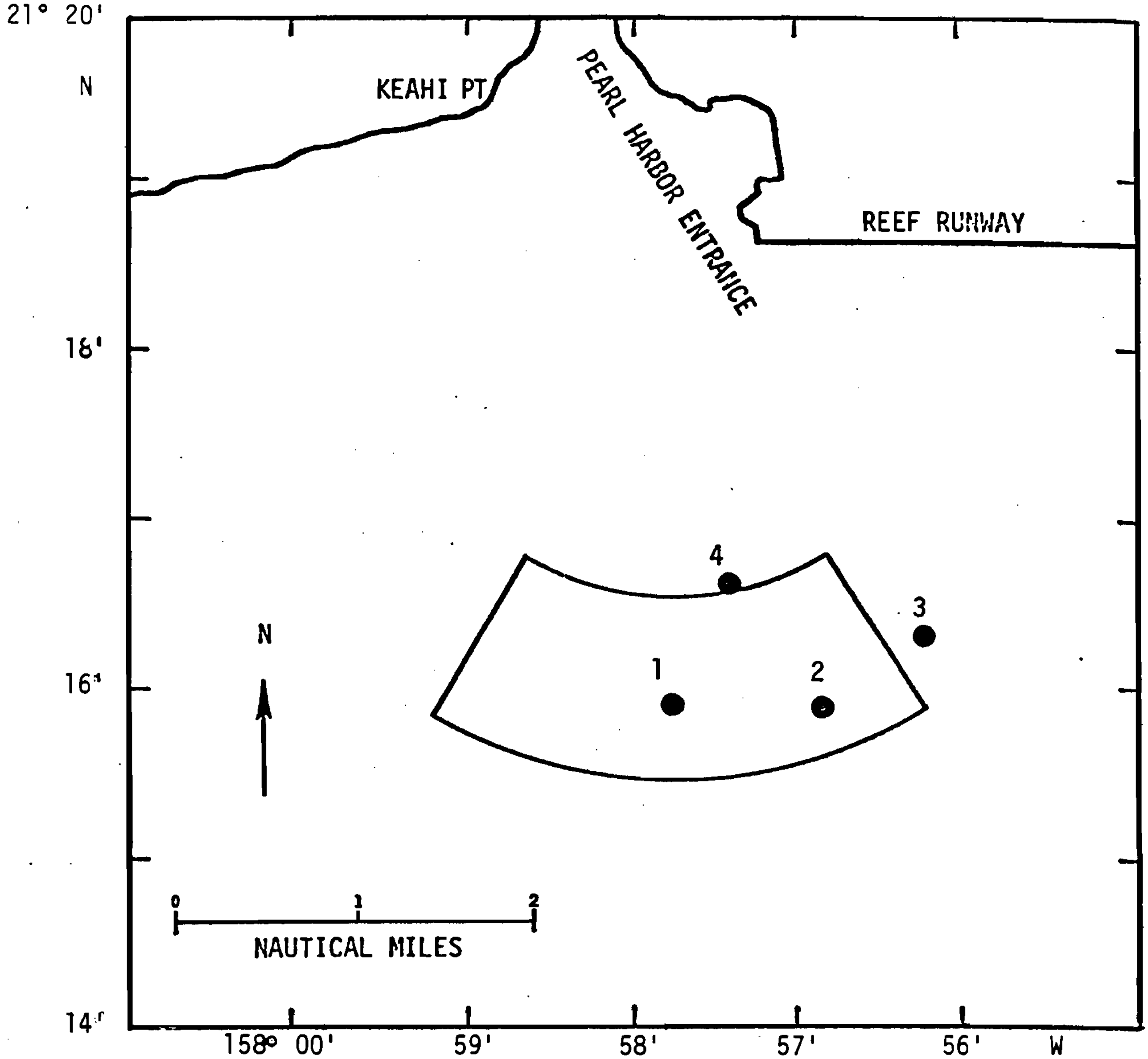


Figure VI-1. Pearl Harbor Dredge Spoil Disposal Site Study, Water Chemistry Stations, Phase B

	Stations Sampled	Dates
Part 1 (General Site Survey)	1, 2A, 2B, 3, and 4	April 26-27, 1977
Part 2 (Plume Behavior)	three casts at 2B	May 18, 1977
Part 3 (Follow-up Survey)	1, 2A and 3	June 1, 1977

Weather conditions during collection of water samples deviated somewhat from the norm. Typical "trade wind" weather (winds 10-20 knots, ENE) were present only on June 1. Winds were "Kona" or southerly, 5-10 knots, on the other two sampling periods.

b. Spoil Material from the *Harding*

Sediment samples for heavy metals analysis were collected from the hoppers on board the *Harding* on May 3, 16, and 31, 1977. Samples to be analyzed for pesticides were collected on May 3, 6, and 9. During the period the *Harding* was operating in Pearl Harbor, between April 11 and May 31, 1977, dredging was limited to the Ford Island Channel, NE area.

c. Sediment Stations at the Disposal Site

Oven-dried sediment samples originally collected in September 1976 during baseline investigations (Figure IV-2) and samples collected on April 22, May 31, and June 1, 1977 (Figure IV-3), were analyzed for heavy metals in an attempt to trace the dispersal of spoil from the disposal site.

d. Shrimp Trapping Stations

Shrimp (*Heterocarpus ensifer*) were collected on July 15, 1977 from the two locations shown in Figure IV-4. Basis for the selection of station locations are discussed in "Section VII. Fisheries." Sampling was performed approximately 45 days after dumping operations had ceased. Station S1 was located in close proximity to the dump site. The bottom at Station S2, 2 miles to the west, was presumably unaffected by dredge spoil disposal and shrimp collected at this station were used as "controls."

2. Field Methods, Collection and Preservation of Samples

a. Receiving Water Samples

Receiving water samples were collected and preserved as described in the baseline study (Char and Chave, 1977).

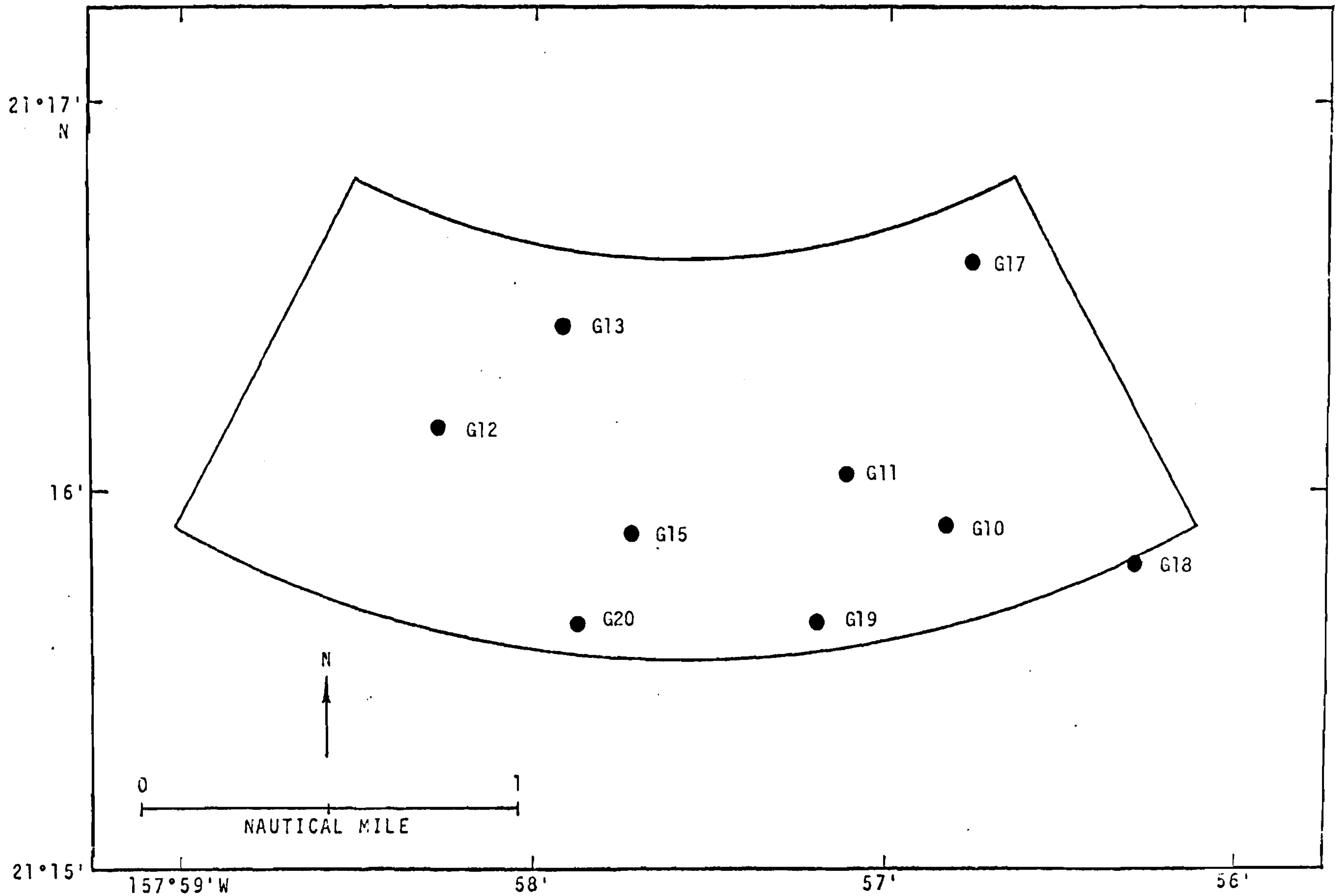
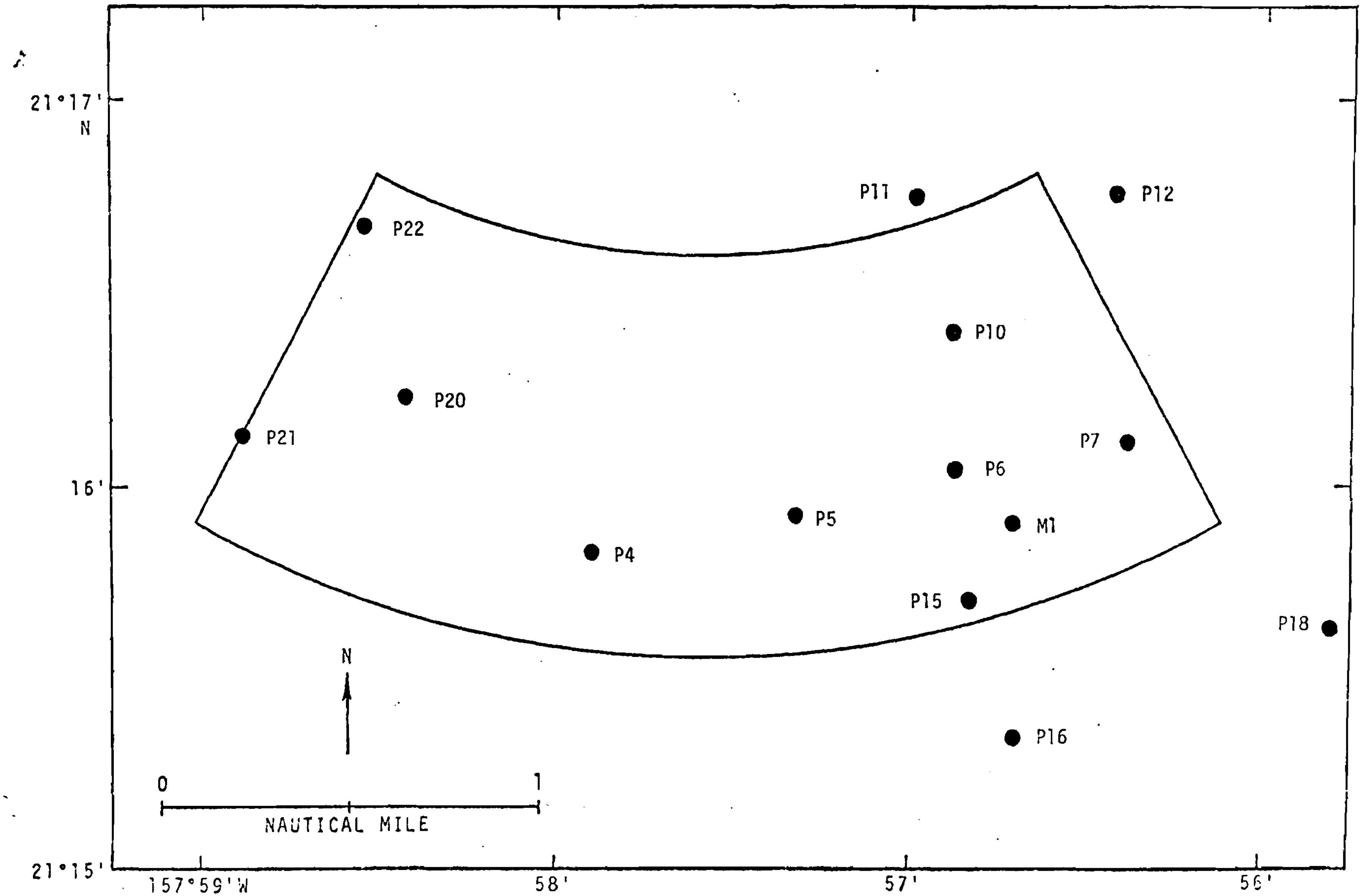


Figure IV-2. Location of Baseline Sediment Samples

Figure IV-3. Location of Sediment Samples, Present Study



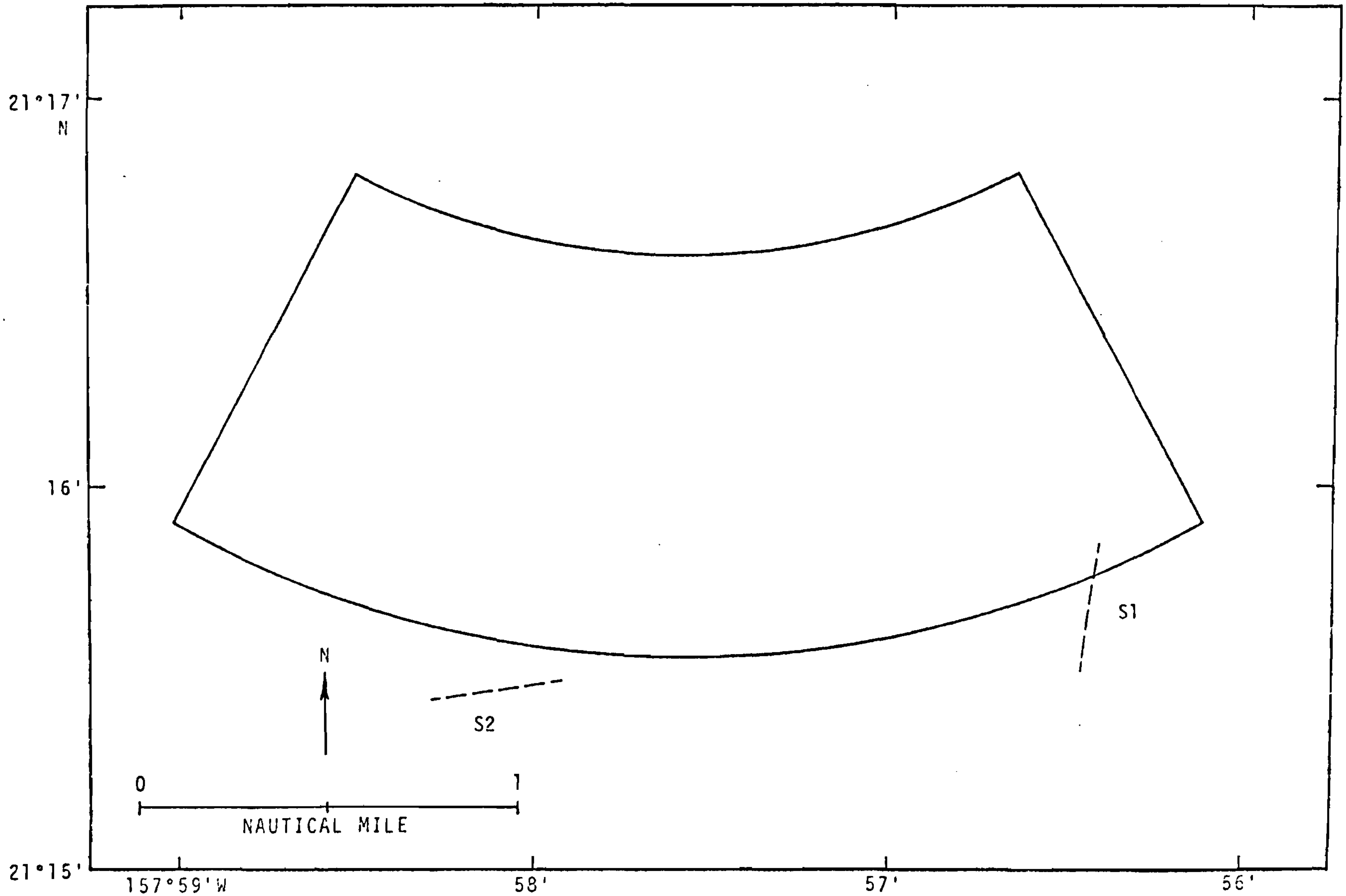


Figure IV-4. Shrimp Trapping Stations, July 15, 1977

b. Spoil Material from the Harding

Sediment samples for heavy metals were stored in plastic bags at 4° C. Pesticides samples were likewise refrigerated after being collected in glass jars.

c. Sediment Samples from the Disposal Site

Sediment samples from the disposal site were collected with a small, Peterson-type grab sampler, stored in plastic bags, and refrigerated at 4° C.

d. Shrimp Samples

Shrimp were collected in traps as described in "Section VII. Fisheries."

3. Methods of Analysis

a. Receiving Water Analysis

Chemical analysis of receiving water samples were performed as described in Standard Methods for the Examination of Water and Wastewater (APHA et al., 1971) and the Environmental Protection Agency's Manual of Methods for the Chemical Analysis of Water and Wastes (EPA, 1974). Analysis for heavy metals was completed on a Perkin-Elmer model 305A atomic absorption spectrophotometer following a preliminary chelation-extraction procedure developed by the United States Geological Survey (Brown et al., 1970).

The thermal structure of the water column was approximated from the temperature measurements made on board at the time of sample collection rather than in situ by means of expendable bathythermographs (XBTs). The resulting "temperature profiles" show the effects of the water samples being warmed after being brought to the surface (Figures IV-5, -6, and -7) when compared to a typical XBT for the month of May from approximately the same location off Pearl Harbor (Figure IV-8; Fleet Weather Central, Pearl Harbor, unpublished data). Nevertheless, the depth of the permanent thermocline from the surface was, as expected (Bathen, 1970), approximately 120 meters.

b. Spoil Material from the Harding

Sediment metals were determined by atomic absorption spectrophotometry following nitric acid-hydrogen peroxide digestion (Krishnamurty et al., 1976). Pesticides were extracted and analyzed on the Micro Tek model 220 gas chromatograph following procedures described by Thompson (1974) and Young et al. (1976). Results of both metals and pesticides analysis were expressed on a dry weight basis after determination of the sample solids content.

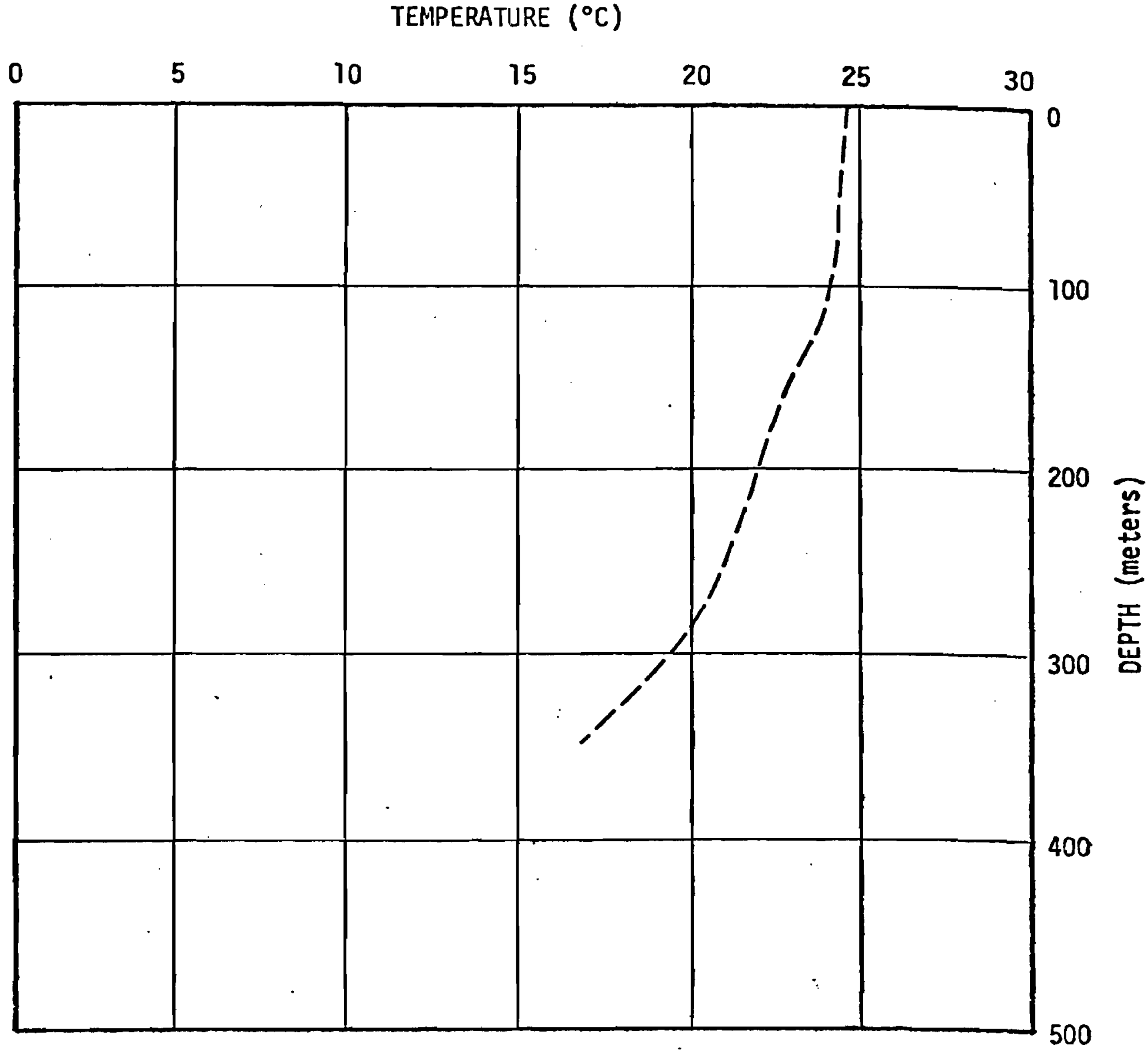


Figure IV-5. Temperature Profile (4/26-27)

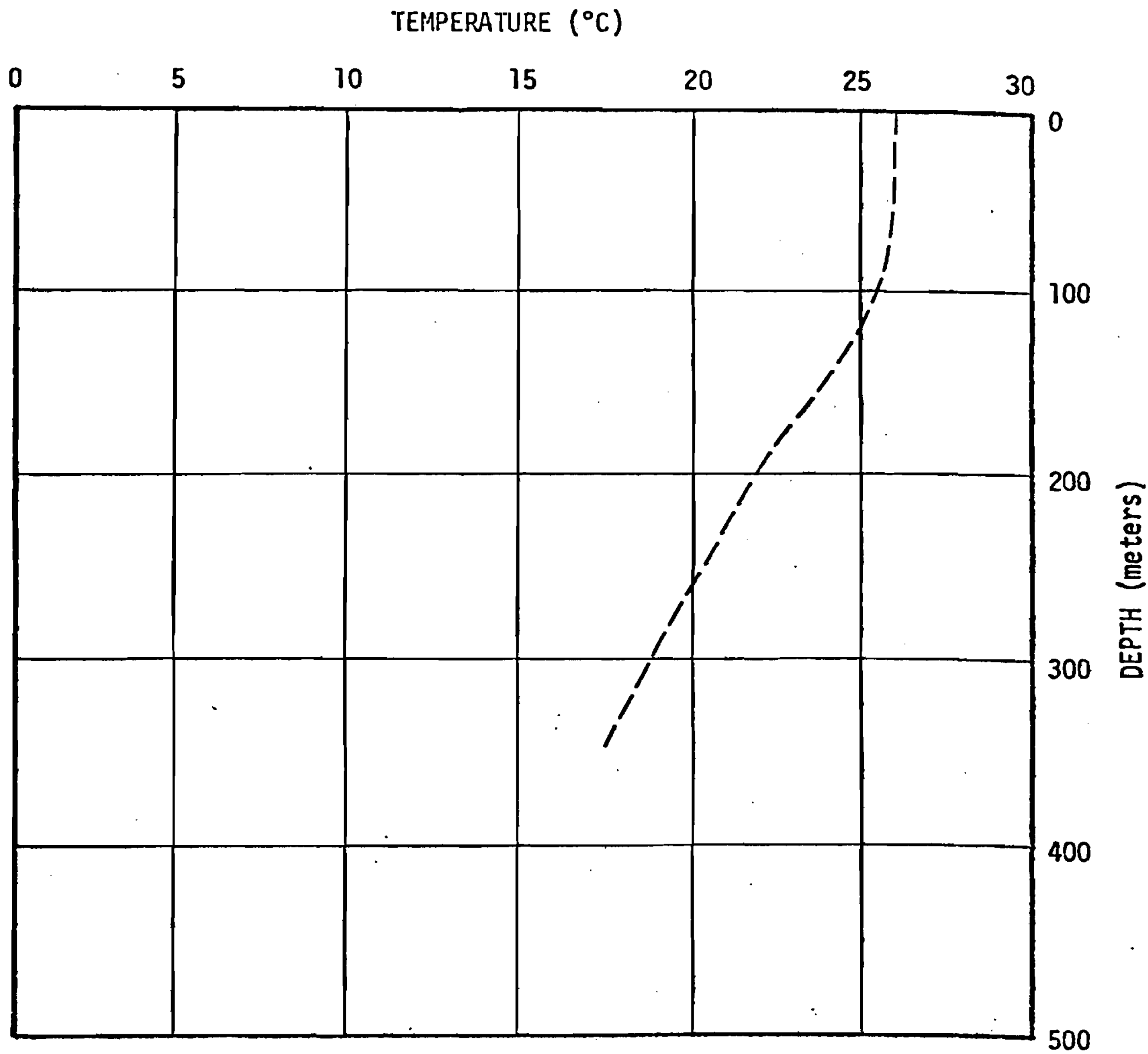


Figure IV-6. Temperature Profile (5/18)

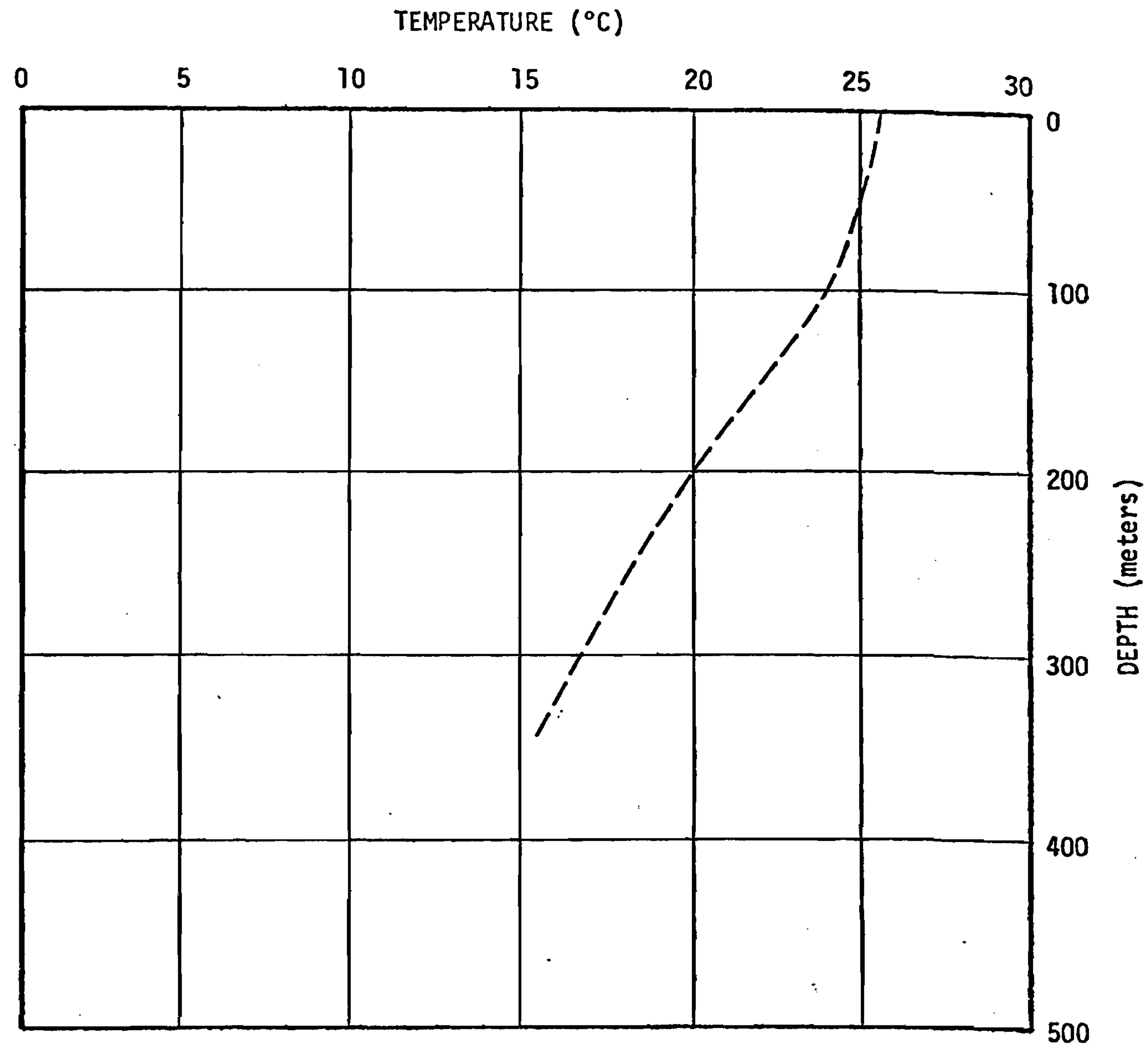


Figure IV-7. Temperature Profile (6/1)

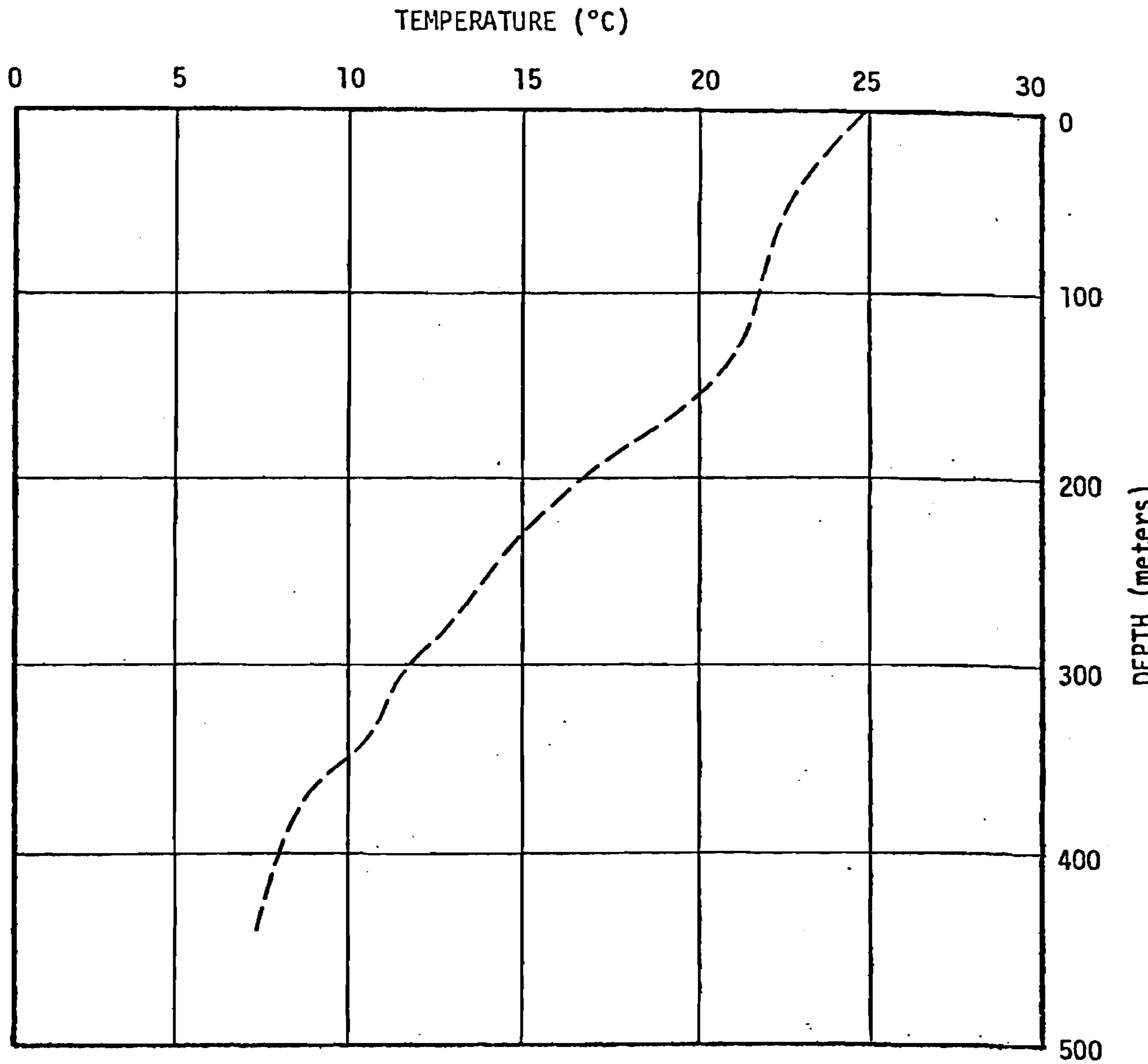


Figure IV-8. Temperature Profile, Navy XBT (5/13)

c. Sediment Analysis from the Disposal Site

Sediment metals from samples collected at the disposal site were determined using the same methods already described (Krishnamurty et al., 1976). However, since oven-dried sediment collected during the initial phase of this study were used to provide the baseline data for metals, analysis of mercury was omitted from these and subsequent samples. Mercury is a very volatile element and easily evaporated when heated. Therefore, mercury analysis of sediment samples collected during the present study from the Harding and from the disposal site was not performed due to the lack of a reliable set of baseline conditions.

d. Shrimp Samples

Shrimp collected from the study area were analyzed for heavy metals following the same preliminary acid digestion procedure as described for sediment samples (Krishnamurty et al., 1976). Analysis for mercury was omitted. The results for the remaining metals were expressed on a wet weight basis as mg of metal per kilogram of muscle tissue.

C. Results

1. Receiving Water Surveys

The results of field measurements are summarized in Table IV-1 (temperature salinity, dissolved oxygen, and pH). In all cases, results were averaged since there were no significant differences among stations (Part 1). For purposes of illustration, Station 2B in the plume was compared to the averages from the remaining stations observed during the general site survey (Table IV-1, Part 1). Except for slightly lower salinity measurements, differences between Station 2B and the other stations were not significant. It is difficult to say at this time whether the salinity difference observed was real (i.e. caused by dredge spoil disposa and not due to instrument error, user error, or "natural" variation in the distribution of salinity values. Nevertheless, the difference was only slight, from an environmental viewpoint, being only a few tenths of a part per thousand (or a few hundredths of a percent).

Data from laboratory analysis (suspended solids, turbidity, total Kjeldahl nitrogen, total phosphorus, and heavy metals) are presented in Tables IV-2 through IV-8.

Table IV-1. Average Temperature, Salinity, Dissolved Oxygen, and pH

PART 1 - GENERAL SITE SURVEY
A: Sta. 1, 2A, 3, and 4 Average
B: Sta. 2B Plume

Depth		T (°C)		S (°/₀₀)		D.O. (ml/l)		pH	
		A	B	A	B	A	B	A	B
0 m	0 fm	24.6	24.8	34.6	34.2	5.4	5.4	7.6	7.5
50	30	24.4	24.3	35.1	34.7	5.6	5.7	7.7	7.7
100	55	24.0	23.8	34.7	34.1	5.7	5.7	7.8	7.7
150	80	22.9	22.7	34.8	34.5	5.4	5.3	7.8	7.7
200	110	21.8	21.5	35.3	34.0	5.2	5.2	7.7	7.7
300	165	19.4		33.6		5.0		7.7	
350	190	16.6	17.4	34.8	32.4	4.6	4.4	7.6	7.6
400	200			34.4		4.4		7.6	

PART 2 - PLUME BEHAVIOR (Sta. 2B)

Depth		T (°C)	S (°/₀₀)	D.O. (ml/l)	pH
0 m	0 fm	26.1	34.6	5.4	7.8
50	30	26.0	35.0	5.4	7.9
100	55	25.5	34.5	5.4	7.9
150	80	24.0	35.0	5.1	7.8
200	110	21.8	34.2	5.0	7.8
350	190	17.4	33.5	4.7	7.6

PART 3 - FOLLOW-UP SURVEY (Sta. 1, 2A, and 3)

Depth		T (°C)	S (°/₀₀)	D.O. (Ml/l)	pH
0 m	0 fm	25.5	34.1		
50	30	25.0	34.2		
100	55	23.9	34.2		
150	80	21.7	34.5		
200	110	19.8	34.4		
350	190	15.1	32.8		

Table IV-2. Suspended Solids (mg/l)

PART 1 - GENERAL SITE SURVEY (Time after dump in hours and minutes)

Depth		Sta. 1	Sta. 2A	Sta. 2B (0:24)	Sta. 3	Sta. 4
0 m	0 fm	9.2	8.0	27.8	4.8	8.8
50	30	10.2	10.4	9.0	11.6	11.2
100	55	6.0	5.4	3.0	2.8	3.4
150	80	6.6	8.8	51.4	8.6	13.4
200	110	15.4	2.0	2.4	14.4	2.8
300	165					2.0
350	190	3.6		1.0	1.4	
400	220		3.6			

PART 2 - PLUME BEHAVIOR (Time After Dump in Hours & Minutes)

Depth		Sta. 2B (0:14)	Sta. 2B (0:55)	Sta. 2B (1:38)
0 m	0 fm	63.2	20.0	12.0
50	30	4.8	4.6	3.8
100	55	17.8	16.4	12.2
150	80	10.2	10.8	8.0
200	110	4.6	6.8	11.8
350	190	7.2	4.2	3.4

PART 3 - FOLLOW-UP SURVEY

Depth		Sta. 1	Sta. 2A	Sta. 3
0 m	0 fm	7.2	11.6	10.2
50	30	2.2	7.4	5.8
100	55	19.2	11.2	7.2
150	80	11.0	4.6	6.0
200	110	18.6	7.0	2.6
350	190	6.6	5.8	6.2

Table IV-3. Turbidity (NTU)

PART 1 - GENERAL SITE SURVEY

Depth		Sta. 1	Sta. 2A	Sta. 2B (0:24)	Sta. 3	Sta. 4
0 m	0 fm	0.31	0.47	10.00	0.28	0.25
50	30	0.22	0.33	0.15	0.10	0.24
100	55	0.16	0.26	0.53	0.13	0.42
150	80	0.15	0.11	23.00	0.23	0.87
200	110	0.28	0.80	0.22	0.15	0.32
300	165					0.33
350	190	0.56		0.40	0.27	
400	220		0.34			

PART 2 - PLUME BEHAVIOR (Time After Dump in Hours & Minutes)

Depth		Sta. 2B (0:14)	Sta. 2B (0:55)	Sta. 2B (1:38)
0 m	0 fm	34.00	4.00	1.80
50	30	0.33	0.20	0.17
100	55	0.58	0.18	0.13
150	80	1.50	1.70	1.50
200	110	1.30	1.10	0.66
350	190	0.72	0.65	0.90

PART 3 - FOLLOW-UP SURVEY

Depth		Sta. 1	Sta. 2A	Sta. 3
0 m	0 fm	0.21	0.26	0.16
50	30	0.22	0.23	0.15
100	55	0.18	0.12	0.13
150	80	0.14	0.13	0.14
200	110	0.12	0.19	0.18
350	190	0.18	0.17	0.13

Table IV-4. Total Kjeldahl Nitrogen (mg/l)

PART 1 - GENERAL SITE SURVEY (Time affer dump in hours and minutes)

Depth		Sta. 1	Sta. 2A	Sta. 2B (0:24)	Sta. 3	Sta. 4
0 m	0 fm	0.08	0.17	0.13	0.18	0.14
50	30	0.12	0.16	0.09	0.14	0.16
100	55	0.13	0.08	0.13	0.11	0.12
150	80	0.15	0.12	0.18	0.13	0.08
200	110	0.08	0.12	0.07	0.14	0.11
300	165					0.08
350	190	0.04		0.06	0.12	
400	220		0.11			

PART 2 - PLUME BEHAVIOR (Time After Dump in Hours & Minutes)

Depth		Sta. 2B (0:14)	Sta. 2B (0:55)	Sta. 2B (1:38)
0 m	0 fm	0.38	0.24	0.15
50	30	0.14	0.14	0.12
100	55	0.13	0.16	0.10
150	80	0.16	0.15	0.12
200	110	0.11	0.09	0.09
350	190	0.12	0.08	0.08

PART 3 - FOLLOW-UP SURVEY

Depth		Sta. 1	Sta. 2A	Sta. 3
0 m	0 fm	0.09	0.05	0.06
50	30	0.04	0.08	0.10
100	55	0.06	0.06	0.13
150	80	0.08	0.08	0.08
200	110	0.09	0.05	0.03
350	190	0.09	0.04	0.05

Table IV-5. Total Phosphorus (mg/l)

PART 1 - GENERAL SITE SURVEY (Time after dump in hours and minutes)

Depth		Sta. 1	Sta. 2A	Sta. 2B (0:24)	Sta. 3	Sta. 4
0 m	0 fm	0.008	0.013	0.019	0.014	0.009
50	30	0.008	0.009	0.008	0.010	0.007
100	55	0.006	0.009	0.008	0.009	0.009
150	80	0.007	0.008	0.034	0.012	0.008
200	110	0.009	0.009	0.010	0.011	0.009
300	165					0.017
350	190	0.027		0.025	0.021	
400	220		0.016			

PART 2 - PLUME BEHAVIOR (Time After Dump in Hours & Minutes)

Depth		Sta. 2B (0:14)	Sta. 2B (0:55)	Sta. 2B (1:38)
0 m	0 fm	.060	.003	.010
50	30	.009	.008	.008
100	55	.006	.006	.007
150	80	.010	.008	.009
200	110	.011	.011	.011
350	190	.027	.027	.038

PART 3 - FOLLOW-UP SURVEY

Depth		Sta. 1	Sta. 2A	Sta. 3
0 m	0 fm	.005	.007	.006
50	30	.006	.006	.007
100	55	.004	.005	.005
150	80	.005	.005	.006
200	110	.009	.009	.009
350	190	.031	.031	.025

Table IV-6. Receiving Water Heavy Metals, General Site Survey (μg/l)

Station-Depth		Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn
1- 0 m	0 fm	<1.	ND	ND	4.	0.5	ND	<2.	19.
50	30	ND	ND	ND	1.	0.3	<2.	ND	4.
100	55	ND	ND	ND	3.	<0.2	<2.	ND	3.
150	80	ND	ND	ND	<1.	0.6	<2.	ND	1.
200	110	ND	ND	ND	ND	6.5	ND	ND	3.
300	165								
350	190	<1.	ND	ND	ND	0.7	<2.	ND	1.
400	220								
2A- 0 m	0 fm	ND	5.	ND	4.	<0.2	2.	3.	97.
50	30	ND	<1.	ND	1.	0.9	<2.	ND	8.
100	55	ND	0.	ND	ND	ND	<2.	ND	4.
150	80	ND	0.	ND	1.	0.4	2.	ND	3.
200	110	ND	<1.	ND	3.	19.2	<2.	<2.	15.
300	165								
350	190								
400	220	ND	ND	ND	ND	0.7	<2.	ND	8.
3- 0 m	0 fm	ND	<1.	ND	3.	ND	ND	<2.	17.
50	30	ND	<1.	ND	<1.	6.8	ND	ND	5.
100	55	ND	ND	ND	2.	0.6	<2.	ND	4.
150	80	ND	ND	ND	ND	<0.2	ND	ND	4.
200	110	ND	ND	ND	ND	0.8	ND	ND	3.
300	165								
350	190	ND	ND	ND	ND	<0.2	ND	ND	1.
400	220								
lower reportable limits		1.	1.	1.	1.	0.2	2.	2.	1.

ND = not detectable

Table IV-7. Receiving Water Heavy Metals, Plume Behavior (μg/l)

Station (Time after dump) - Depth			Ag	Cd	Cr	Cu	Hg	Ni	Pb	Zn
2B(0:14)	0 m	0 fm	1.	3.	ND	20.	ND	4.	14.	48.
	50	30	<1.	<1.	ND	4.	ND	ND	<2.	5.
	100	55	ND	ND	ND	3.	8.4	ND	<2.	4.
	150	80	ND	ND	ND	ND	<0.2	<2.	<2.	3.
	200	110	ND	ND	ND	ND	<0.2	ND	<2.	3.
	350	190	ND	ND	ND	ND	ND	<2.	<2.	1.
2B(0:55)	0 m	0 fm	ND	1.	ND	9.	ND	<2.	3.	71.
	50	30	ND	<1.	ND	2.	ND	ND	ND	7.
	100	55	ND	ND	ND	1.	<0.2	ND	ND	5.
	150	80	ND	ND	ND	ND	ND	ND	ND	3.
	200	110	ND	ND	ND	ND	0.4	ND	ND	1.
	350	190	ND	ND	ND	ND	0.6	ND	ND	3.
2B(1:38)	0 m	0 fm	ND	2.	ND	8.	ND	<2.	3.	44.
	50	30	ND	ND	ND	ND	ND	ND	ND	4.
	100	55	ND	ND	ND	1.	0.4	ND	ND	4.
	150	80	ND	ND	ND	ND	<0.2	ND	ND	3.
	200	110	ND	ND	ND	ND	0.4	ND	ND	1.
	350	190	ND	ND	ND	ND	0.5	ND	ND	3.
lower reportable limits			1.	1.	1.	1.	0.2	2.	2.	1.

ND = not detectable

Table IV-8. Receiving Water Heavy Metals, Follow-up Survey (μg/l)

Station	Depth (m)	Depth (fm)	Ag	Cd	Cr	Cu	Hg	Hi	Pb	Zn
1	0 m	0 fm	ND	ND	ND	4.	<0.2	2.	ND	8.
	50	30	ND	ND	ND	1.	<0.2	ND	ND	5.
	100	55	ND	ND	ND	ND	0.3	ND	ND	ND
	150	80	ND	ND	ND	ND	3.6	ND	ND	ND
	200	110	ND	ND	ND	ND	0.4	ND	ND	ND
	350	190	ND	ND	ND	ND	<0.2	ND	ND	ND
2A	0 m	0 fm	ND	15.	ND	16.	<0.2	5.	ND	63.
	50	30	ND	ND	ND	ND	<0.2	2.	ND	ND
	100	55	ND	ND	ND	1.	<0.2	ND	ND	ND
	150	80	ND	ND	ND	ND	0.3	ND	ND	3.
	200	110	ND	ND	ND	1.	<0.2	ND	ND	ND
	350	190	ND	ND	ND	1.	0.4	ND	ND	14.
3	0 m	0 fm	ND	ND	ND	2.	ND	2.	ND	4.
	50	30	ND	ND	ND	ND	0.3	ND	ND	2.
	100	55	ND	ND	ND	1.	ND	ND	ND	ND
	150	80	ND	ND	ND	1.	1.1	ND	ND	ND
	200	110	ND	ND	ND	ND	<0.2	ND	ND	ND
	350	190	ND	ND	ND	ND	1.5	ND	ND	ND
lower reportable limits			1.	1.	1.	1.	0.2	2.	2.	1.

ND = not detectable

Analysis for total organic carbon (TOC) was omitted from the present phase of investigations. Samples preserved with HCl and refrigerated at 4° C have been stored far too long beyond the 24-hour, EPA recommended holding time (EPA, 1974) while awaiting repair of the Dohrmann Envirotech Carbon Analyzer (model DC 50). If TOC analysis were to be performed on these samples at this late date, the data generated would be suspect because the holding times were exceeded. Furthermore, preliminary examination of the total Kjeldahl nitrogen (ammonia plus organic-N) and total phosphorus (inorganic plus organic-P) data suggested that the input of organic carbon and resulting oxygen demand from dredge spoil disposal is probably negligible.

2. Characterization of Spoil Material from the Harding

Results of laboratory analysis for metals and pesticides are presented in Tables IV-9 and IV-10. Total metals (Ag+Cd+Cr+Cu+Ni+Pb+Zn) are also calculated for preliminary comparison with disposal site sediments. Average solids content for spoil samples as received was 67%.

3. Disposal Site Sediments

Total metals content (Ag+Cd+Cr+Cu+Ni+Pb+Zn) for baseline sediment samples collected in September 1976 and sediment samples collected during the present phase of investigations are shown in Figures IV-9 and IV-10 respectively.

4. Heavy Metal Body Burdens of Shrimp

The average metal content of four individual specimens from each station are presented in Table IV-11.

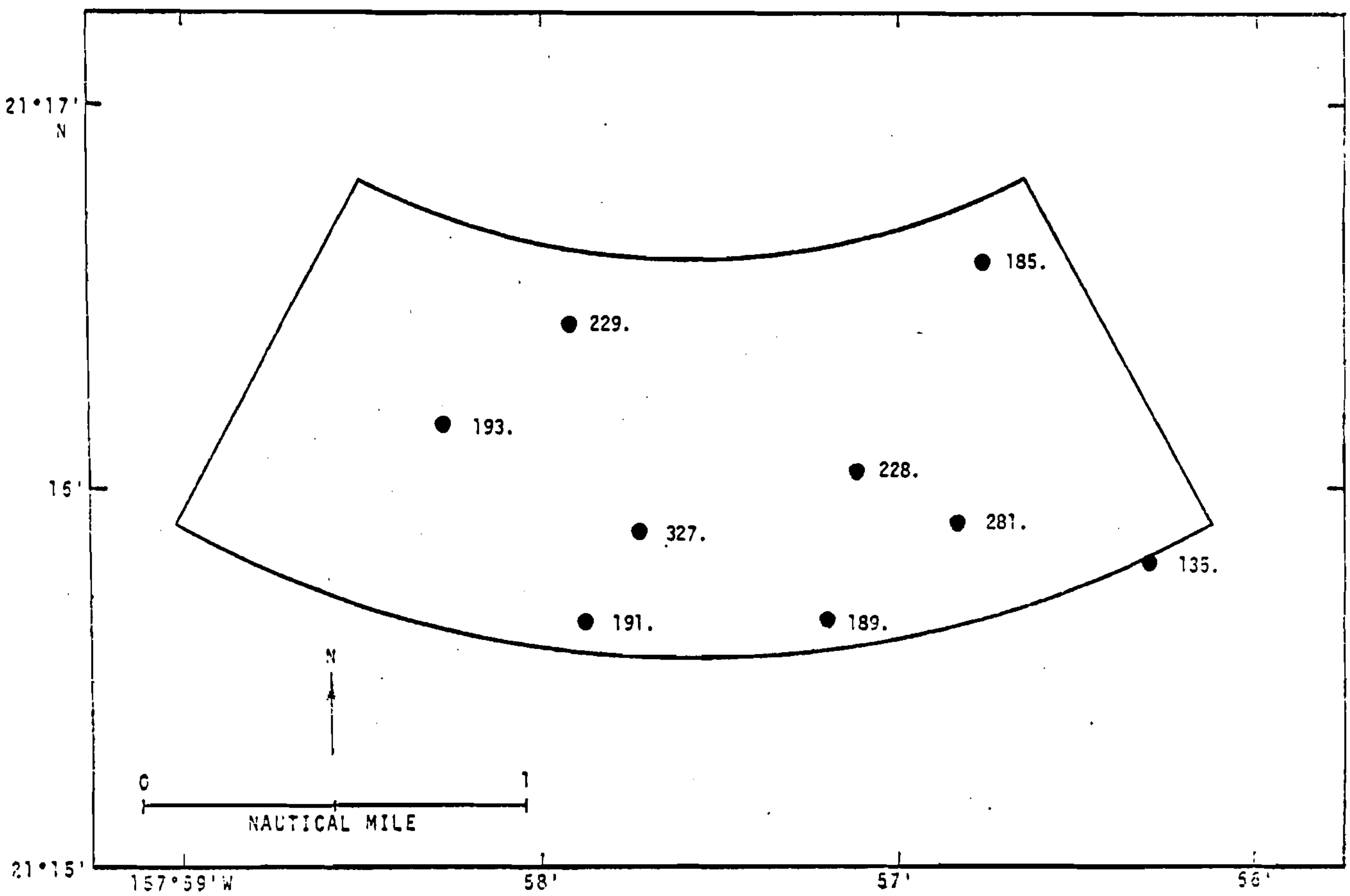


Figure IV-9. Total Metals in Bottom Sediments, Baseline Survey (mg/kg)

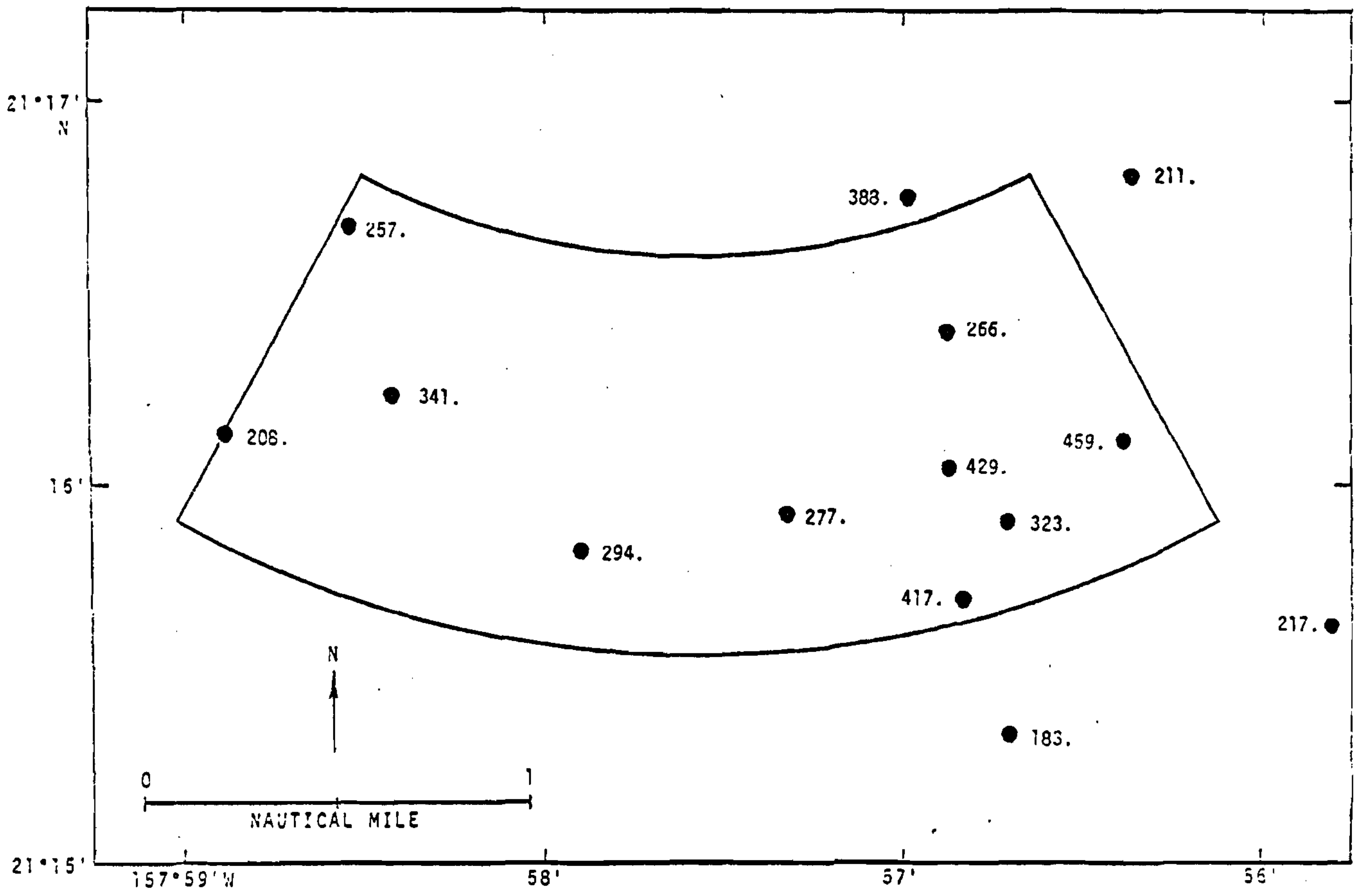


Figure IV-10. Total Metals in Bottom Sediments, Present Study (mg/kg)

Table IV-11. Heavy Metals,
Shrimp (*Heterocarpus ensifer*) Collected on July 15, 1977
(mg/kg wet weight)

Station	Ag	Cd	Cr	Cu	Ni	Pb	Zn	Total
S1 (dump site)	ND	ND	ND	12.	ND	ND	12.	24.
S2 (control)	ND	ND	ND	19.	ND	ND	12.	31.

D. Discussion

1. Receiving Water Surveys

a. Part 1: General Site Survey

The vertical distribution of temperature, salinity, dissolved oxygen, and pH apparently were not affected to any great extent by dredge spoil disposal (Table IV-1). As was described earlier, the horizontal distribution of these four parameters appeared to be fairly uniform.

Suspended solids and turbidity were high in samples taken in the surface plume as expected (Tables IV-2 and -3). However, suspended solids and turbidity at Station 2B (plume) also showed a very pronounced maximum at 150 meters. All other stations also exhibited a maximum for both these parameters at either 150 or 200 meters, with the former depth being more prevalent. But the subsurface maximum values recorded at other stations were not nearly as great as that recorded in the plume.

Total phosphorus (TP) showed a similar surface distribution, with a noticeably higher concentration in the plume (Table IV-5). The concentration of total Kjeldahl nitrogen (TKN), on the other hand, was lower in the surface sample at Station 2B than at several of the other surface stations. Moreover, both TKN and TP exhibited only little indication of a subsurface maximum except of course at Station 2B at a depth of 150 meters.

Samples from Station 2B (plume) were not analyzed for heavy metals. However, data from Station 2A (disposal site with no visible plume present) revealed generally higher metal concentrations than was found at Stations 1 and 3 (Table IV-6). A subsurface maximum for zinc (15 ug/l) was apparent at 200 meters below the surface.

The evidence clearly suggests that material was accumulating just below the top of the thermocline (150-200 meters depth) throughout the study area, but particularly at the disposal site. This phenomenon (i.e. the accumulation of suspended material at the pycnocline) was also apparent, but to a somewhat lesser extent, for data collected during the baseline study (Char and Chave, 1977). However, since only one hydrocast was done in the plume in Part 1 investigations, it still might be argued that the high suspended solids and turbidity observed was merely material in the process of "falling" to the bottom at a near constant rate (approximately 150 meters/24 minutes or 1.0 cm/second). Therefore, monitoring of a single plume with a series of three successive hydrocasts was attempted in Part 2.

b. Part 2: Plume Settling Behavior

Three successive hydrocasts following a single plume was accomplished on May 18, 1977. The first cast was completed 14 minutes after the Harding had dumped a full load (approximately 2700 cubic yards) of Pearl Harbor dredge spoil at the designated dump site (Station 2B). The next two casts followed about 40 minutes apart.

As expected, suspended solids and turbidity (Tables IV-2 and -3) showed a surface maximum (probably due to the material being kept in suspension by surface turbulence) which decreased steadily with time. A subsurface maximum was observed throughout all three hydrocasts at approximately 150 meters (for turbidity, and 100 meters for suspended solids). The reason for this slight discrepancy between suspended solids data and turbidity measurements is unclear, but filters used for suspended solids determinations showed a definite accumulation of fine, silty material at 150 meters, with lesser material also being found at greater depths. Moreover, the silt collected on the filters (from visual estimates) seemed to be dispersing with time (Figure IV-11).

The same trend can be seen in the nutrient data (Tables IV-4 and -5). Generally maximum concentrations observed at the surface decreased with time, while subsurface accumulations were less distinct.

Metals data (Table IV-7) in the surface plume showed rather high concentration over expected ambient levels. However, this is no doubt due to the suspended sediment-associated metals with little being in dissolved form. Concentrations either remained approximately constant (for metals found in low concentrations) or showed a decreasing trend (for metals found in relatively higher concentrations) with time. Similar to the nutrient data, a subsurface maximum for metals was more difficult to detect.

In conclusion, however, it appeared that at least a small fraction of the fine silt component of dredge spoil was accumulating at about 150 meters as it encountered the denser waters of the pycnocline. This accumulation seemed to persist for a long enough period of time to enable some deposition of fine

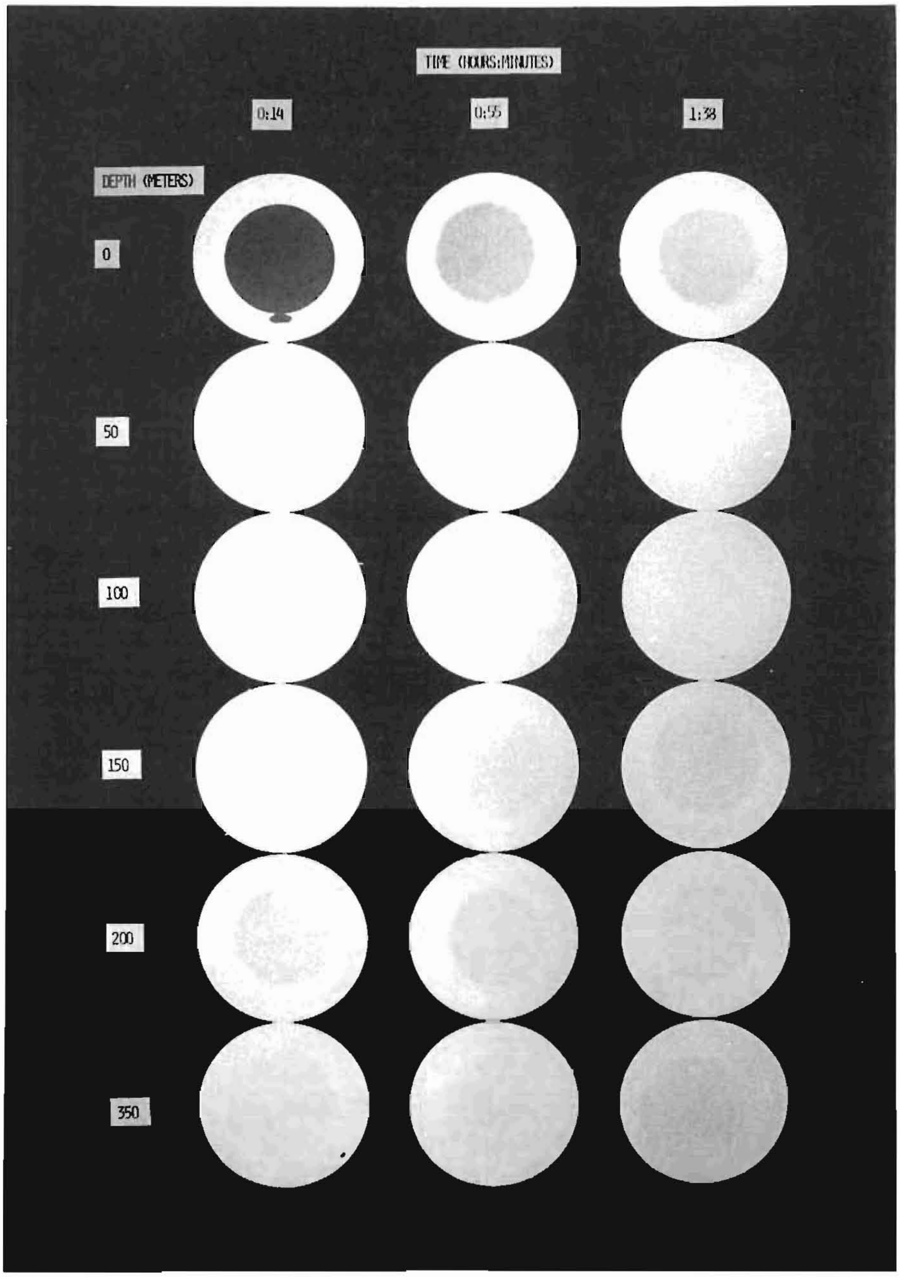


Figure IV-11. Suspended Solids
During Plume Settling Behavior Survey
(Part 2, Station 2B).

material over a wide geographic area. The fact that larger, sand-sized material was not collected seemed to suggest that the bulk of the sediment sank very rapidly to the bottom.

c. Part 3: Follow-up Site Survey

A receiving water quality survey immediately after dumping had ceased on June 1 revealed a slight accumulation of suspended solids at Stations 2A and 3 (100 meters depth). Further west, a more pronounced subsurface maximum was observed at Station 1 (Table IV-2). Turbidity and nutrient data were generally inconclusive.

Concentrations of receiving water metals (Table IV-8) were still relatively high at Station 2A (dump site). This apparently was the result of disposal operations concluded only the day before, although no trace of spoil material was visible in surface waters.

d. General Observations Regarding Water Quality

It is difficult to compare results from this phase of the Pearl Harbor dredge spoil disposal investigation with results obtained in the earlier baseline study (Char and Chave, 1977). The present surveys were conducted in late spring-early summer while baseline data were collected in September. A deeper mixed layer depth in April-May may be partly responsible for the relatively higher total Kjeldahl nitrogen and total phosphorus values observed at this time. The higher total phosphorus concentrations associated with deeper waters at the site have already been described (Char and Chave, 1977) and may be the result of nutrient depletion in surface waters by phytoplankton uptake or the resuspension of bottom sediments into the water column. Also the diversion of the City and County of Honolulu's Sand Island Sewage Treatment Plant effluent to a new deep ocean outfall (ca. December 1976) may have altered baseline conditions by adding more suspended material and nutrients to waters near the study area. All these factors make it difficult to determine the absolute impact of dredge spoil disposal using baseline water quality data collected seven months ago.

Generally speaking, however, it appears that water quality changes are confined to an area associated within the plume itself. Locally high surface values for suspended solids, turbidity, nutrients, and metals seemed to dissipate rapidly over the short time period observed in this study (approximately 2 hours). Moreover, the higher than expected metal concentrations were probably due to sediment-associated rather than dissolved metals. A subsurface maximum for suspended solids and turbidity at about 150 meters depth was less distinct for the other parameters measured. Nevertheless, this may still mean the distribution of a small fraction of fine spoil material over a wide geographic area.

2. Characterization of Spoil Material from the Harding

Both metals (Table IV-9) and pesticides (Table IV-10) concentrations from the hopper dredge Harding were surprisingly low (with the exception of the pesticide lindane) when compared to other locations in Hawaii (Lau, 1973; Lau et al., 1976). However, this is apparently characteristic of the area of Pearl Harbor being dredged (Ford Island Channel, NE). Metals concentrations in the South Channel of Pearl Harbor, at one time receiving substantial amounts of industrial waste effluents, are in comparison much higher (Youngberg, 1973). It was from a location in this latter area (corresponding to Youngberg's (1973) sample "ES06") that sediment for the elutriate test (Char and Chave, 1977) was collected and on which basis sediment tracing at the disposal site using heavy metal burdens was proposed.

3. Disposal Site Sediments

Baseline metal concentrations for disposal site sediments (Figure IV-9) were comparable to concentrations observed in another study near this location (Neighbor Island Consultants, 1976). Metal concentrations near the completion of disposal operations showed a significant increase (t test, $p < 0.5$) only in the immediate vicinity of the dump site (M1, P6, P7, and P15 average concentration 407 mg/kg), within a radius of approximately 0.5 mile (Figure IV-10). The somewhat scattered distribution about the dump site may be due in part to both movement of the deposited spoil material by moderate bottom currents or inaccuracies in the Harding's navigations.

No significant difference (t test, $p > 0.05$) was observed between the averages for stations outside the immediate dump site area in the present study (264 mg/kg) and all samples collected during baseline studies (218 mg/kg). That no spoil was found at any of the other locations examined, based on the chemical evidence, may have been due to a number of reasons. The grab sampler used in the study may have "smeared" whatever surface accumulation of spoil that was originally present at a station. Also, the sediment was not as strongly labeled with metals as was first anticipated. Therefore, any real increase in disposal site sediment metals was more difficult to detect.

The evidence presented seemed to suggest that most of the spoil was deposited within a short distance of the dump site. Large-scale transport of spoil material out of the immediate area did not appear to be occurring during disposal operations. However, this does not preclude the possibility of spoil dispersal at some later date.

4. Heavy Metal Body Burdens of Shrimp

The heavy metal body burdens of shrimp (Heterocarpus ensifer) collected from the study area are presented in Table IV-11. With the exception of copper and zinc, all other metals were below the analytical limits of detectability. Furthermore, copper and zinc values were generally lower than those reported for crustacea (crabs) collected from Pearl Harbor (Evans et al., 1972). Both copper and zinc are believed to have one or more catalytic (enzymatic) functions, and in fact the relatively high Cu-burdens observed in shrimp are expected since crustacea accumulate this element as an essential component of their blood protein (hemocyanin; Bowen, 1966).

E. Summary

1. Below the surface plume, as predicted in the baseline study (Char and Chave, 1977), a small as yet undetermined amount of fine spoil material was observed to be accumulating near the top of the pycnocline.

2. Higher nutrient concentrations (TKN and TP) appeared to be locally restricted to the surface plume and dissipated with time.

3. Surface metals concentrations were higher than those expected from the elutriate tests (Char and Chave, 1977), but this may have been due to sediment-associated rather than dissolved metals. As with the nutrients, higher metal concentrations seem to be restricted to the surface plume and were dissipated with time.

4. Water quality generally improved to pre-disposal conditions shortly (approximately 24 hours) after disposal operations had ended. The only notable exception appeared to be sediment-associated heavy metals concentrations in surface samples, although no trace of spoil material was visible.

5. Suspended solids and turbidity were the most useful parameters for tracing the movement of the plume, both horizontally and vertically.

6. As reflected by the heavy metals distribution, the majority of dredge spoil was apparently being deposited in the general vicinity of the disposal site (within a 0.5 mile radius) during disposal operations.

7. Spoil material from the Harding was low in metals and pesticides (with the exception of lindane). As a result, attempts to trace the movement of spoil material on the bottom were difficult using the spoil metals burden as a label.

8. Shrimp were collected from the study area 45 days after disposal operations had ceased. There was no appreciable difference in heavy metal bodv burdens in shrimp collected from the disposal site and a site approximatelv 2 miles to the west.

F. Acknowledgements

Laboratory space was furnished for this project by Dr. Reginald H.F. Young, Assistant Director of the Water Resources Research Center, University of Hawaii. Technical assistance in the pesticides analysis was provided by John Demetriou and the laboratory staff at WRRC. Captain Bill Austin and crew of the R/V Machias aided in the collection of water and sediment samples at the disposal site. Lt. Cdr. John Carlmark, Fleet Weather Central, Pearl Harbor, was instrumental in obtaining temperature profiles from the vicinity of the study site. In addition, Captain Harkness and crew of the Corps of Engineers hopper dredge Chester Harding aided in the collection of dredge spoil material. We gratefully acknowledge the efforts, generosity, and patience of these and others who have made this study possible.

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V. ZOOPLANKTON

by
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A. Objectives

1. Comparison of abundance and diversity of the zooplankton community with baseline values.
2. Determination of effects of suspended particulate matter on feeding and respiration of zooplankton.

B. Methods and Procedures

Zooplankton tows were taken on the night of 18-19 May 1977, from R/V Machias. A 1-m diameter conical plankton net with 333μ mesh (erroneously reported as 303μ in the Part A report) was used for a series of 10 oblique tows from the surface to about 150 fm, each lasting about 25 min (Table V-1). A flowmeter in the mouth of the net recorded the volume of water filtered. During the sampling period, the Harding had shifted from its usual dump site to a temporary site 0.5 nm closer to shore (21°16.5'N; 157°56.9'W). Four tows (including one abortive tow sampling to only 60 fm) were taken at the usual dump site, two tows were taken at the temporary site, and four control tows were taken in the southwest corner of the disposal area (Figure V-1).

Zooplankton samples were preserved in 5 per cent formalin, and aliquots from each sample were sorted into major taxa and counted. The raw counts were converted into numbers per square meter of sea surface as in the Part A report.

All adult euphausiids were sorted from the whole samples and were examined for evidence of gill clogging by suspended sediment. Two species, *Euphausia tenera* and *E. recurva*, were selected as abundant and easily identifiable. Individuals of these species were cleared in concentrated potassium hydroxide and their stomach contents were examined under a compound microscope. Specimens were taken from a control tow (no. 2), a tow at the usual dump site (no. 5), and a tow at the temporary site (no. 9), and were compared with specimens from a Part A tow (no. 1). Thirty specimens of *Euphausia recurva* were examined, and 28 of *E. tenera*.

Table V-1. Zooplankton tows, 18-19 May 1977

1 m plankton net, 333μ mesh

Tow no.	Time	Duration (min)	Maximum depth (fm)	Volume filtered (m^3)
1	2238-2251	13	60	431
2	2301-(2325)*	(24)*	150	988
3	2355-(0020)	(25)	185	765
4	0030-0057	27	165	791
5	0123-0147	24	135	867
6	0222-0248	26	170	673
7	0303-0328	25	150	771
8	0335-0400	25	155	710
9	0409-0433	24	175	587
10	0443-0509	26	125	851

(*) estimated times

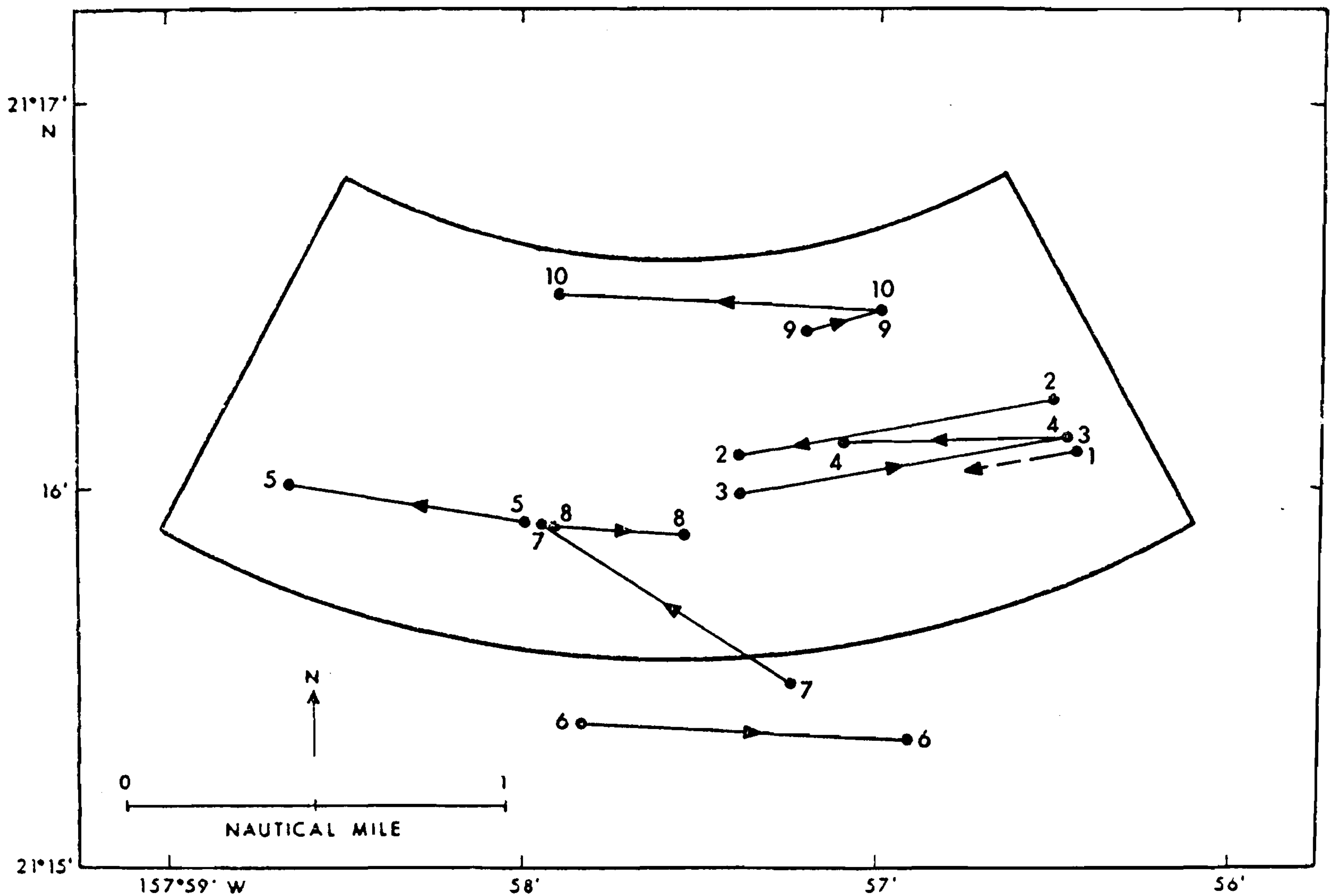

Figure V-1. Zooplankton tows, May 18-19, 1977.

C. Results

1. Non-living suspended matter

The sampling program was designed to compare the zooplankton from a relatively unaffected control area with an area of active spoil disposal and an area in the early stages of recovery from disposal (two days). It was expected that some suspended sediment from the dumping might be collected by the plankton net in the immediate vicinity of the temporary dump site but not elsewhere, as the settling rate of a sediment particle large enough to be retained by the plankton net should be high enough to remove it from the water column in a matter of a few hours (Sverdrup et al., 1942). No particulate matter resembling dredge spoil was found in the samples from the temporary dump site. However, fecal pellets of the type used by E. H. Chave as a tracer of dredge spoil in bottom sediments were taken in large quantities (∿5000 per m^2 of sea surface) in the three deep tows (nos. 2, 3, and 4) at the usual dump site, but in none of the other tows. Since the shallow tow did not take any fecal pellets, they must have been suspended at depths below 60 fm. Although they appeared to have a much higher specific gravity than the rest of the plankton sample, it is possible that gas bubbles produced by bacterial decomposition could have kept them in suspension. Alternatively, strong bottom currents could have resuspended the fecal pellets. Neither hypothesis is completely satisfactory; the first fails to explain why no fecal pellets were taken at the temporary dump site, while the second fails to explain why other kinds of particles of the same size (∿1 mm diameter) were not found along with the fecal pellets.

A far more abundant kind of suspended matter was a brown, fibrous or membranaceous material found in all samples except the first shallow tow. This material occurred in such large volumes that sorting the zooplankton samples was extremely difficult and obtaining accurate dry weights was impossible. Along with the brown material were smaller quantities of a whitish, friable material usually floating on the surface of the samples. M. Chun of the University of Hawaii's Water Resources Research Institute identified the brown material as fecal matter and the white material as detergent residues, both common components of sewage. The most likely source of sewage in such quantities is the Sand Island sewage outfall, which discharges about 2.4 nm northeast of the dump site at depths of

220 to 240 ft (38 to 40 fm). Again, the absence of sewage in the first tow implies that this material is found below 60 fm.

A variety of larger pieces of debris, such as twigs, bagasse, pieces of plastic, and cigarette butts were found in some of the samples. The surface waters throughout the disposal area as observed from R/V Machias contained large amounts of debris, particularly in the region sampled by tow no. 5, forcing the other control tows to be taken closer to the dump site than first planned.

2. Zooplankton

The composition of the zooplankton community sampled by the plankton tows is presented as numbers per square meter of sea surface in Table V-2 and as percentages of the whole sample in Table V-3. Copepods were the dominant zooplankton group, comprising about 50-60 per cent of the community. Ostracods and larvaceans both made up about 10-20 per cent of the community. Most of the remainder were euphausiids and chaetognaths, both about 5-10 per cent of the community. The Other Crustacea category consisted mostly of larval crabs, and the Other Jelly was mostly salps.

Table V-4 compares the results of the current sampling with baseline results from Part A. The most noticeable difference is the significantly higher concentration of organisms in the samples taken during dumping than in the baseline samples (t test, $p<0.05$). Part of the difference may be due to the greater maximum depths sampled by the Part B tows (the five night tows of Part A had an average maximum depth of 64 fm). However, the abortive first tow, which sampled to only 60 fm, yielded numbers more similar to the other Part B tows (except for copepods) than to the Part A tows, which it more closely resembled in duration and maximum depth. It thus appears that zooplankton were more abundant in the disposal area during dumping than during the baseline study.

The composition of the zooplankton community also changed. Copepods, which composed about 80 per cent of the Part A samples, made up only about 55 per cent of the Part B samples. Euphausiids and ostracods were relatively more abundant in the Part B samples. The most striking increase, however, was in the number of larvaceans, whose concentration increased by two orders of magnitude. Larvaceans were conspicuous in the surface waters as viewed from the ship, in numbers possibly as high as 100 per m^3. Although

Table V-2. Zooplankton composition, numbers per m^2 of sea surface

Tow no.	1	2	3	4	5	6	7	8	9	10
Crustacea										
Copepods	6040	10,100	12,400	10,700	10,900	29,800	10,900	12,800	13,800	8160
Ostracods	1100	2660	3690	1210	1890	3910	2020	1830	5320	2200
Amphipods	245	306	284	243	46	590	56	126	262	259
Euphausiids	801	1150	933	1110	959	1990	1060	875	2200	2680
Other[1]	286	175	355	61	230	1030	672	315	436	86
Molluscs	286	131	355	364	276	885	336	126	349	173
Jelly										
Siphonophore Fragments	204	44	568	121	369	664	0	126	262	173
Chaetognaths	122	480	1280	1330	968	1990	672	1320	1920	1430
Larvaceans	1550	2230	3770	2430	3550	9370	2300	4540	3580	950
Other[2]	326	393	355	303	230	443	168	189	174	0
Larval Fishes	0	44	71	61	92	221	0	0	0	43

[1] Including mysids, isopods, decapods, and larval forms.

[2] Including medusae, pyrosomes, salps, and doliolids.

Table V-3. Zooplankton composition, per cent of total sample

Tow no.	1	2	3	4	5	6	7	8	9	10
Crustacea										
Copepods	55.1	57.0	51.5	59.7	55.9	58.6	59.9	57.5	48.8	50.5
Ostracods	10.0	15.0	15.3	6.7	9.7	7.7	11.1	8.2	18.8	13.6
Amphipods	2.2	1.7	1.2	1.4	0.2	1.2	0.3	0.6	0.9	1.6
Euphausiids	7.3	6.5	3.9	6.2	4.9	3.9	5.8	3.9	7.8	16.6
Other	2.6	1.0	1.5	0.3	1.2	2.0	3.7	1.4	1.5	0.5
Molluscs	2.6	0.7	1.5	2.0	1.4	1.7	1.8	0.6	1.2	1.1
Jelly										
Siphon-ophore Fragments	1.9	0.2	2.4	0.7	1.9	1.3	0.0	0.6	0.9	1.1
Chaetognaths	1.1	2.7	5.3	7.4	5.0	3.9	3.7	5.9	6.8	8.9
Larvaceans	14.1	12.6	15.7	13.6	18.2	18.4	12.6	20.4	12.6	5.9
Other	3.0	2.2	1.5	1.7	1.2	0.9	0.9	0.8	0.6	0.0
Larval Fishes	0.0	0.2	0.3	0.3	0.5	0.4	0.0	0.0	0.0	0.3

Table V-4. Comparison of present results with baseline results.

	Part A		Part B					
	Night tows (#2,3,7,8,9)		Control tows (#5,6,7,8)		Usual dump site (#2,3,4)		Temporary dump site (#9,10)	
	no./m^2	%	no./m^2	%	no./m^2	%	no./m^2	%
Copepods	6350	79.5	16,100	58.1	11,100	55.7	11,000	49.5
Ostracods	486	6.1	2410	8.7	2520	12.6	3760	16.9
Amphipods	218	2.7	204	0.7	278	1.4	260	1.2
Euphausiids	132	1.7	1220	4.4	1060	6.1	2440	9.9
Other Crust.	56	0.7	562	2.0	197	1.0	261	1.1
Molluscs	77	1.0	406	1.5	283	1.4	261	1.1
Siph. Fragments	38	0.5	290	1.0	244	1.2	217	0.9
Chaetognaths	549	6.9	1240	4.5	1030	5.2	1670	6.8
Larvaceans	52	0.7	4940	17.8	2810	14.1	2260	9.2
Other Jelly	7	0.1	258	0.9	350	1.8	87	0.4
Larval Fishes	26	0.3	78	0.3	59	0.3	21	0.1
Total	7991		27,708		19,931		22,237	

the numbers of jelly-like organisms such as siphonophores and salps were higher in the Part B samples, there seemed to be a decline in the number of large forms, such as large medusae.

Table V-4 also breaks down the Part B results into control tows in an area relatively unaffected by dumping, tows at the usual dump site, then in its second day of recovery from dumping, and tows at the temporary dump site, where dumping was occurring at the time of sampling. The four columns thus should indicate the effects of increasing influence of suspended dredge spoil on the zooplankton community, from a baseline of zero dumping to a maximum effect of concurrent dumping. For most groups the effects were minimal. Euphausiids and ostracods showed an increasing percentage with increasing dredge spoil influence, while larvaceans declined, but the actual concentrations were not much different in the three locations.

3. Effects of suspended particles on respiration and feeding

Most of the 2,449 euphausiids examined had been damaged in the course of capture, often severely. Because of their exposed location on the sides of the cephalothorax, the gills were usually damaged or missing. There was no evidence of clogging by sediment on intact or partially intact gills, however, and the observed damage appeared to be due entirely to the trauma of capture.

Examination of stomach contents proved disappointing. Euphusiids chew up their food so thoroughly that individual food items were rarely identificable. Occasionally a diatom frustule or fragments of a foraminiferan test could be distinguished, and fragments of crustacean exoskeleton were found in one stomach. Angular opaque fragments were found in the stomach and intestine of euphausiids from the temporary dump site, and it was assumed that this material represented suspended dredge spoil particles. However, similar fragments appeared in similar quantities in euphausiids from the other sample areas, as well as in euphausiids taken during the Part A baseline sampling. If this material was actually suspended sediment of some sort, it appears that the euphausiids were able to discriminate against ingesting excessive amounts of inorganic detritus, so that the suspended dredge spoil material had little or no net effect on the diet of euphausiids in the disposal area.

D. Discussion

There are a number of possible explanations for the increased amount of zooplankton in the disposal area over that observed during the baseline study. Since the Part A samples were collected in July and the Part B samples were collected in May, a seasonal variation in zooplankton abundance might explain the increase. Nakamura (1967) reported on seasonal variations in zooplankton abundance around the Hawaiian islands. The most applicable of his data were gathered in the vicinity of the disposal area in May and August, 1956, yielding zooplankton volumes of 8.1 and 12.1 cm^3 per 1000 m^3 of water. Unfortunately, his May sample was a day tow and his August sample was a night tow. In the Part A study, the dry weights of three night tows averaged 1.22 times the dry weights of three comparable day tows. If this factor is applied to Nakamura's May, 1956 tows, a corresponding night value would be 9.9 cm^3 per 1000 m^3, 82 per cent of the August figure. The values found in the present study average 290 per cent of the values found the previous July, suggesting that the variation observed is not a seasonal effect.

Another possible cause of increased zooplankton abundance might be the dredge spoil, possibly through stimulation of the phytoplankton through released nutrients. If this is the major factor, zooplankton numbers might be expected to be higher in the vicinity of the dump sites than in the control area (the effect on the phytoplankton might be expected to require several days, so that numbers would be higher at the usual dump site than at the temporary site). However, Table V-4 shows that the control area averaged somewhat higher zooplankton numbers than the dump sites. It appears unlikely that the dredge spoil accounted for the increase in zooplankton abundance.

The most probable cause of the increased zooplankton abundance is runoff from land. The mechanism by which land runoff can increase the zooplankton population is that suggested above for the dredge spoil: increased nutrient levels producing an increase in the production of phytoplankton, which in turn is eaten by the zooplankton. Doty and Oguri (1956) documented such an increase in phytoplankton primary productivity in the inshore waters around Oahu, the "island mass effect." Gilmartin and Revelante (1974) showed that this effect is normally noticeable only within about 1 km of shore. However, the Part B sampling occurred during a period of kona weather, when the prevailing northeast trade winds were replaced by light variable or southerly winds. Under these conditions discharges from land, including sewage from the Sand Island sewage outfall, can accumulate in the disposal area rather than dispersing offshore (DPW-Honolulu, 1972: Figure 12).

Most of the visible debris in the surface water probably represents runoff from Pearl Harbor rather than sewage effluent, as sewage was found only in the tows sampling below 60 fm. Had samples been taken during kona weather during the baseline study, sewage would probably have been found throughout the water column. In November, 1976, between the Part A and Part B sampling, sewage from the Sand Island sewage treatment plant was diverted from a relatively short, shallow (5 fm) outfall to the present longer, deep (40 fm) outfall, which traps the effluent in the thermocline below the surface mixed layer. Thus in spite of appearances, the euphotic zone of the disposal area is probably under less environmental stress from sewage than it was during the Part A study.

The interpretation of data from the Part B sampling thus seems to hinge more on the effects of land runoff than on dredge spoil disposal. Dredge spoil seemed to have no effect on the feeding or respiration of two species of euphausiids, although gill damage from capture and the homogeneity of the stomach contents make this conclusion somewhat equivocal. The numbers and composition of the zooplankton assemblages in the three sampling areas showed little systematic difference, although trends in the numbers of euphausiids, ostracods, and larvacenas may prove useful indicators for monitoring post-dumping recovery of the zooplankton community. The unforeseen effects of kona weather on the sampling appear to have swamped any effects of dredge spoil disposal itself. In this regard, it perhaps is conforting that during kona weather, a time when dredge spoil disposal was anticipated to have its most deleterious effects, the effects of land runoff appears to have been much greater.

E. Acknowledgments

I would like to thank Jed Hirota, Jeffrey Leis, and Thomas Clarke for the loan of sampling gear, and Mike Chun for consultation and advice. Thanks also to the crew of R/V Machias for their assistance in the sampling.

F. Summary

1. Zooplankton was three times as abundant in the disposal area as during the baseline study. Copepods comprised a smaller percentage of the total, and other groups, notably larvaceans, were more abundant.

2. Kona weather prevailing on the night of sampling, rather than seasonal variation or effects of dredge spoil disposal, appears to have been responsible for the increase in zooplankton numbers, by allowing land runoff, including sewage disposal, to accumulate in the disposal area.

3. No effects of suspended dredge spoil were noted on the respiration or feeding of two species of euphausiids, but damage from capture may have obscured any damage to euphausiid gills resulting from suspended sediment.

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VI BENTHIC BIOLOGY

by

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A. Objectives

The basic objectives of the Part B Benthic Biology studies in the Pearl Harbor disposal area were to determine the immediate and short term effects of dredge spoil on the benthic fauna.

The specific objectives accomplished in this part of the survey were:

1. Quantitative analysis of fecal pellets in the sediment samples to determine the drift of the lighter sand-size fraction of dredge spoil material.
2. Selection of large and small tracer species from Pearl Harbor sediments and evaluation of their distribution in the disposal area.
3. Examination of the living, non-commercial macrofauna in and around the disposal area and the determination of changes in the community.
4. Examination of the sand, pebbles, and/or rocks in the samples to determine the location of dredge spoil around the disposal site.

B. Methods

Samples taken during and after dumping at the Pearl Harbor dredge spoil disposal site were examined and compared with samples from baseline studies and from the dredge "Harding."

1. Field Methods

The methods of obtaining the core and grab samples are described by Allen and Moberly (1977). Equipment used in this phase of the study was similar to that used in Part A of the Pearl Harbor disposal site study and is described under Methods in Section III. Color photographs were taken along 14 lines within the disposal area (Figure III-1). The procedure is described in Section III.

2. Laboratory Methods

a. General Procedure

Cobbles (rocks) were initially removed from the samples, examined and placed in alcohol to preserve the living material. The surface of a core (K1c) was infused in rose bengal. The grab samples (M, J, P, and G series) were gently washed and sieved to remove most of the silt fraction but retain intact fecal pellets. Silt is defined as particles of less than .063 mm; sand, between .063 and 2.0 mm; and pebbles, 2.0 to 64 mm. Fecal pellets are ovoid particles of waste material from worms, mollusks and other organisms. These range in size from about 0.5 to 1.5 mm and are shown in Figure 3. The samples were dried and five ml of sediment was split into 5 aliquots. Pellets were counted in one of the aliquots and expressed as the number per ml in the sand and pebble fraction of each sample. Twenty-five ml of sediment was rewashed thoroughly to remove all of the mud and dried again. The pebble portion of this subsample was separated from the sand portion and both were examined.

b. Tracer species

Tracer species, including fecal pellets and non-organic framboids*, found in the sediment samples were distinguished from the other grains by at least two of the following criteria:

1) They were not seen in the sediment samples taken during the baseline study;
2) They were infilled or coated with iron compounds such as pyrite which are characteristic of strong reducing environments such as are found in the Pearl Harbor sediments;
3) When alive, they are able to withstand broad fluctuations in salinity;
4) They have been previously described from Pearl Harbor.

These species are found in Table VI-1 and are marked with an asterisk. The other species listed were not used in the analysis because they were observed in baseline study samples or were so rare in post disposal samples to be of questionable use in tracing dredge spoil material.

The first three species in Table VI-1 are shallow water algae which were found only occasionally in samples close to the dumpsite. They are included in the table because it appears unlikely that the rocks to which these delicate plants were attached, could be moved offshore by natural forces without losing their occupants. The three algal species were alive at the time of recovery whereas all other species restricted to shallow water were dead.

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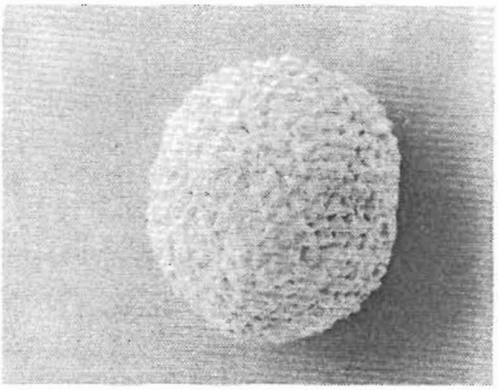
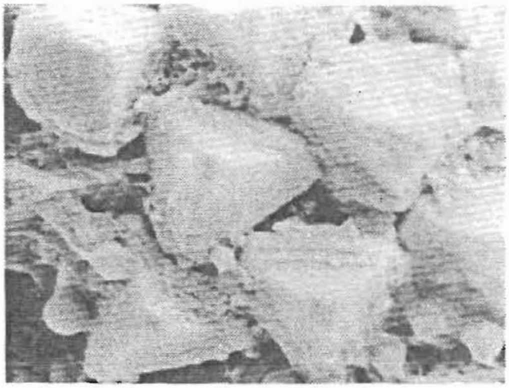
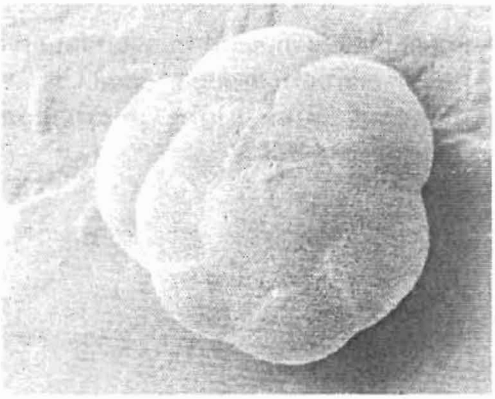
*clusters of tiny pyrite cubes and grains, the whole with a spheroidal outline (Figure 1, Figure 2).



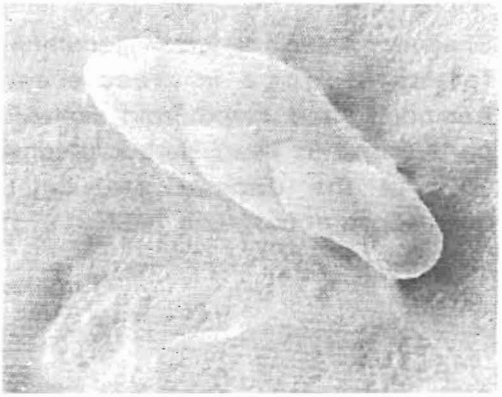
Framboid 500X



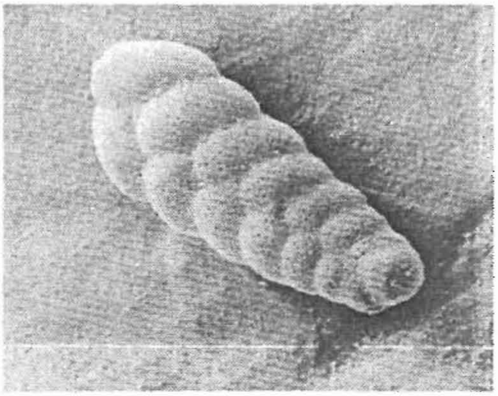
Framboid crystals 5000X



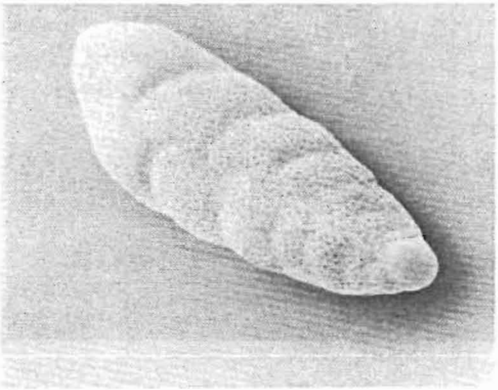
Ammonia beccarii tepida 195X



Cassidella schreibersiana 260X



Bolivina sp. 300X



Bolivina striatula 240X

Figure 1.

Shallow water foraminiferans and framboids found in Pearl Harbor dredge spoil at the disposal site. S.E.M. photographs.

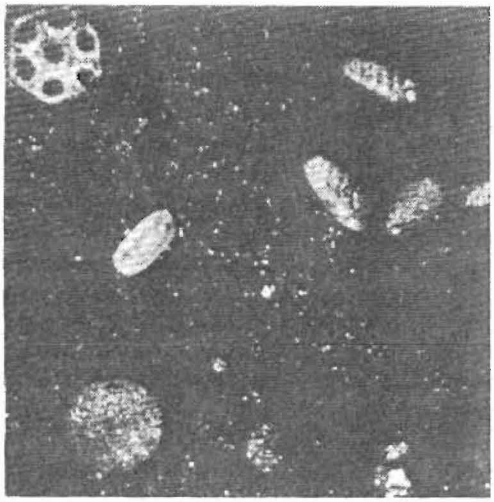


Figure 2.

Shallow water diatoms, foraminiferans, sponge microscleres, framboids, and holothuroid skeletal parts found in Pearl Harbor dredge spoil at the disposal site. Light microscope photograph 100X.

Figure 3.

Fecal pellets in sand fraction found in Pearl Harbor dredge spoil at the disposal site. Light microscope photograph 30X.

Figure 4.

Large species found in Pearl Harbor dredge spoil at the disposal site. Oyster in lower left corner is 4cm across.

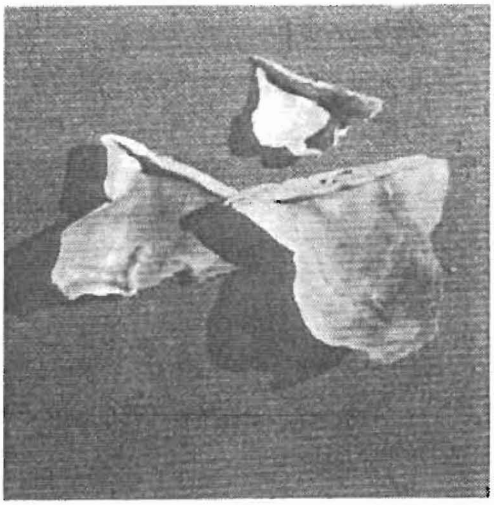


Figure 5.

Pinctada spp. found in Pearl Harbor dredge spoil at the disposal site. Smallest shell is 5 cm across.

Table VI-1. Shallow water species found in Pearl Harbor dredge spoil at the disposal site and in hopper dredge samples. Tracer species are starred (*).

Species	Description
Phylum Rhodophyta	
Acanthophora spicifera	living attatched to cobbles
Phylum Chlorophyta	
Ectocarpus sp.	"
Ulva fasciata	"
Phylum Protozoa	
*Ammonia beccarii tepida	dead, unbroken and unworn
*Bolivina striatula	dead, clear or filled with pyrite
*Bolivina sp.	"
*Cassidella schreibersiana	"
Elphidium advenum	dead, clear, eroded
*Florilus japonicus	dead, clear or filled with pyrite
*Cornuspira planorbis	"
*Quinqueloculina poeyana	"
Phylum Porifera	
*Tethya spp	skeletal sphaerasters clear
Phylum Annelida	
*Ficopomatus enigmaticus	large conglomerations of individuals
*Hydroides spp.	"
Phylum Mollusca	
Crepidula aculeata	shells
Hiatella hawaiiensis	valves
Odostomia oxia	shells
*Vermetus alii	tubes
*Dendropoma platypus	"
*Crassostrea spp.	valves
*Pinctada spp.	"
Phylum Echinodermata	
*Ophiodesoma spectabilis	skeletal parts
Phylum Arthropoda	
*Cyprideis aff. beaconensis	valves
Non-living Material	
* framboids	small spheres of pyrite
* pellets	fecal material

Seven foraminiferans, the sponge Tethya spp sphaerasters, the micromollusks, Ophiodesoma spectabilis skeletal parts, Cyprideis aff. beaconensis valves, and framboids are designated as small tracer species. They are very small, rarely reaching 2 mm in length (Some of these are shown in Figures 1 and 2.)

The eight foraminiferans listed are known either from Pearl Harbor (Turner, 1975), the shallow water lagoonal parts of the Ewa cores (Resig, 1972), or other shallow water bays on Oahu (Coulbourn, 1971; Bell, 1976). Six of the species were not seen in the baseline study and were infilled with pyrite to varying degrees. The other two species, Ammonia beccarii tepida and Elphidium advenum, were not filled with iron compounds and were occasionally observed in the baseline samples. Ammonia is used as a dredge spoil tracer because it only occurs in bays near the shoreline and often is found living in brackish water. Specimens seen in post-disposal samples were unworn and unbroken whereas the few seen in the baseline study were badly eroded or broken. Too few Elphidium were seen in post-disposal samples to be considered as tracers.

Tethya spp. are described from Kaneohe Bay (de Laubenfels, 1950). The micromollusks described from Pearl Harbor by Kay (in Evans, et al. 1974) were seen in samples obtained during the Part A baseline study. Although Ophiodesoma was not seen by Evans, et al. (1974) in Pearl Harbor, it is relatively common at Fort Kamahameha on the reef flat near the main Pearl Harbor channel (Chave, pers. obs. 1977). It is known only from silty areas in bays (Edmonson, 1946; Smith, et al., 1973; Evans, et al., 1974). The brackish water ostracod, Cyprideis aff. beaconensis was described from the Ewa cores and from Kahana Bay (Resig, 1969; Coulbourn, 1971). Framboids are accretions of pyrite around an organic nucleus. Their formation is discussed by Turner (1975) who found them to be abundant in the reducing environments of Pearl Harbor.

Large tracer species at the disposal site were usually larger than 64 mm. Large identifiable fragments of apparently recently living oysters Crassostraea spp. and two species of Pinctada were found offshore only in post dredge spoil disposal samples and appear to be good tracers (Figures 4 and 5). Crassostrea spp. were introduced into the bay from the mainland United States and were reported there by Evans, et al. (1974). Pinctada spp. were reported from the bay by Edmondson (1946) but not seen in Evans' studies. Valves of Pinctada spp. were often blackened and probably represented old pearl oyster material dredged from Pearl Harbor but the worn valves and the extinct oyster, Ostrea retusa, were not used as tracers since deep fossil reef material was abundant in at least one pre-dump sample.

Masses of worm and mollusk tubes (Hydroides spp. [Figure 4], Ficopomatus enigmaticus, Dendropoma platypus, and Vermetus alii) were also used as large tracer species. According to Evans (1972, 1974), the tube building worms and mollusks in Pearl Harbor attach to pilings or other substrates and in nutrient rich areas often form clusters of several to thousands of individuals per square meter. They are reported from Pearl Harbor or quiet bay environments by Brock, pers comm., Evans et al., 1972; Evans, et al., 1974; and Hadfield, et al., 1972 respectively. I observed thousands of worm tubes near the main channel of Pearl Harbor. Parts or clusters of tubes were used as tracers only if they reached a length of over 20 mm and could be recognized as the above species. In the baseline studies shallow water worm tubes were present in the samples but only as small broken pieces, never as clusters.

C. Results

Table VI-2 summarizes the results of the microbenthic studies by showing the composition of the samples in the dredge spoil area during and after dumping. Table VI-3 shows the living macrofauna taken from traps or seen in the bottom photographs.

1. Large Tracer Species

Figure VI-6 shows the distribution of the large tracer species from Pearl Harbor. These are concentrated in two areas, the first in a radius of 1/2 mile around the dump site; the second, in a radius of 1/4 mile around a point near J2. After 123 loads of spoil were dumped large tracer species were found at M1 and M9. Other sites close to the disposal site such as M11, M4 and M6 showed no large tracer species. Station M9 is discussed later. After 342 loads of spoil were disposed, J1, J2, J10, and J11 contained large tracer species. At the end of dumping, large tracer species were found in samples P7b, P6, P10, P11, and P15a.

2. Small Tracer Species

Figure VI-2 shows the distribution of the small tracer species. Apparently these species drifted north and west for over 2 miles as far as the base of the Barbers Point ledge (G1) but not on top of it (G2). Samples 1/2 mile east of the disposal site did not contain dredge spoil. Dredged material travelled at least 1/2 mile to the south.

Table VI-2. Selected characteristics of Pearl Harbor dredge disposal area samples. H = samples from hopper dredge; M = samples obtained on April 26 and 27, 1977; J = samples obtained on May 19, 1977; P = samples obtained on May 31 and June 1, 1977; G = samples obtained on June 14, 1977. Silt is removed.

Station	Depth fms	Pellets Number/ml	Framboids	Small Tracers	Small Tracers	No Sample
H 1-4	10	3700	+	+	+	
M 1 c	225	1700	+	+	+	
M 2	207	750	+	+	-	
M 3 a	205					+
M 3 b	213				-	rock
M 4	224	590	+	+	-	
M 5	243	80	-	+	-	
M 6	238	220	-	+	-	
M 8 a,b	217,210					+
M 9	183	20	+	+	+	
M11	215	70	+	+	-	
M14 b	198	680	+	+	-	
J 1	211				+	rocks
J 2	190	1330	+	+	+	
J 3 a,b	194,186					+
J 3 c	191	190	+	+	-	
J 4	173	420	+	+	-	
J 5	138	250	+	+	-	
J 6	170	390	+	+	-	
J 7	195	70	-	+	-	
J 8	223	60	+	+	-	
J 9	216	small sample used for geological work				
J10	224	120	+	+	+	
J11	240	130	+	+	+	
J12	214					+
P 1 a,b	200,204					+
P 2 a,b	214,211					+
P 3 a,b	211,211					+
P 4 a	217					+
P 4 b	222	80	+	+	-	
P 5	222	320	+	+	-	
P 6	223	2070	+	+	+	
P 7 b	227	90	+	+	+	
P 8	218					+
P 9	183	1	-	-	-	
P10	212	340	+	+	+	
P11	163	320	+	+	+	
P12	160	40	-	-	-	
P13 a	192	30	+	+	-	

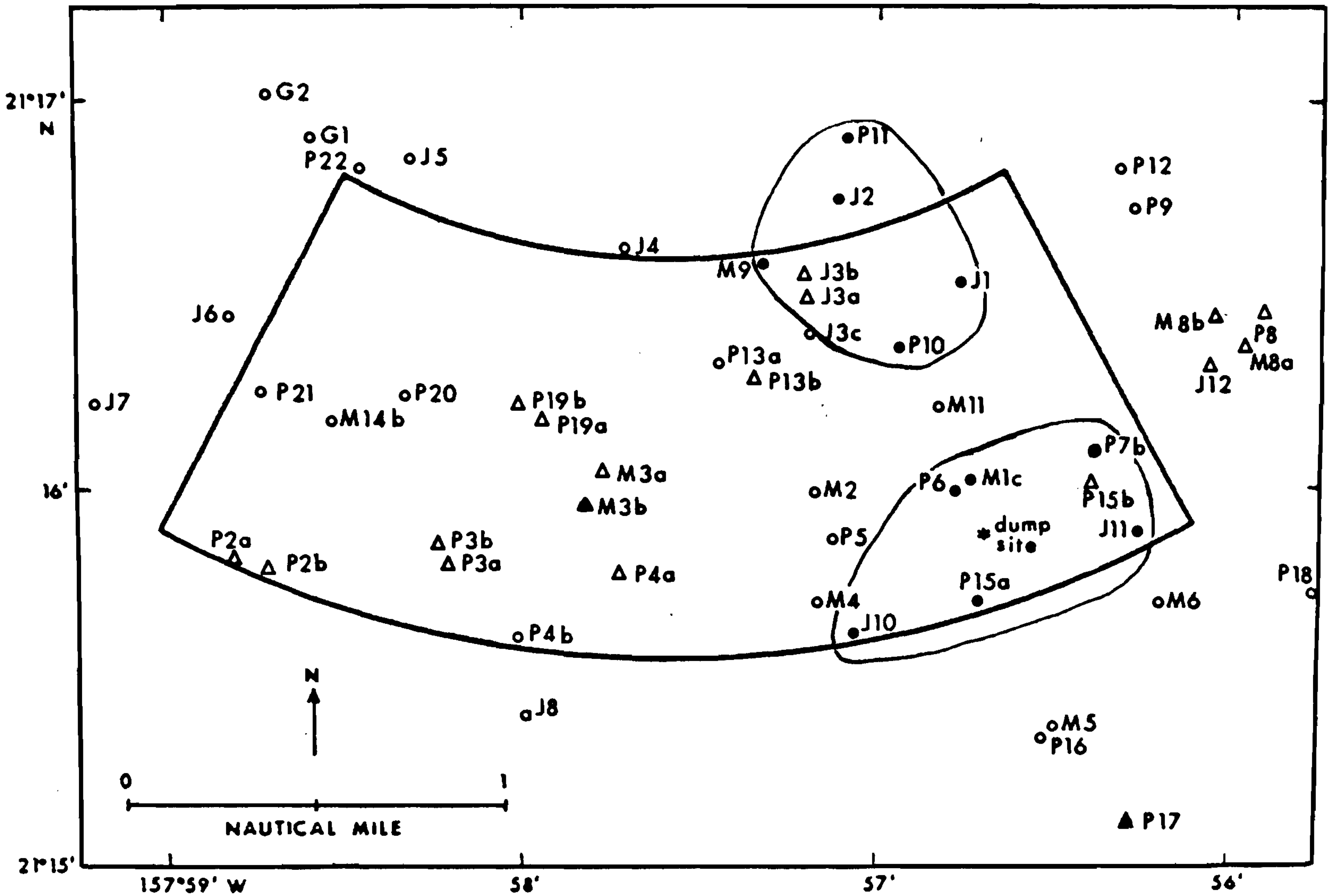
Table VI-2 (continued)

Station	Depth fms	Pellets Number/ml	Framboids	Small Tracers	Small Tracers	No Sample
P13 b	197					+
P14	220	small sample used for geological work				
P15 a	230	350	+	+	+	
P15 b	232					+
P16	241	90	+	+	-	
P17	247				-	old disposal site
P18	243	9	-	-	-	
P19 a,b	194,193					+
P20	191	530	+	+	-	
P21	188	310	+	+	-	
P22	126	190	+	+	-	
G 1	115	180	+	+	-	
G 2	47	0	-	-	-	
G 3	132	20	-	-	-	
G 4	75	0	-	-	-	

Table VI-3. Living macrofauna at the Pearl Harbor Dredge Spoil disposal area identified in photos and from specimens obtained in traps.

Taxa	Abundance (indiv/unit)	Sample #
Mollusca		
Notodarus hawaiiensis	1.0	photo line 1
Crustacea		
Heterocarpus ensifer	41.7/trap	disposal area, May 18
	137.6/trap	control area, May 18
	35.1/trap	disposal area, July 18
	45.2/trap	control area, July 18
	1.0	photo line 9
anemone crab/anemone	1.7/trap	control area, May 18
	0.8/trap	control area, July 18
xanthid crab	0.1/trap	control area, July 18
Randallia distincta	0.1/trap	control area, July 18
	1.0	photo line 10
Cyrtomya smithi	1.0	photo line 10
Pisces		
Conger wilsoni	0.1/trap	disposal site, July 18
Polymixia berndti	2.0	photo line 10

Figure VI-6. Distribution of large tracer species in the disposal area: ● large tracer species; ○ no large tracer species; ▲ rocks in sample; △ no sample, apparent hard substrate. The areas containing large indicator species are circled.



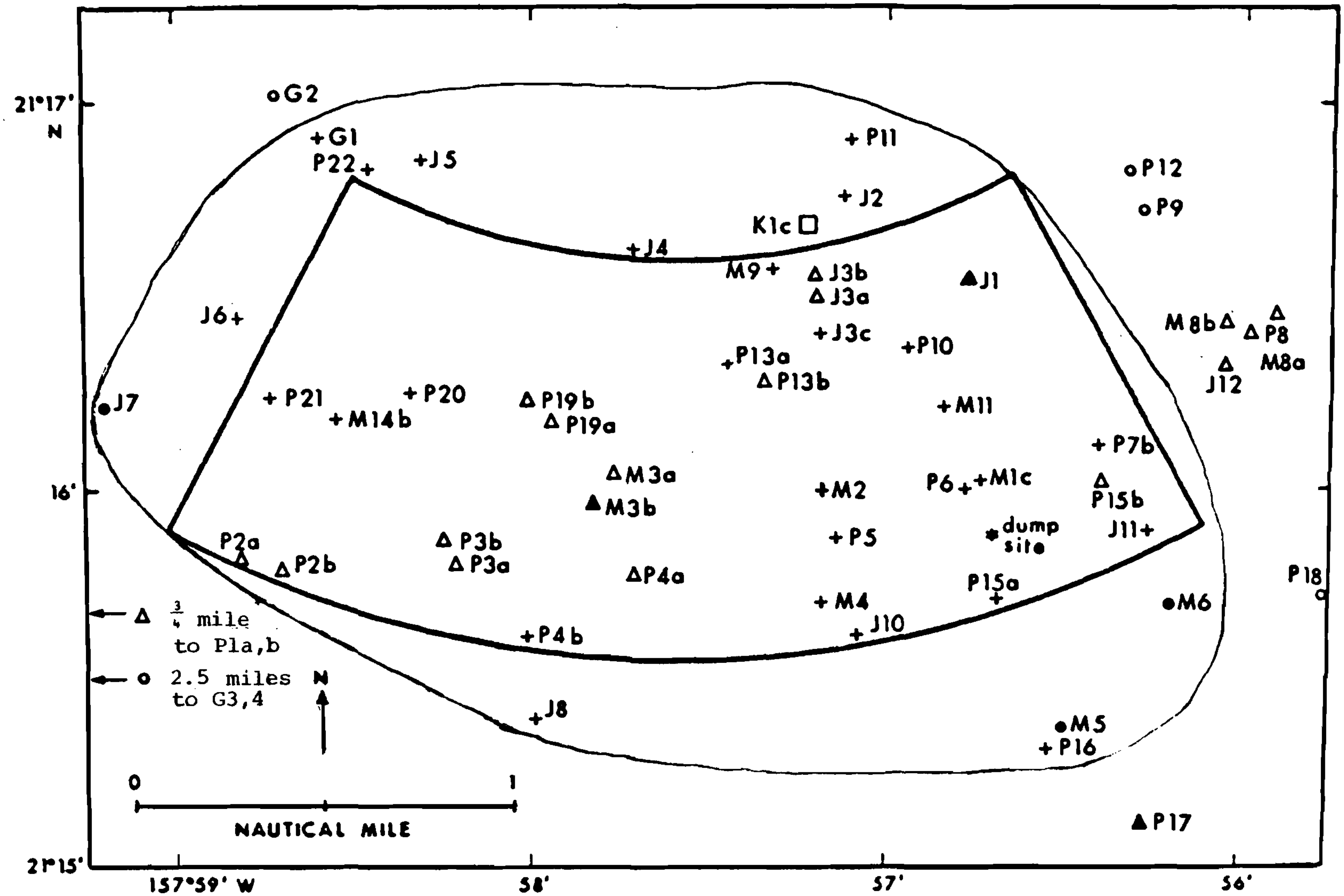


Figure VI-7. Distribution of small tracer species and framboids in the disposal area; + small tracer species and framboids; ● small tracer species; O no framboids or small tracer species in sample; ▲ rocks in sample; Δ no sample, apparent hard substrate. The area containing small tracer species and framboids is outlined.

3. Fecal Pellets

Figure VI-8 shows the number of pellets/ml sample in the disposal area. Pellets travelled as far as the small tracer species although pellets were larger than the latter. They also were often 100 times more abundant than small species and were, therefore, used in quantitative estimates of dredge spoil distribution. Over 1000 pellets/ml were found only in three stations, P6, M1c and J2. Significant numbers (between 100 and 900 pellets/ml) were found in two areas, one around the dumpsite, the second around J2. They appear to have drifted in a westerly direction. Pellets were found in very low concentrations in all other samples except for G2 and G4 above the 50 fm contour of the Barbers Point ledge where they were not present.

4. Sediment "Stability"

Using criteria set in the Pearl Harbor baseline study (Part A) the post disposal samples were checked to see whether sediment maps were similar. The categories used were as follows: beach sand present or absent, 75% of fragments identifiable, total number of intact foraminifera >40% benthic, more worn that intact shallow water foraminifera present. These categories are presented in Table VI-4 and the stations termed stable, unstable, or both. The results in post disposal sediment samples (Figure VI-9) are similar to baseline studies (Baseline Survey Map 1) with the exception of the sediment around the disposal site. These latter samples exhibit a mixture of stable and unstable criteria: beach sand is usually present, 75% of the fragments (usually pieces of coral and coralline algae) are unidentifiable, foraminifera are >40% benthic, and there are fewer worn than intact foraminiferans. The difference in sediment composition is probably attributable to dredge spoil in the area. Pictures from photo lines 3 and 8 (Section III, Figures III-16 and III-19) show large indicator species present in the area around the dumpsite. It cannot be dtermined whether dredge spoil is present in the other photos in the dumpsite area.

5. Living Fauna

Core K1c and the rocks were examined for living microfauna. Deepwater fauna consisted of two spionid and one syllid worms, two foraminiferans (*Pyrgo* sp. and *Amphistegina bicirculata*) and one bivalve (*Nucula*) in the sediments. Several planktonic forams and one heteropod also stained red with rose bengal.

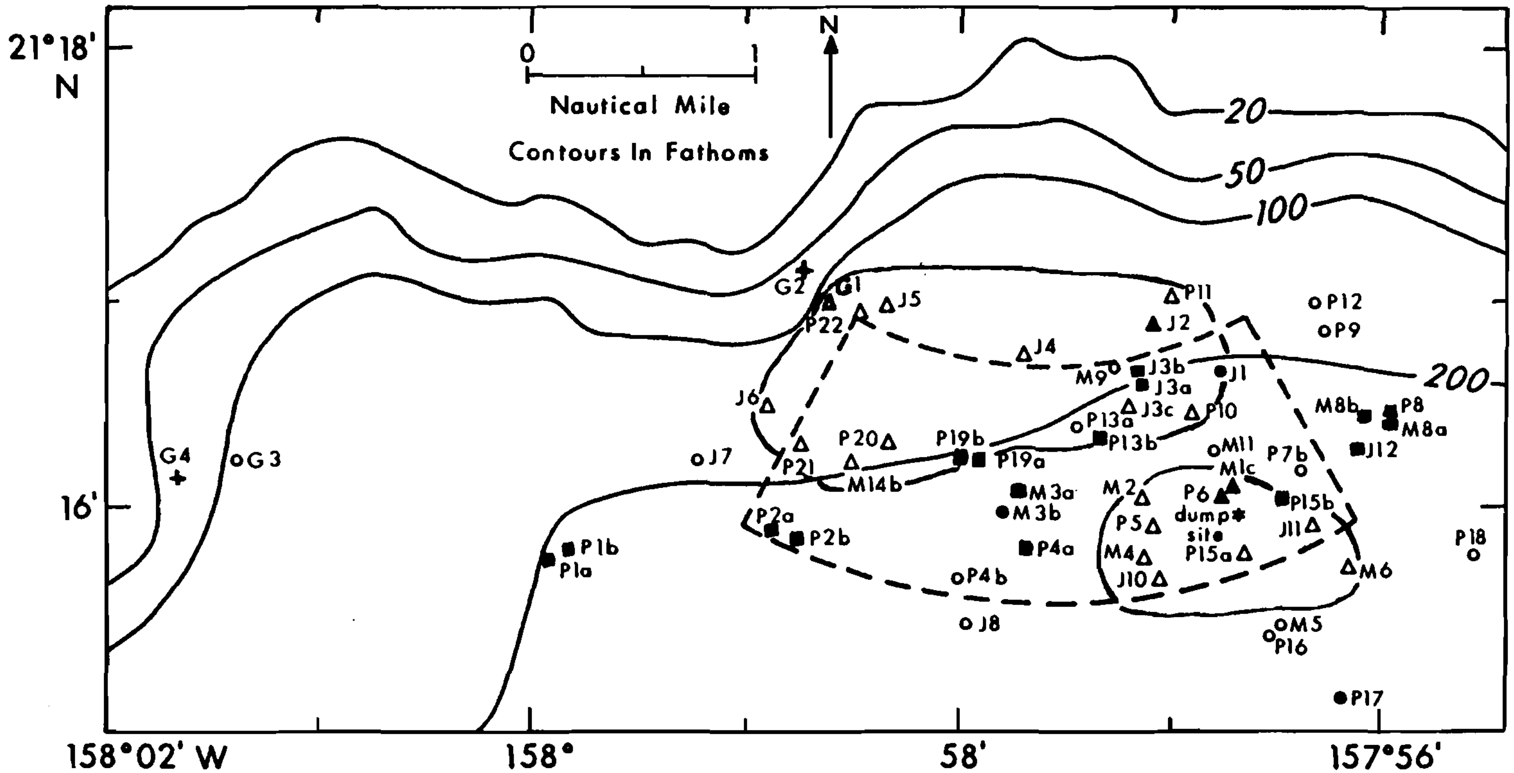
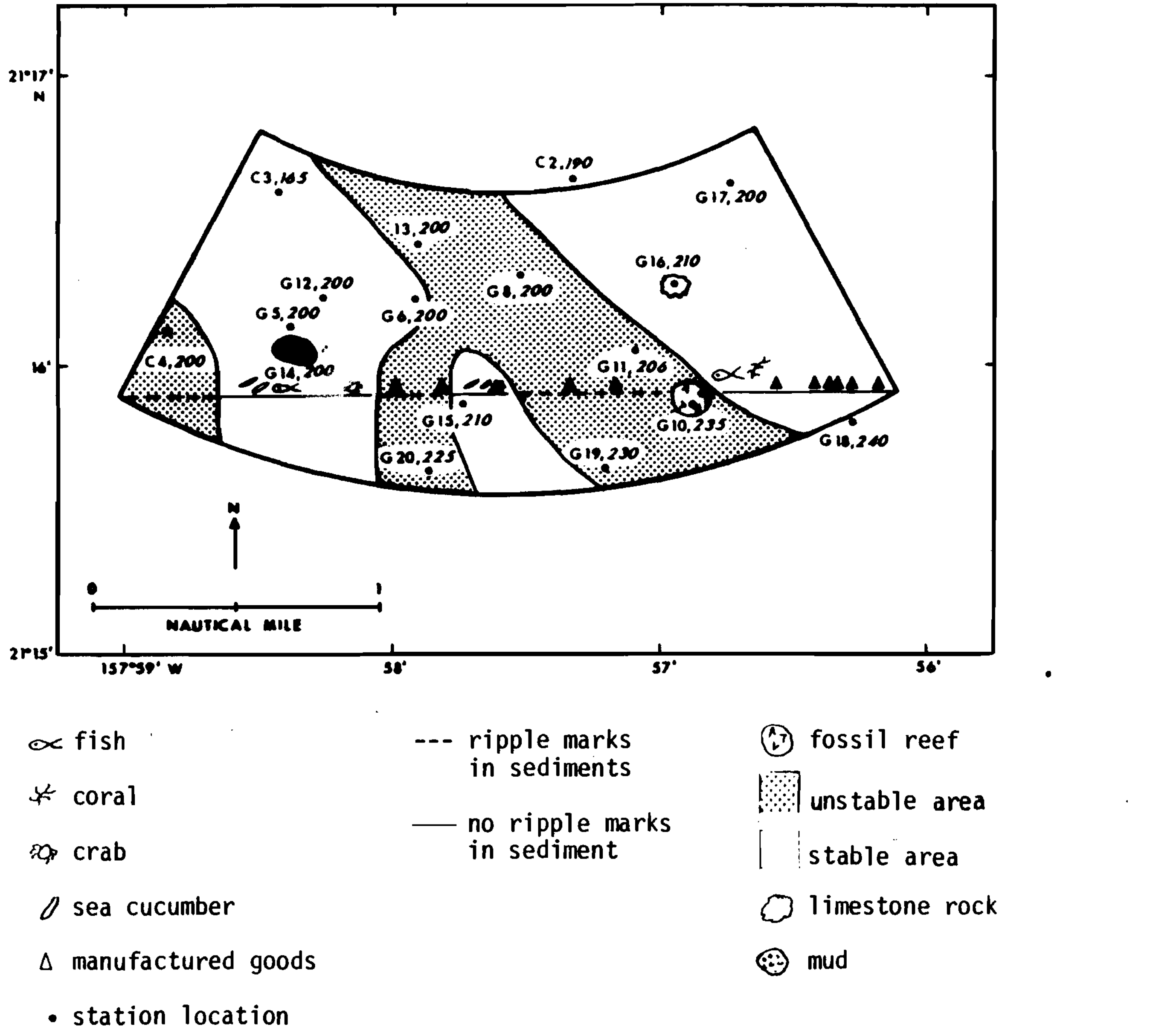


Figure VI-8. Number of pellets/ml sample at each station in and around the disposal area: + no pellets in sediment; O <100 pellets/ml; Δ between 100 and 900 pellets/ml; ▲ >1000 pellets/ml; ● rocks in sample; ■ no sample, apparent hard substrate. The areas containing >100 pellets/ml sample are outlined.



Baseline Survey

Map 1. Location of stable and unstable areas at the proposed Pearl Harbor Dredge Spoil Disposal Site. The photo transect is shown as the dashed and solid line across the site. From Chave and Kay, 1977.

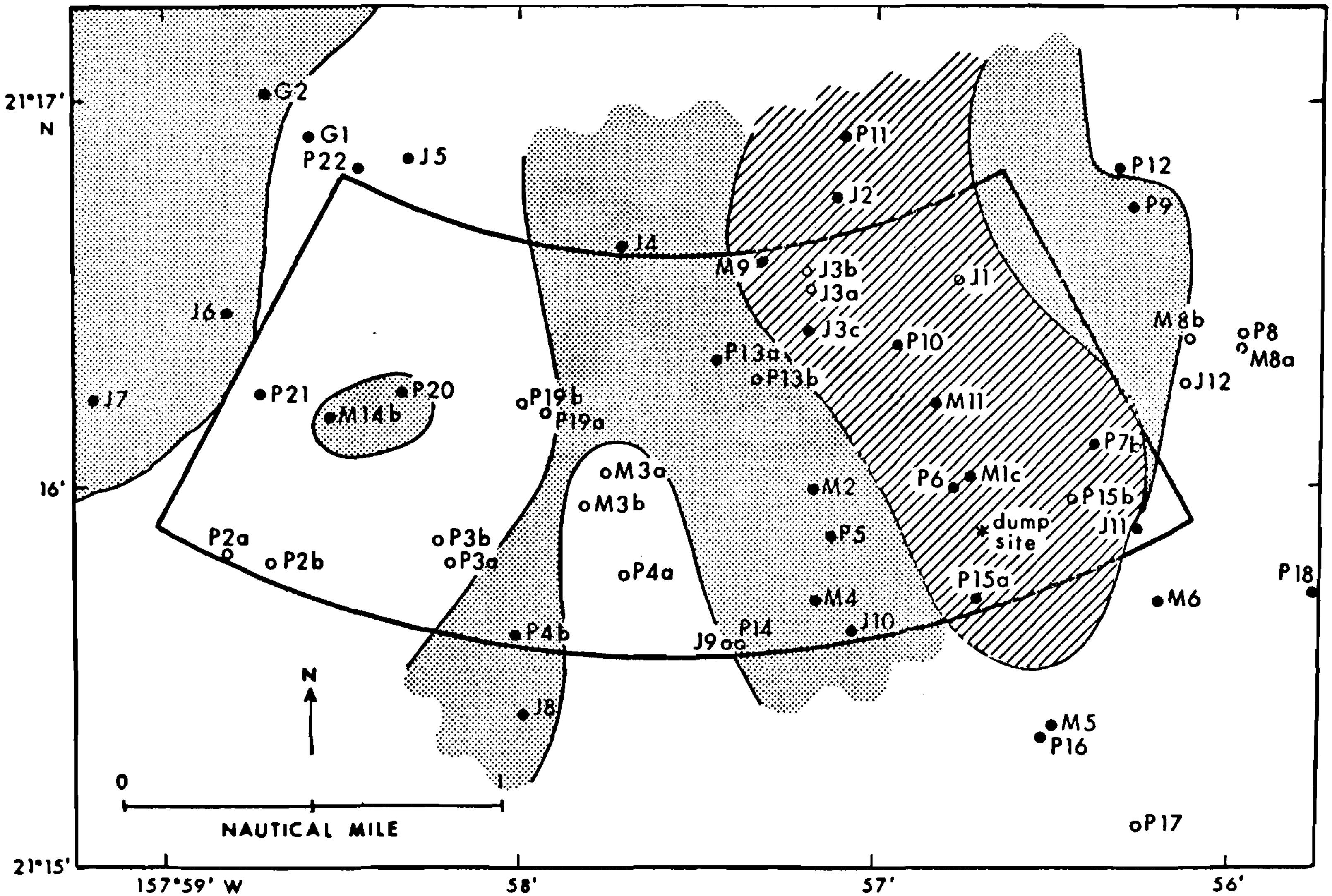


Figure VI-9. Location of stable, unstable, and mixed sediments in the disposal area. ● sediment samples used for this analysis, O samples containing rocks or no samples obtained. Samples from stations J9 and P14 contained less than 1 ml of sand and were used for geological investigations only.

Table VI-4. Summary of stable and unstable sediments in the dredge spoil disposal area. S = stable, U = unstable, M = mixture. Stations without sand are not included.

Station	Designation	Beach Sand	75% frags Unidentificable	Total intact forams 40% benthic	More worn than intact SW benthic forams
M1c	M	+	-	+	-
M9	M	+	-	+	-
M11	M	+	-	+	-
J2	M	+	-	+	-
J3c	M	+	-	+	-
P6	M	+	-	+	-
P7b	M	-	-	+	-
P10	M	+	-	+	-
P11	M	+	-	+	-
P15a	M	-	-	+	-
M5	S	-	-	-	-
M6	S	-	-	-	-
J5	S	-	-	-	-
J11	S	-	-	-	-
P12	S	-	-	-	-
P16	S	-	-	-	-
P18	S	-	-	-	-
P21	S	-	-	-	-
P22	S	-	-	-	-
G1	S	-	-	-	-
M2	U	+	+	+	+
M4	U	+	+	+	+
M14b	U	+	+	+	+
J4	U	+	+	+	+
J6	U	+	+	+	+
J7	U	+	+	+	+
J8	U	+	+	+	+
J10	U	+	+	+	+
P4b	U	+	+	+	+
P5	U	+	+	+	+
P9	U	+	+	+	+
P13a	U	+	+	+	+
P20	U	+	+	+	+
G2	U	+	+	+	+

These animals represent .25 individuals/ml sediment. Rocks were examined for shallow water organisms and apart from the algae (Table VI-1), only Carpenteria monticularis and one species of white sponge were found covering up to 8% of some of the rocks. The known depth distribution of these two animals is from shallow to very deep water and both animals were found in baseline samples and under rocks along the shoreline. Only when the two species were found associated with entire, fresh barnacle and oyster shells or (living) algae could they be designated of shallow water origin.

Trapped non-commercial macrofauna were not as diverse or abundant as in Part A Studies (Table VI-3). The camera photographed some of the animals in the area. The squid, Notodarus, may be seen on the sand (Section III, Figure 15). This animal feeds in midwater at night. One heterocarpid shrimp was photographed (Section III, Figure 20). This animal is benthic during the day and presumably feeds on or just above the bottom at night. Two fishes (Polymixia) can be seen in the photo in Section III, Figure 21. This species feeds on the bottom. Randallia and Cyrtomya are benthic crabs which probably capture small living or dead animals on the bottom.

D. Discussion and Recommendations

Investigations of the nature of the substrate and overlaying dredge spoil have yielded the results summarized in Figures VI-6 and -9.

Of primary importance is that the sand to pebble fraction of the dredge spoil did not blanket the area leaving deepwater, benthic microfauna smothered. Except in the immediate dumpsite, from 0.01 to 3.0 per cent of sediment samples were composed of pellets. Other tracer organisms were usually fewer in number and considerably smaller than pellets. The remainder of each sample is almost indistinguishable from sediments described in the baseline study (Part A). This is due in part to the nature of the dredge spoil. Material from the hopper dredge samples was about 70 to 98% silt by volume; consequently there was only a relatively small amount of spoil of over .063 mm grain size. The fate of the silt fraction is discussed in Section III of this report.

Other than shallow water algae, no living dredge spoil material was found in the disposal area although a few living, deepwater worms, micro-mollusks and foraminiferans were observed in core K1a (.2 indiv./ml sediment). These low densities compare well with the densities seen in baseline survey samples. Cobbles at Station J1 averaged about 8 percent coverage of animals, a higher value than in the baseline study. This is probably due to the shallow water origin of these cobbles. Other cobble samples had little or no fauna on them (.01% coverage). The diversity and abundance of living non-commerical macrofauna was lower than that in the baseline study.

Of all Pearl Harbor tracers present in post disposal sediments, fecal pellets are the most valuable for determining the extent of drift of the lighter sand to pebble sized fraction of dredge spoil. Although pellets comprise a small percentage of most samples, they are present in sufficient quantities for reexamination in Part C of this survey. The pellets will probably erode, drift away or be eaten by benthic organisms over time and it is likely that the other small tracer species may break or drift out of the area. An attempt will be made during Part C to determine the length of time for this to occur.

Large tracer species will probably remain in the area longer. Part of the spoil in the immediate dump site area is located on substrate termed stable in baseline studies and part is on an unstable area. It will be valuable to determine whether the large tracer species on unstable sediments move out of the area faster than those in stable areas or whether they collect in areas determined by bathymetric configurations of the area. Resampling of this area should help determine the fate of this material.

It appears as if some of our samples contain material from an older dumpsite. M9, a station over a mile away from the 1977 dumpsite contained large indicator species but very few pellets (Figures VI-6 and -8). Since the M sample series was taken after 123 loads of spoil were dumped it is probable that the M9 sample contains large tracer species from the earlier 1959-1974 disposal site 'A' (21°17'13"N; 157°57'45"W) located immediately shoreward of the 1977 disposal area. Station M11, northwest of Station M1c near the disposal site (Figures VI-6 and -8), remained relatively clear of large indicator species and pellets whereas Stations M1c, J2, and P11 contained spoil.

High numbers of pellets indicate that recent dredge spoil is present at J2 and P11; however, the additional presence of large indicator species at these sites indicate spoil derived at least in part from earlier disposal operations. The photos show man-made debris along all lines except #6. Owing to the precise location of the 1977 disposal site and the "Harding's" strict adherance in using the designated site for dumping, it appears as if much of the debris seen on the lines was dropped either by previous dredges or by passing ships.

E. Acknowledgements

I wish to thank Drs. Johanna Resig, Geology Department, E. Alison Kay, General Science Department, and Julie Bailey-Brock, Zoology Department, University of Hawaii for their help in identifying Pearl Harbor tracer species. I also wish to thank Mr. Bill Austin of the R/V MACHIAS for his patience and support in the project.

F. Summary

Large Pearl Harbor tracer species are found in two areas, one within 1/2 mile radius of the dump site; the second within 1/4 mile of J2. It is suggested that their presence in Stations M9, J2 and P11 to the north is in part due to 1977 dredge spoil disposal in combination with 1959-74 dredge spoil from a previous dump site designated "A" by the Navy.

Fecal pellets in significant quantity were found in two areas, one around the dump site, the other around J2. They were apparently drifting in a westerly direction. They were not found on the Barber's Point ledge.

The maps of stable and unstable areas are similar for Parts A and B of the study except for the area around the disposal site where dredge spoil provided a major contribution to the sediments.

Small tracer species drifted throughout the disposal area as far as the base of Barber's Point ledge to the north and west. Stations to the south and east of the site were relatively free of spoil deposits.

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VII. FISHERIES

by

E.H. Chave
University of Hawaii

A. Objectives

The only potentially commercially important organisms found in the Pearl Harbor disposal site area are heterocarpid shrimps. An important fishery for akule and opelu is located on the Barbers Point ledge approximately 1 mile east of the disposal area. These two fisheries were examined to determine the effects of dredge spoil disposal on their population and distribution. The specific objectives were:

1. Quantitative investigations of the benthic shrimp fauna in the area.
2. Determination as to whether the dredge spoil physically affected the shrimp and fishes in the area, i.e. clogged gills.
3. Investigation of the effects of dredge spoil disposal on the commercial akule and opelu fishery through catch report analysis and discussions with fishermen.

B. Methods

The methods used in this survey were similar to those in the baseline study (Chave, 1977) with the following exceptions.

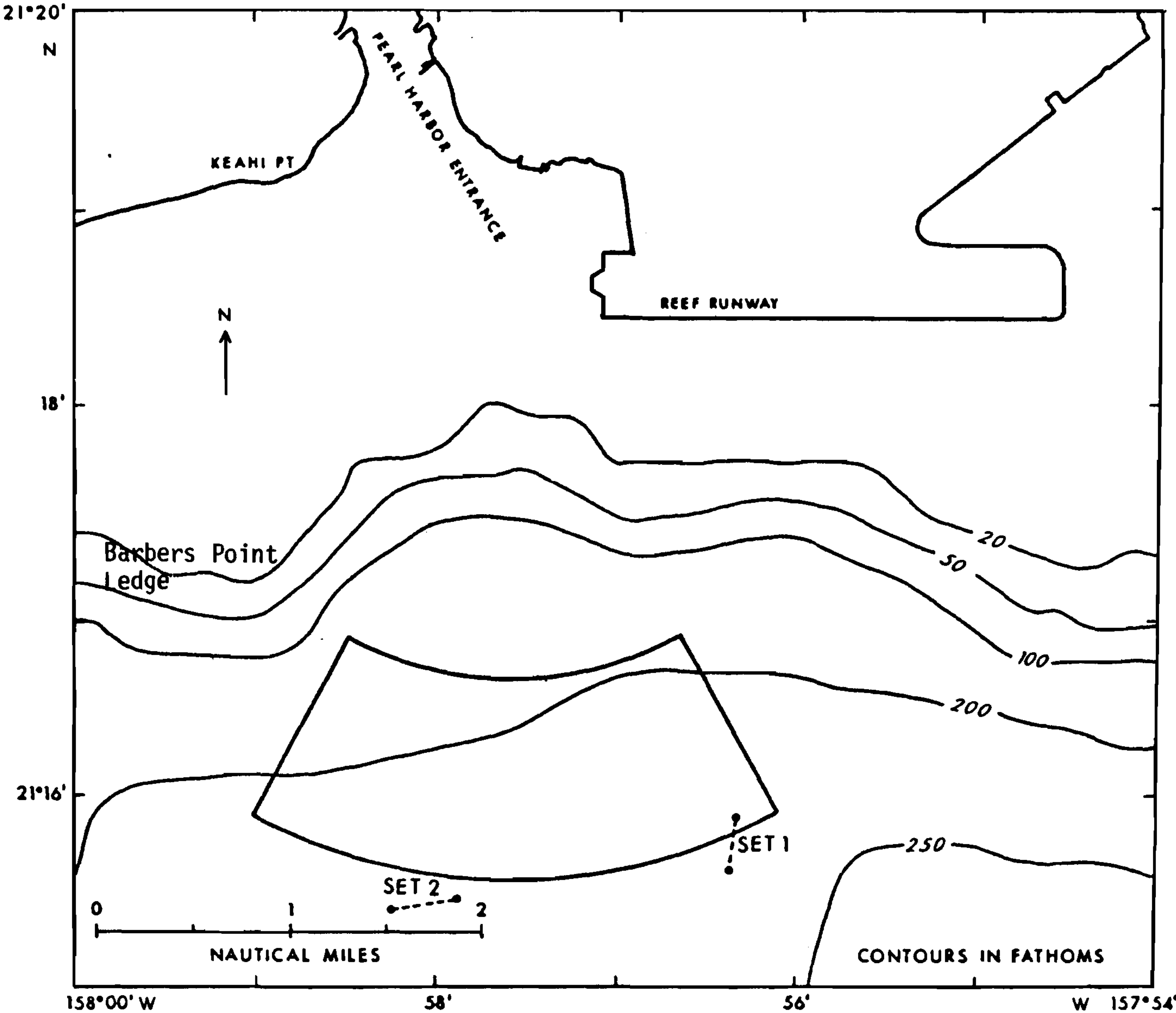
Two sets of shrimp traps were set at the dump site and in a control area on May 18 and July 18, 1977 (Figure VII-1). These areas were chosen for the following reasons:

Shrimp trapping results from the baseline study showed that more shrimp were trapped at 230 fms than in shallower water (Chave, 1977, VII-4). Since the dump site was located at 230 fms it appeared advisable to establish a control site at 230 fms about two miles distant from the dumpsite.

The principal current vector was unpredictable at the time. Since there was possible influence from the Honolulu Sewer Outfall and the Honolulu dump site to the east of the Pearl Harbor disposal site, the control site was established two miles to the west of the Pearl Harbor dump site at 230 fms. Trapping within the disposal area at 230 fms was impossible to the west because of the shallower depths there (see Allen and Moberly, 1977, Section III, p. 2).

During Set 1 on May 18, the dump site traplines were set on the disposal site coordinates but were recovered to the south-east (Figure VII-1) of a sandy area (Section III, photo line 1, Figures 9 and 10). The second dump site trapline (Set 1, July 18) was set and recovered in the same areas.

Figure VII-1. Shrimp trap Sets 1 and 2 in May and July, 1977.



Shrimp gills and intestines were examined for dredge spoil. Heavy metal analyses were conducted by Char (Section IV).

The area was not fished with handlines since no fishes were caught during the baseline survey. Fish catch data for April-June, 1977 (Areas 401 and 421) were prepared by the Hawaii State Department of Fish and Game. These were expanded using fish catch records from 1972-1976. Bottom photography methods are described in Section III of this report.

C. Results

1. Shrimp

The only commercially important species taken in the traps was Heterocarpus ensifer. The numbers taken and subsample size distributions are summarized in Figures VII-2 and -3. The catch ranged from 351 to 1376 individuals per set of 10 traps. The animals were in good condition. Their gills and intestines did not contain dredge spoil. The heavy metals tested in their tissues were in extremely low concentrations or not detectable (Section IV, this report). One shrimp was photographed during the photo trawls (Section 3, Figure 20).

2. Fish

No commercially valuable fishes were photographed.

Discussions were solicited with local fishermen to attempt to evaluate the effect of the spoil disposal on the fishery.

We found that some fishermen were not aware that dredge spoil disposal operations were being conducted in the area despite the fact that some boats passed by the disposal site enroute from Kewalo Basin to Barbers Point. Some thought that the turbidity in the area was caused by upwelling of the Honolulu sewer outfall. Others were aware of the dredging operations. None appeared to be worried about the fishery partly because we were monitoring the area and partly because they neither saw nor heard reports of spoil outside of the disposal site.

Preliminary catch statistics were compiled by the Hawaii State Department of Fish and Game for April through June in areas 401 and 421 (Barbers Point and surrounding areas). The "uku" or grey snapper (Aprion virescens) catch amounted to $22. A low "uku" catch was also recorded in 1976. The "ulua" or

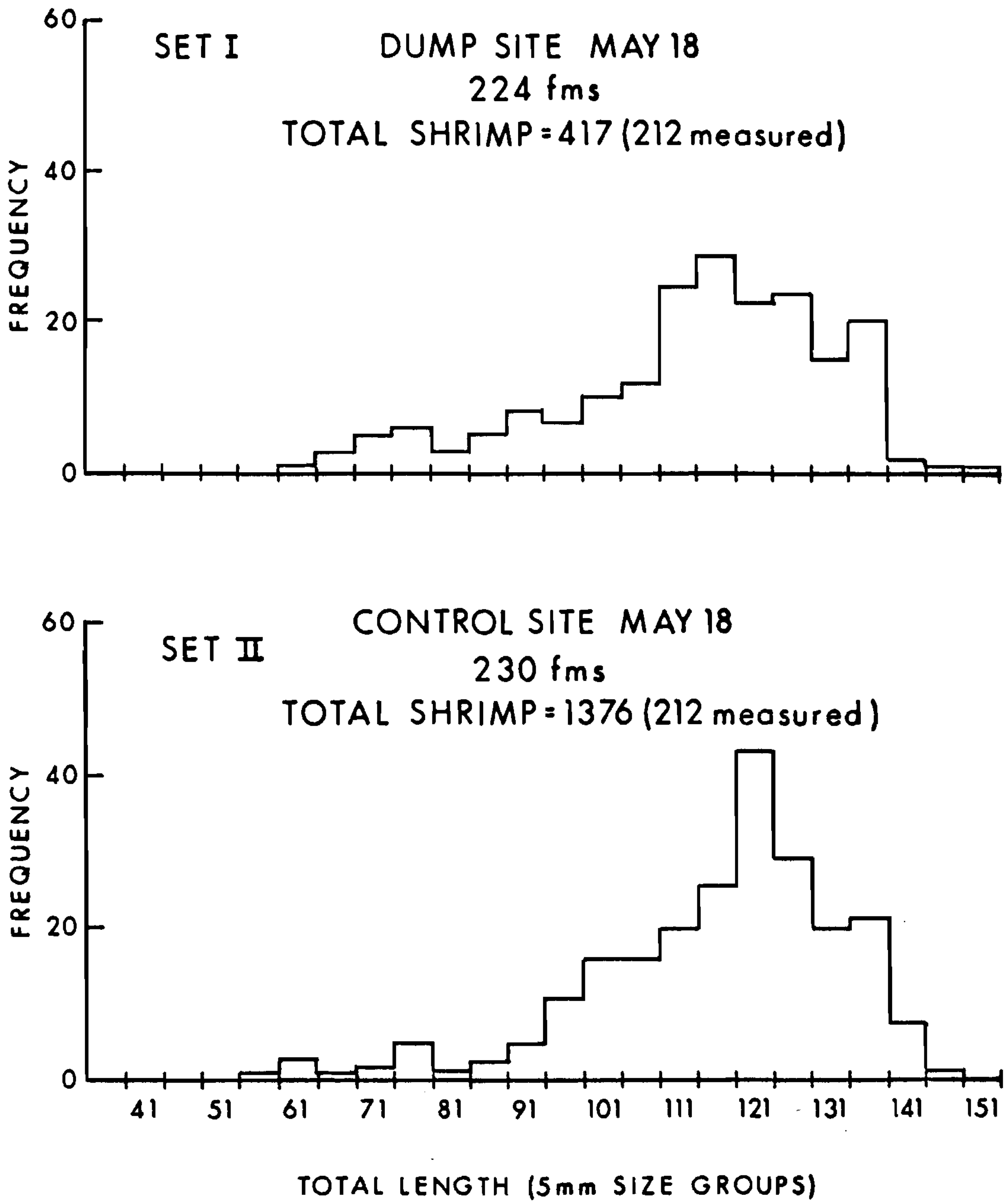


Figure VII-2. Length, frequency histograms of Heterocarpus ensifer subsamples in the Pearl Harbor dredge spoil disposal area on May 18, 1977.

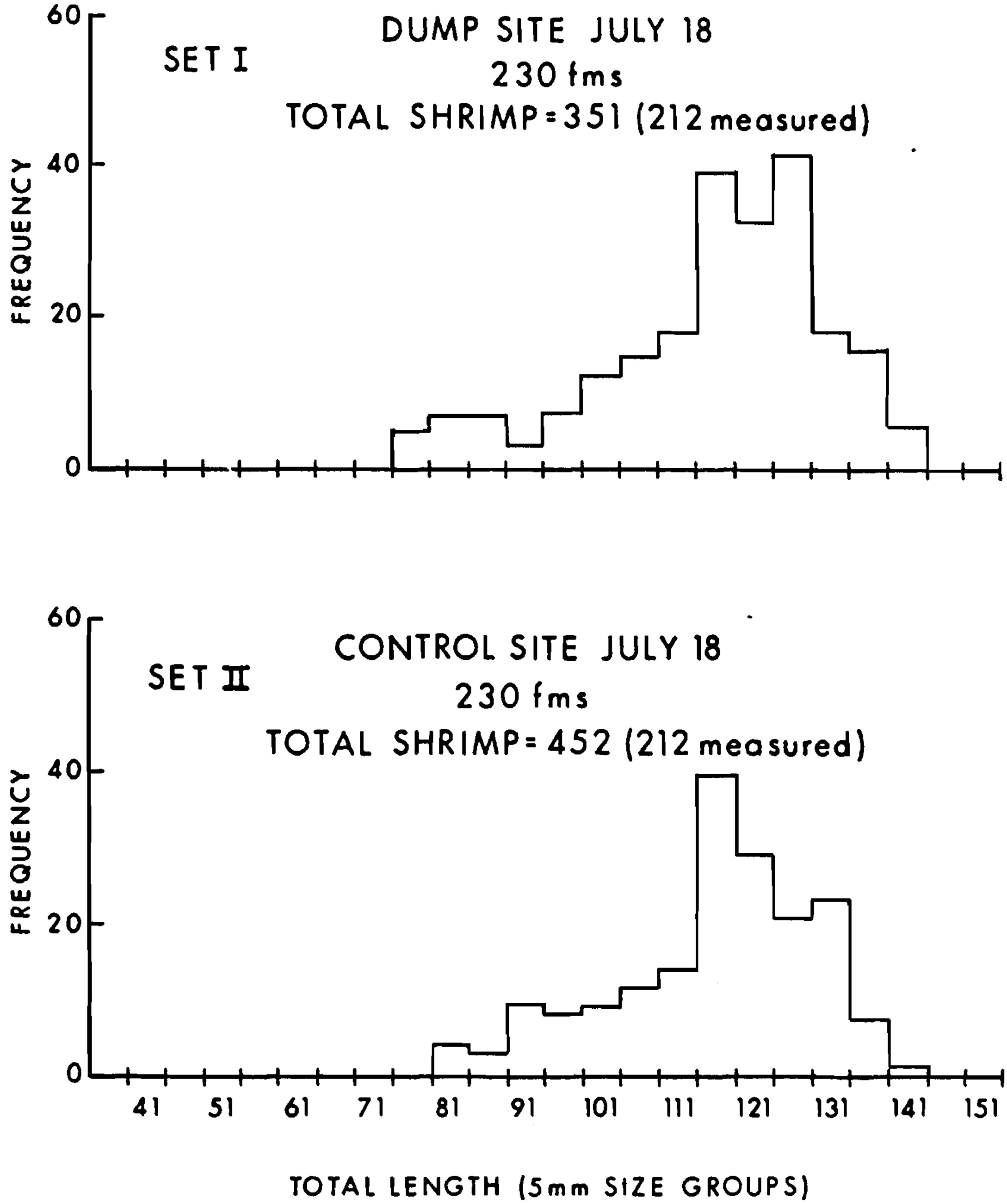


Figure VII-3. Length, frequency histograms of Heterocarpus ensifer subsamples in the Pearl Harbor dredge spoil disposal are on July 18, 1977.

Table VII-1. Values of Hawaiian "akule" and "opelu" fisheries around the disposal area (Fish and Game areas 401-421) during April, May, and June 1972-1977.

	Value $ of "Akule"	Value $ of "Opelu"
April 1972	1891	312
May	3233	1032
June*	2840	948
April 1973	945	372
May	1480	107
June	753	-
April 1974	4118	548
May	4489	282
June	5111	221
April 1975	4268	2887
May	1361	1390
June	2419	1231
April 1976	2850	765
May	3267	901
June	4949	2264
April 1977	2102	109
May	1125	-
June	3388	14

*Results for June preliminary

jack (Caranx, Carangoides) fishery amounted to about $2,951, a tenfold increase from 1976. The above fishes are generally caught along the Barber's Point Ledge. The offshore "aku" (Katsuwonus pelamis) fishery amounted to $6,905, a sixfold increase from 1976. Table VII-1 shows the value of "akule" (Selar crumenophthalmus) and "opelu" (Decapterus spp.) fisheries in the area during April through June 1972-1977. For both these species, catches decreased from 1976. Catch statistics during April-June of previous years show that the 1972 "akule" catch was similar to that in 1977. In 1973 the catch dropped; by 1974, a record "akule" catch was reported. "Opelu" catches in 1977 were slightly lower than the lowest catch in 1973.

D. Discussion and Recommendations

1. Shrimp

A comparison of the results of this study and the baseline study (Chave, 1977) shows that Heterocarpus ensifer was caught in significantly higher numbers during May and July, 1977 (67.2 indiv./trap) than during September, 1976 (27.1 indiv./trap). In May, 1977 there were significantly higher numbers of shrimp caught at the control site (137.6 indiv./trap) than at the dumpsite (41.7 indiv./trap). The differences may be due to several factors described below.

Since all traps were set within the depth range of the species (Clarke, 1972; Struhsaker and AAsted, 1974), depth of set between one area and another is probably not very important.

Time of year may be a factor. Although Clarke, Struhsaker and AAsted report that the Heterocarpus fishery is not seasonal, they stress that very few catch reports support this statement and the fishery needs further investigation.

Proximity to dredge spoil may be important. Of the three sets near the dumpsite, there was an increase in the number of shrimp during dumping (Set 2 in September 1976 yielded 295 animals, Set 1 in May 1977 was made during dumping and contained 417 animals, Set 1 in July 1977 was taken after completion of spoil disposal and contained 351 shrimp). These values are not statistically significant however, and seasonality, substrate type or previous shrimp trapping in the area might have affected the catch in each succeeding set.

Type of substrate seems to be the most important factor in determining shrimp abundance. The sediments near Set 2 in the control area were of coarse sand (Section III, Table 5, Station J8), and a total of 1828 shrimp were taken there. The sediments near Set 1 in the disposal area contained finer sand (Section III, Table 6, Station P4) and dredge spoil (Section VI, Figure 4, Station P4). A total of 768 shrimp were taken in these two sets.

Set 2 (May 1977) yielded 1376 shrimp. Set 2 (July 1977) 452 animals. Since both of these sets were made in the same area, the high number of shrimp in the May sample shows that we found a good shrimp fishing site and the lower number of shrimp caught in July probably indicates that most of the shrimp in the area were fished in May.

There were no significant differences in mean carapace length between the subsamples in the three 1976 and four 1977 sets. In all samples, the mean length varied between 115.2 and 119 mm. The large size of the shrimp in our samples is due to trap mesh size which allows animals of carapace lengths under about 50 mm to escape. Since there was no decrease in carapace length in the shrimp caught in July 1977, shrimp caught during this month were mature adults which either came from surrounding areas after the May set or didn't enter the traps on the first set.

There appear to be no discernable adverse effects of dredge spoil on the area's shrimp populations. Furthermore, the most productive shrimp haul (Set 2 in July 1977) contained 1.35 kg of shrimp per trap and is of marginal commercial value.

It is recommended that further monitoring of shrimp populations near but not at the 1977 sites be conducted during the Part C studies to determine whether these populations reach commercially valuable quantities of over 2 kg/trap during the fall and winter.

2. Fish

Owing to the fluctuating catch statistics, it is not currently possible to determine whether dredge spoil is affecting the fisheries. Dredge spoil disposal operations in 1972-74 do not seem to correlate with changes in the abundance of commercial fishes in the area. During the 1977 disposal operations, "akule" and "opelu" appeared to be healthy but the fishery has declined from 1976. It is, therefore, suggested that when April-June catch statistics for 1978 are available that the Navy request catch statistics on "akule" and "opelu" in areas 401 and 421.

E. Acknowledgements

I wish to thank Dr. Paul Struhsaker for his help in the shrimp study. Without the analysis of 1977 fish catch data by Mr. Clyde Miyazawa of the Hawaii State Department of Fish and Game, this report would be incomplete. I also appreciate the expertise of Mr. Skip Naftel and his crew aboard the R/V Easy Rider.

F. Summary

All fishes and shrimp examined showed no dredge spoil contamination in the gut or gills.

Shrimp were found in substantially higher numbers during and after dredge spoil disposal than during the baseline survey. More shrimp were caught at the control site than at the dumpsite probably because the substrate is more suitable for shrimp in the former area. Shrimp biomass is low in the disposal area. Set 2, July, 1977 contained the greatest amount of shrimp (1.35 kg/trap).

Fluctuating fish catch statistics make it impossible to evaluate the effects of the 1977 dredge spoil disposal on the Barbers Point fishery. Although the "aku" and "ulua" catch increased, the "akule" and "opelu" catch decreased from 1976. It is suggested that 1978 "akule" and "opelu" fish catch statistics for April-June be requested from the Department of Fish and Game.

G. Literature Cited

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VIII. RESPONSE TO REVIEW COMMENTS

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, HONOLULU
BLDG. 230, FT. SHAFTER, HI 96858

PODED-PV

21 October 1977

SUBJECT: Baseline Studies and Evaluation of the Physical, Chemical, and Biological Characteristics of Nearshore Dredge Spoil Disposal, Pearl Harbor, Hawaii

Commander, Pacific Division
Naval Facilities Engineering Command
Pearl Harbor, HI 96860

1. We have completed our review of the Navy's pre-final report dated 15 September 1977 and entitled "Baseline Studies and Evaluation of the Physical, Chemical, and Biological Characteristics of Nearshore Dredge Spoil Disposal, Pearl Harbor, Hawaii; Part B: Immediate Effects of Dumping: Monitoring Studies." We have no significant comments to offer, but have attached a number of suggestions for your consideration to improve the clarity of the report.

2. As you know, the primary responsibility for approval of your disposal site located at 21° 15.9' N, and 156° 56.7' W, rests with the U.S. Environmental Protection Agency. The opinions of other agencies, including the Corps of Engineers, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, and the Hawaii State Division of Fish and Game will also influence the decision to approve the site on a permanent basis for deep ocean disposal of harbor dredged materials. The acceptability of the site to these agencies is also a stated condition of the Department of the Army Permit issued to the Navy for this action under authority of Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972.

3. We thank you for the opportunity to review your report.

[redacted]

1 Incl
as

F. M. PENDER
Colonel, Corps of Engineers
District Engineer

U.S. CORPS OF ENGINEERS
COMMENTS ON THE PRE-FINAL REPORT OF THE
PEARL HARBOR DREDGE SPOIL DISPOSAL STUDY
PART B

GENERAL COMMENTS

1. Summary of Findings:

a. Suggest adding information on who performed the work and where it was concentrated.

b. Explain how the bottom photographs confirm the other evidence which indicates that coarse material settled to the bottom rather than fine material. From the photographs, were the investigators able to distinguish fine or coarse dredged materials from fine or coarse non-dredged materials?

2. Chapter II: Description of the Area and Dredging Operations:

Suggest adding more data from the Part A study to facilitate comparison to the Part B study. This comment also applies to the other sections of the report, including comparisons of methodologies from Parts A and B.

3. Chapter III: Geology and Physical Oceanography:

a. Page 5: Several of the symbols used on the figures are not explained, e.g., Maps III-2, and III-3.

b. Page 13: C results: Suggest adding a table which summarizes the type, quantity, and times that current data were successfully obtained from each station.

c. Pages 18-22: Explain the technical jargon used for the figure captions.

d. Page 24, Paragraph 3: Suggest expansion of interpretation of the acoustical tracking data results to consider which size fractions and the percentage of the total quantity of spoil material which could be tracked in this manner.

e. Page 25: Explain the criteria that were used to distinguish the dredged material from the non-dredged or ambient bottom material in the bottom photographs. Has the site been used in the past for dredged material disposal? If so, were the investigators able to distinguish dredged materials generated from the latest disposal operations from those of earlier ones?

f. Page 25, 33: State the vertical and horizontal precision of the bathymetric surveys. Is it valid to conclude that the precision of such surveys would be inadequate to detect shoaling at the disposal site attributed to the recent disposal activities given the depth of the water, volume of material and other factors?

4. Chapter IV: Water Chemistry:

Page 29: Is it possible to quantify what is meant by "at least a small fraction of fine sedment"? If known, how was this quantity estimated?

5. Chapter VII: Fisheries:

a. Page 2: Suggest labelling the location of the Barbers Point Ledge in the figure.

b. Page 3: What percentage of fishery areas 420 and 421 actually encompass the disposal site? Would a small percentage complicate interpretation of the fish count data for the areas?

c. Page 5: Figure VII-2, Set 2: Explain the reason for the two rows of numbers along the horizontal axis.

d. Page 7: Suggest consideration of the hypothesis that disposal operations could have attracted shrimp to the disposal site.

Response to Review Comments

Submitted by
U.S. Army Corps of Engineers

1. Summary findings:

   a. See Table of Contents for names of individuals responsible for each of their sections.

   b. See Discussions on pages III-32, III-38-42.

2. Chapter II: Description of the Area and Dredging Operations.

   Text has been modified to incorporate this recommendation.

3. Chapter III: Geology and Physical Oceanography.

Page III-5a	Captions have been revised on most figures and tables throughout the report.
Page III-13b	See Table III-1, page III-13.
Page III-18-22	Captions have been revised and expanded.
Page III-24	The percentage of the total quantity of spoil material which could be tracked acoustically is uncertain due to the potential cohesiveness of the finer grained sediments. Presumably the coarse sand-gravel material which forms something less than 25 percent of the spoil was initially observed in the disposal. Finer grained sediments, settling much more slowly, were difficult to distinguish from background noise.
Page III-25	See discussion on pages III-32, III-38-42.
Page III-33	See page III-32. It would indeed be invalid to conclude that the precision of the survey is adequate to detect any shoaling in the absolute sense. We do not attempt to do this. We are concerned instead with "significant shoaling in this context.

Page IV-29	The quantity of fine sediment is estimated by the suspended solids and turbidity measurements discussed on pages IV-2,3 IV-27-29.
Page VII-2	The Barbers Point ledge is a general area above the 50 fm contour in the vicinity of stations G2 and G4 on Figure VI-8, page VI-12, 13 and Figure VII-1, page VII-2.
Page VII-3	We do not have the actual percentage of fishery areas covered by 401 and 421. The areas were selected on the basis that the dredge spoil disposal site was included within those State Fish and Game Fishery areas and that the records would provide some fishery data otherwise unattainable. The specific area of the disposal site is considered by the local fisherman to be of extremely low yield.
Page VII-5	Caption was modified to remove second set of numbers.
Page VII-7	See discussion on page VII-7,8.

2405 W
FL H

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Division of Ecological Services
300 Ala Moana Blvd., Rm. 5302
P. O. Box 50167
Honolulu, Hawaii 96850

Reference: ES

September 26, 1977

Mr. Warren C. Johnson, Director [redacted]
Design Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860

Dear Mr. Johnson:

As requested in your letter of September 19, 1977, we have reviewed the Pearl Harbor Dredge Spoil Disposal Site Study, Pearl Harbor, Hawaii, Part B. We are concerned that a number of the conclusions reached in your study are not supported by the data presented. Our specific comments are as follows:

Page IV-4 - Shrimp Trapping Stations. The "control" station appears to be down-current from the point at which spoil was dumped. The direction of current flow (Page III-13, last paragraph) would move suspended material toward the "control" trapping station. This conclusion is supported by the data presented on pages V-4 (last paragraph), VI-11, and VI-19 (summary paragraphs 2 and 4).

Page IV-27 - Higher heavy metal concentrations in shrimp taken at the "control" site tend to support our concerns presented above.

Page IV-33 No. 8 - Although the data on page IV-27 indicate that the "control" shrimp had a total heavy metal load 29.2% greater than those captured at the dump site, the data presented make it impossible to verify the conclusion in item No. 8. If anything they tend to disprove it, since a 29.2% difference would seem to be significant. Were statistical tests run to determine if there was a significant difference in heavy metal concentrations between shrimp taken at the two sample sites? If so, what tests were used? Where is the data on which such statistical

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

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tests were (or should have been) based?

Page V-5 - Zooplankton. The variations in zooplankton sampling methodologies between parts A and B of the study make comparisons of the sampling extremely difficult, and any conclusions on zooplankton population changes highly questionable. As the situation now stands, the effect of spoil disposal on zooplankton populations is unknown.

Page V-9 - Paragraph 3. The extent of gill damage noted in this paragraph precludes a determination on the effect of spoil disposal on euphausiid respiration. Therefore, conclusion No. 3 on page V-12 is misleading, since it would lead one to believe that your studies revealed no gill clogging. The sentence should be reworded as follows:

> "Due to physical damage to gill structures sustained during zooplankton capture, the effects of spoil disposal on euphausiid respiration could not be determined."

Finally, we wish to emphasize that we believe that spoil from Pearl Harbor and Honolulu Harbor maintenance dredging should be placed in a single site. Regardless of the ecological values, or lack thereof, at either site, this is only logical, environmentally sound procedure.

We appreciate the opportunity to provide comments. Please keep us informed of any new project developments.

Sincerely yours,

[redacted]

Field Supervisor

cc: HA
ARD(AE)
EPA - San Francisco
NMFS HDF&C

Response to Review Comments

Submitted by
U.S. National Marine Fisheries Service

Page VII-5 — The shrimp population will be monitored during the fall and winter of 1977. Continuation of the monitoring program to determine long term potential enhancement of the shrimp population at this site is beyond the scope of this study.

Page V-9

It is true that any physical damage to euphausiid gills due to suspended sediment could not be determined due to damage resulting from capture. However, none of the euphausiids examined whose gills were wholly or partially intact showed any evidence of sediment adhering to the gills. This section has been reworded to clarify the findings (page V-9).

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
Southwest Region
Western Pacific Program Office
P. O. Box 3830
Honolulu, Hawaii 96812

October 6, 1977 FSW1/JJN

Mr. Warren C. Johnson
Director, Design Division
Naval Facilities Engineering Command
Pearl Harbor, Hawaii 96860

Dear Mr. Johnson:

Subject: Review of Pearl Harbor Dredge Spoil Disposal Site Study, Part B

We have reviewed the subject study as requested in your letter of 19 September 1977. This office has been reviewing and commenting on all aspects of your ongoing study as well as the Corps of Engineers' study entitled, "Environmental Surveys of Deep Ocean Dredged Spoil Disposal Sites in Hawaii," since the inception of both. Our primary concern has been the effects of dredge spoil deposition on existing and potential fisheries at the proposed dump sites.

Data from these studies indicate that impacts on the existing bottom handline and midwater handline fisheries from dredge spoil deposition at the proposed site will be minimal. We continue to be concerned, however, with the potential of the general area for development of a shrimp fishery. Of particular interest is an indication during both ongoing studies of a post-spoil deposition increase in biomass of shrimp in the immediate vicinity of the dump site. Therefore, we concur with the study recommendation that the shrimp population near the 1977 test site be monitored further to determine whether the population reaches commercially valuable quantities during the fall, winter, and early spring of 1977-78. Ideally the shrimp population should be sampled for an additional year beyond this period.

In light of the potential and existing fisheries along the southern coast of Oahu, and in order to minimize environmental damage in general, we again strongly recommend that only one site be utilized for dumping dredge spoil in Mamala Bay.

Sincerely,

[redacted]

Doyle E. Gates
Administrator

cc: Gary Smith, FSW3
Maurice Taylor, FWS, Honolulu
Hawaii State Div. of Fish & Game
EPA, Region IX, San Francisco
Col. Pender, U.S. Corps of Engineers

Encl(2)

Response to Review Comments

Submitted by
U.S. Fish and Wildlife Service

Page IV-4

The control station is downstream from point at which spoil was dumped. The direction of current flow would tend to move suspended sediment toward the "control" trapping station.

However, results of this study indicate that the bulk of the material appeared to settle within a small radius (<0.5 mi) of the designated dump site as evidenced by heavy metals concentrations in bottom sediments (Figure IV-9). While a small amount of fine material was observed to have remained in suspension, its distribution over a wider geographic area, including its dispersal towards the "control" trapping station, would also mean greater dilution of the resulting sediment metals concentrations. In other words, sediment metals at the "control" station and other stations outside the immediate dump site area should not have increased significantly over concentrations found prior to dumping operations. This in fact is what was observed in the present study (t test, $p>0.05$). The difference between dump site total metals ($\bar{x}$ = 407.) and other stations $\bar{x}$ = 264.), on the other hand, was significant during Part B monitoring studies (t test, $p<0.05$).

Page IV-27, IV-33 #8

The data presented in Table IV-11 were based on four shrimp collected from each site. Due to the small sample size, caution should be exercised in applying any statistical test to these data. However, the t test for a difference between two means was applied to the total metal body burdens of shrimp from S1 and S2, and the difference observed at these stations was not significant ($p > 0.05$). The difference observed between the two means appears to be a result of chance and/or small sample size.

Page V-5

Sampling methodology in Part B differed from Part A only in eliminating day tows and towing somewhat deeper at night. The biggest obstacle to comparing Part A and Part B results is the difference in the physical characteristics of the water column due to kona weather prevailing during Part B sampling, not variations in sampling methodology. See the discussion on page V-10,11.

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

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October 25, 1977

Mr. Warren C. Johnson, P.E.
Director, Design Division
Pacific Division
Naval Facilities Engineering Command
Makalapa, Hawaii
FPO San Francisco 96610

Dear Mr. Johnson:

As requested in a telephone conversation with Mr. Richard Leong of your staff on October 14, 1977 and document transmittal of October 18, 1977 we have reviewed "Part B - Immediate Effects of Dumping: Monitoring Studies" - Prefinal Report: Pearl Harbor Dredge Spoil Disposal Site Study, Pearl Harbor, Hawaii.

From the fisheries standpoint, the report generally appears satisfactory in regards to the immediate environmental effects asso[illegible]ed with the disposal of current amounts of dredge spoil at the propose[illegible] [illegible]y's site. No further comments are offered at this time.

Yours truly,

[redacted]

MICHIO TAKATA, Director
Division of Fish & Game

MT:AZK:rfm

cc: Roger Evans
Planning Office, DLNR

ENCLOSURE 1