A PRELIMINARY STUDY OF SOME ECOLOGICAL EFFECTS OF SUGAR MILL WASTE DISCHARGE ON WATER QUALITY AND MARINE LIFE KILAUEA, KAUAI

by

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ABSTRACT

Mill discharge from Kilauea Sugar Company discolors the receiving waters off the north coast of Kauai and increases the turbidity thirty-fold over that for normal waters. Coral growth is abundant in this area except near the mill discharge outfall. The epibenthic community is dominated by a single genus of coral, Montipora, *and shows very little diversity. Bagasse and other cane debris were observed and photographed on intertidal reefs and in the subtidal zone as far as three miles from the outfall.*

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INTRODUCTION

For the past 80 years, lands in the Kilauea area along the northern shore of the island of Kauai have been used extensively for agriculture. Over 4,000 acres have been utilized primarily for the production of sugarcane by the Kilauea Sugar Company (See Appendix A for a short description of the plantation). Virtually all of these agricultural lands are located along the coast. The area between Hanalei Bay to Kilauea Bay is dissected by numerous streams and valleys, resulting in a complex topography. The coastline is exposed to predominantly northeast tradewinds and has elevations ranging from sea level to 1,000 feet[1] in the interior. Most of the crops lie below the 600-foot altitude. Agricultural lands extend to the coast and drop off sharply to the sea with declivities, in most areas, of greater than 80 percent. There are ample beaches and future parks have been proposed for the area.

The streams between Hanalei and Kilauea carry the natural runoff from land served by these tributaries and contribute large amounts of terrigenous silt, clay, and mud along with incidental agricultural fertilizers and organic debris into the offshore waters. In addition, sugar processing and industrial facilities have been discharging various amounts of silt, bagasse, cane stalks, fly ash, factory restroom wastes, sugar, and traces of oil from factory lubricants into the offshore waters. This discharge of over 3 million gallons per operating day, which has been found to contain fertilizers, herbicides, insecticides, fungicides, and heavy metals, enters Niu Stream, about one mile near the town of Kilauea before it reaches the ocean, a drainage area roughly encompassing the land between Kilauea and Kalihiwai Rivers (Fig. 1).

A multi-disciplinary project was planned and submitted in February 1971 by the Water Resources Research Center of the University of Hawaii to the Office of Sea Grant Programs to identify, develop, and evaluate the critical physical, biological, and rational parameters needed in formulating effective policies, institutions, and systems for protecting

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[1]Measurements of surficial or horizontal distance is given in feet, yards, or miles to coincide with maps used to show station sites.

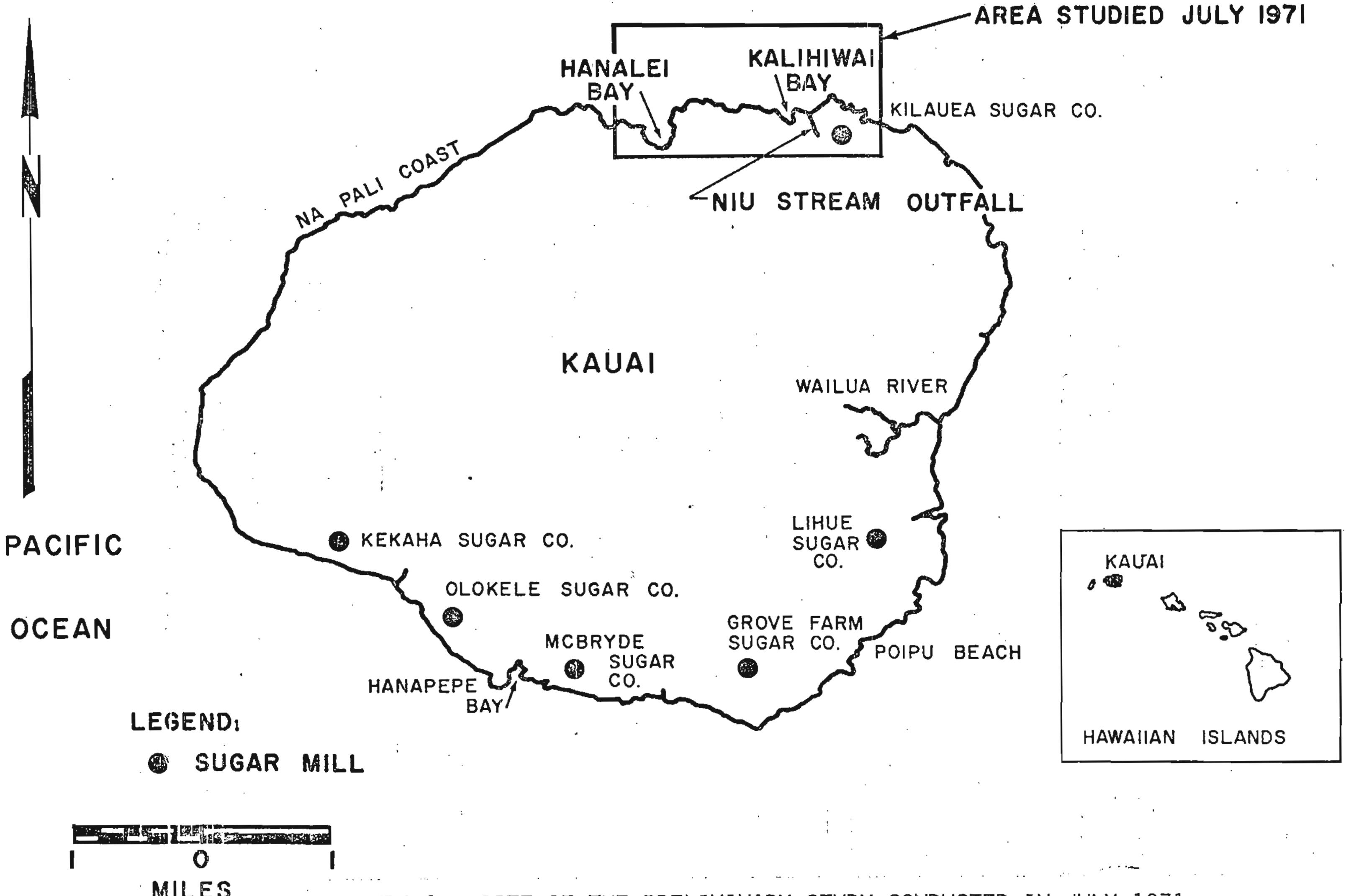

FIGURE 1. SITE OF THE PRELIMINARY STUDY CONDUCTED IN JULY 1971 AND LOCATIONS OF SUGAR MILLS ON THE ISLAND OF KAUAI.

the quality of coastal waters in Hawaii. A preliminary study of the receiving waters off Kilauea to augment the larger statewide effort was conducted during July, 1971 to determine the gross biological conditions of the general effects of the Kilauea Sugar Company Mill discharge on offshore waters. The company is discontinuing its operations in 1971 and this presents an opportunity for determination of *before-and-after* effects.

GENERAL DESCRIPTION

Shoreline

Most of the approximately seven miles of coastline between Hanalei Bay and Kilauea Bay are outlined with broad, fringing algal reefs backed by long stretches of narrow sandy beaches. From Kilauea Bay to Mokolea Point (Fig. 2) the shoreline is mostly sandy beach with a fringing reef extending along the entire length. Background land slopes are generally gentle with declivities of 0-10 percent. Between Mokolea Point and Makapili Rock the coastline is characterized by sheer cliffs and a general absence of beaches. There is some sandy beach shoreward of Makapili Rock perhaps due to the disruption of longshore current processes by the shadowing effect of the rock outcrop. Generally from Makapili Rock to Kilauea Point (Fig. 2) the shoreline is rugged. There is one small stretch of beach west of Makapili Rock. Background declivities are greater than 80 percent. The stretch of coast from Kilauea Point to Kapukaamoi Point (Fig. 2) is characterized by broad sandy beaches with a background of steep cliffs of greater than 80 percent slope. Between Kapukaamoi Point and the Niu Stream outfall, 600 yards to the east, lies a small fringing reef (Fig. 2).

The shoreline of Kalihiwai Bay (Fig. 3) is backed by a broad sandy beach and gently rolling land slopes. The coastal area between Kalihiwai Bay and Puu Poa Point (Figs. 3 and 4) is mostly narrow sandy beach. A broad fringing algal reef extends along this stretch of coast almost continuously around Puu Poa Point into Hanalei Bay. The length of coastline between Kalihiwai Bay and Honono Point is backed by cliffs with greater than 80 percent declivity.

Reef Stations

During low tide observations were made on three reef stations, Stations A, B, and C. Locations of the reef stations surveyed are shown in Figures 2 and 3 and the stations are described in Table 1. Population counts were made of echinoids on the reefs (Table 2).

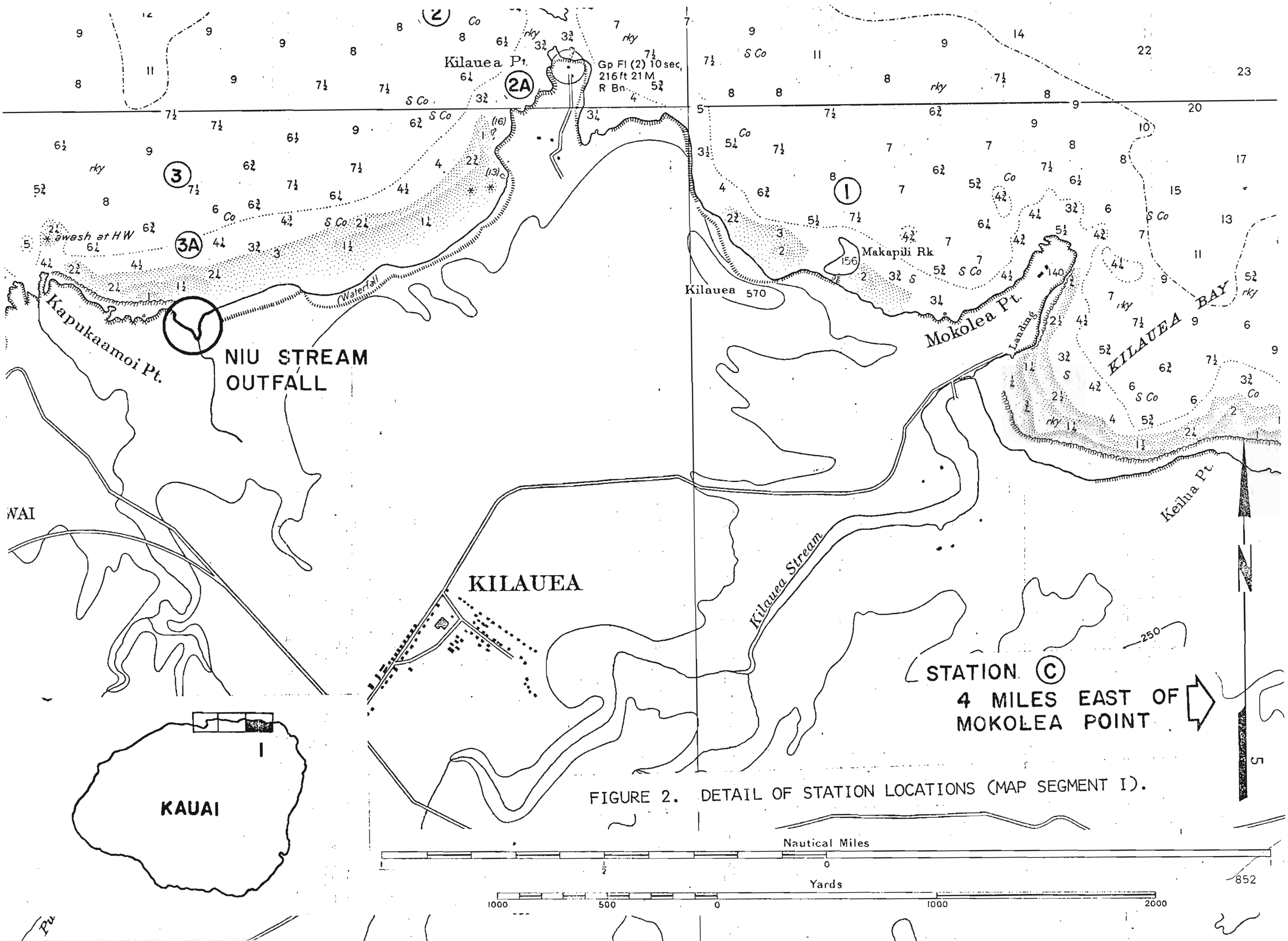

FIGURE 2. DETAIL OF STATION LOCATIONS (MAP SEGMENT I).

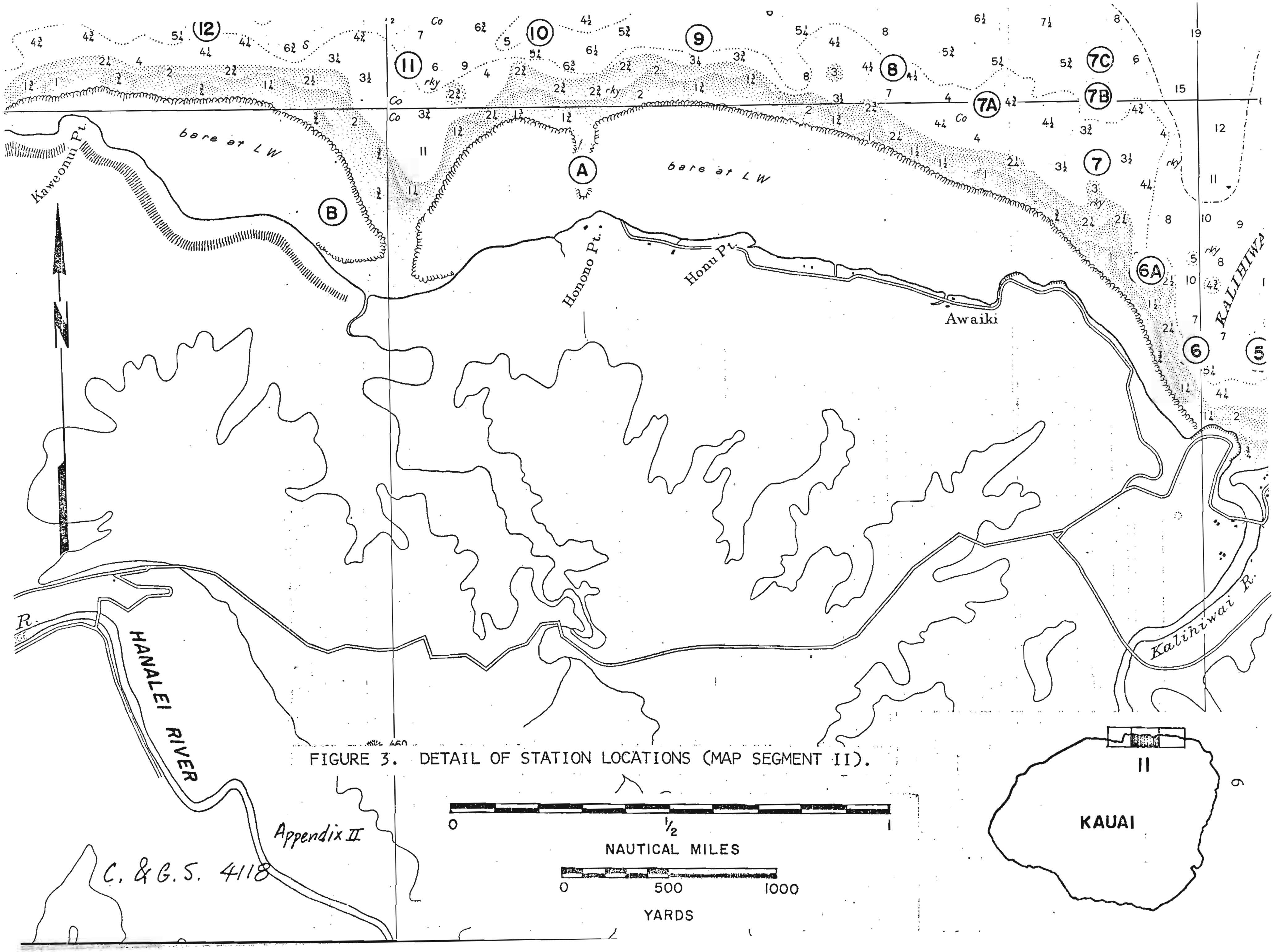

FIGURE 3. DETAIL OF STATION LOCATIONS (MAP SEGMENT II).

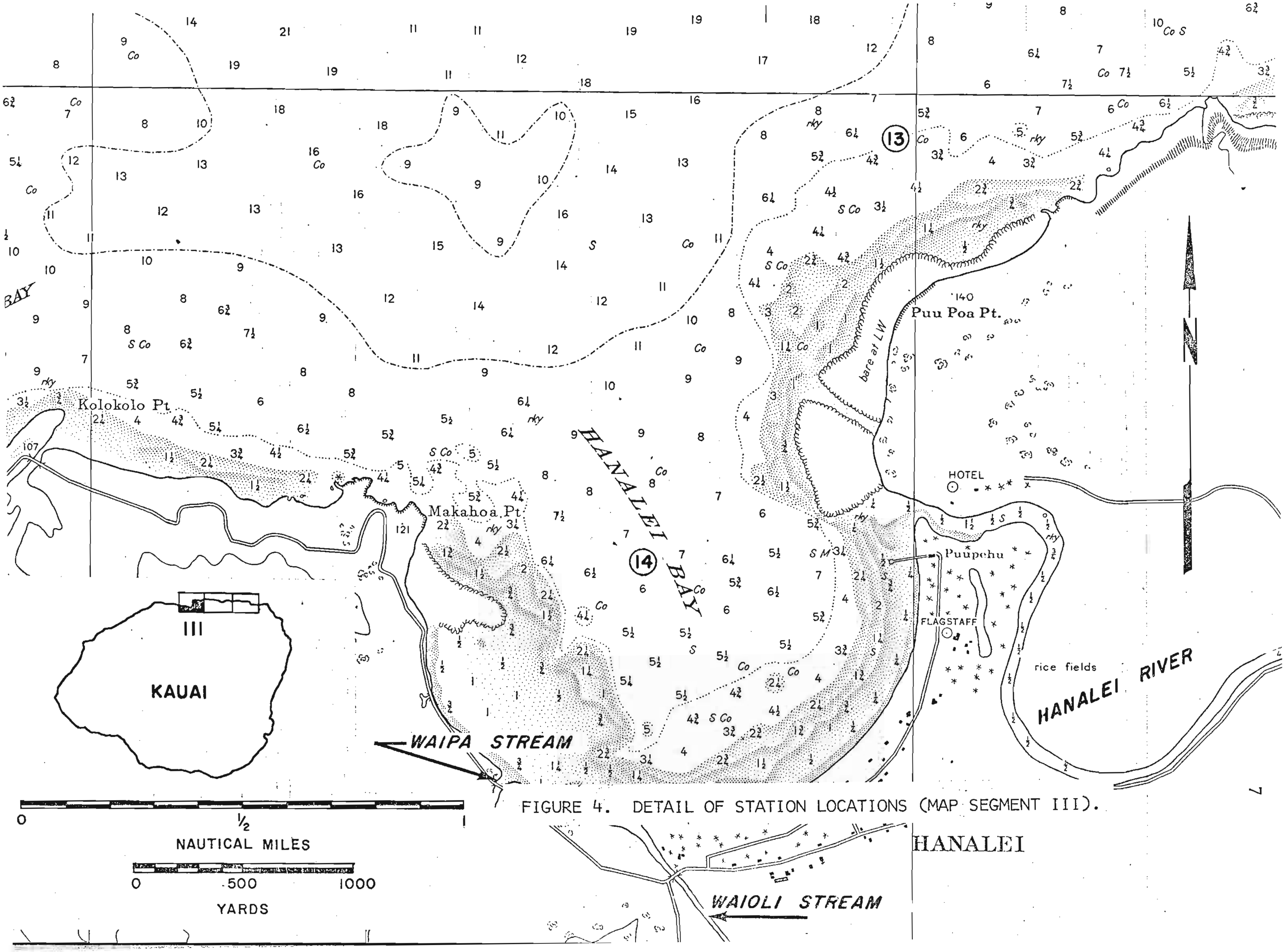

FIGURE 4. DETAIL OF STATION LOCATIONS (MAP SEGMENT III).

Table 1. REEF STATIONS

STATION	LOCATION	GENERAL DESCRIPTION
A	250 yds North of Honono Pt. (Fig. 3) On Anini Reef, 250 yds from the beach.	Both reefs showed little or no coral coverage, numerous dead coral heads *Pocillopora* and *Porites*; large amounts of bagasse and other cane debris strewn on reef, scum collected in shallow static pools, 18 out of 20 quadrats sampled showed extensive silt laden algal growth of *Dictyosphaeria*, *Ulva*, and *Padina*. Sea urchins and other invertebrates were scarce. *E. mathaei* and *E. oblonga* were the most abundant macro fauna observed. (Table 2)
B	½ mile west of Honono Point (Fig. 3) On Anini Reef, 200 yds from the beach.	
C	4 miles east of Mokolea Point (Fig. 2) 100 yds from the beach.	Some coral growth mostly *Montipora*; numerous dead *Pocillopora* coral heads, no bagasse or cane debris seen, abundant silt laden algal growths of *Dictyosphaeria*, and *Padina* noted, very little fauna seen, sea urchins *E. mathaei*, *E. oblonga*, *C. paucispinus*, and *Tripneustes gratilla* were observed. (Table 2)

Table 2. REEF STUDY OF SEA URCHIN POPULATIONS

Species	Density #/m2	Frequency	Relative Density
Station A			
Echinometra Mathaei	3.0	.77	.86
Echinometra Oblonga	0.5	.22	.14
Station B			
Echinometra Mathaei	2.0	.5	.82
Echinometra Oblonga	0.45	.2	.18
Station C			
Echinometra Mathaei	18.0	1.00	.80
Echinometra Oblonga	3.0	0.89	.13
Centrechinus Paucispinus	1.5	0.56	.07

Density = # individual / m2

$$\text{Frequency} = \frac{\text{No. of quadrats with individuals of species X}}{\text{Total no. of quadrats}}$$

$$\text{Rel. Density} = \frac{\text{Density of species X}}{\text{Total density of all species}}$$

Offshore Stations

The description and locations of the major offshore stations surveyed along with a summary of results are given in Table 3 and shown in Figures 2 to 4, respectively. Dives were made on days when seas were calm and winds were light. The discoloration and turbidity of the receiving waters varied from day to day depending on the sea state and wind conditions. The mean monthly ocean wave direction for July, in degrees true for Kilauea Point has been determined to be about 060 or approximately northeasterly (Ho and Sherretz, 1969). During July, 1971 the discharge plume was developed predominantly to the west across the mouth of Kalihiwai Bay. According to local fishermen and aerial photographs taken after 1965, discolored waters from the outfall penetrate the bay (Land Study Bureau, 1967). Figure 5 shows the average extent of discoloration for July, 1971.

Underwater as well as surface photographs taken on the reefs for several shoreline and reef stations are shown in Appendix B.

Table 3. DESCRIPTION OF MAJOR OFFSHORE STATIONS

STATION NO.	DEPTH (m)	O_2 ppm	DEPTH OF CLARITY (m) July 15, 1971	HORIZONTAL VISIBILITY (m)	T °C/S °/°°	SUBSTRATE AND BOTTOM TOPOGRAPHY	LOCATION AND GENERAL DESCRIPTION
1	9	6.1	15	35	27/36.8	flat sandy bottom with large areas of rock formations	1 mile east of outfall, 300 yds. Devoid of benthic fauna. Some *Padina* observed, bottom surge strong, scour marks noted. No bagasse.
2	10	6.4	7	--	26/	flat rocky bottom scattered sand pockets	½ mile east of outfall, 400 yds west of Mokuaae Island. Plume well developed, water very turbid. No bagasse.
2A	8	---	--	15	---	flat, rocky	below Kilauea light house ½ mile east of discharge. Medium coral mostly *Montipora* and *Porites*. No bagasse, some silt observed.
3	8	5.3	8.5	2	26/35.5	flat, rocky	900 yds seaward of Niu Stream outfall, some algal growth windrows of bagasse 50 yds long floating on surface, no bottom fauna seen.

STATION NO.	DEPTH (m)	O_2 ppm	DEPTH OF CLARITY (m) July 15, 1971	HORIZONTAL VISIBILITY (m)	T °C/S ‰	SUBSTRATE AND BOTTOM TOPOGRAPHY	LOCATION AND GENERAL DESCRIPTION
4	8	6.0	5.5	2	26/36.4	bare, flat, rocky w/ long crevices running perpendicular to shore.	½ mile to west of outfall, no flora or fauna seen, large amounts of bagasse and cane stalks
5	10	6.0	8.0	3	25/36.1	Sand; 50 yds to west reef cliff rising to 5m depth	East side of Kalihiwai Bay, *Montipora* seen on reef cliff, reef flat covered w/ mud and silt bagasse and cane stalks seen. Large numbers of burrows of mud shrimp *Callianassa at 15 m*
6	11	6.0	5.0	1	25/36.6	flat, sandy; 100 yds to west reef flat	West side of Kalihiwai Bay, abundant coral of all kinds seen, abundant *Dictyosphaeria* and *Padina* growth, little bagasse.
7	7	5.4	3.2	26	25/35.4	rocky reef w/ sand channels parallel to shore	700 yds outside west edge of Kalihiwai Bay, abundant coral (*Montipora*), bagasse and cane stalks seen, 2-3 m plume thickness, clarity of water increased sharply below this layer of suspended solids.
8	9	6.0	15	32	26/36.4	rocky, rugged, dissected by many crevices and channels	900 yds off the coast west of Kalihiwai Bay 1½ miles from the outfall, bagasse and cane stalks seen in trace amounts, abundant coral, and abundant fish.

STATION NO.	DEPTH (m)	O_2 ppm	DEPTH OF CLARITY (m) July 15, 1971	HORIZONTAL VISIBILITY (m)	T °C/S ‰	SUBSTRATE AND BOTTOM TOPOGRAPHY	LOCATION AND GENERAL DESCRIPTION
9	11	6.2	15	35	26/36.8		2 miles west of mill discharge, 900 yds offshore. no bagasse, abundant coral mostly *Montipora*, abundant fish.
10	---NOT SURVEYED---						
11	---NOT SURVEYED---						
12	8	6.1	15	--	25/34.5	flat, rocky, gentle slope to shore. 800 yds from shore reef drops to 22 m	3½ miles west of outfall and 600 yds NE of Kaweonui Point, abundant coral and fish, sea urchin *C. paucispinus* seen in large numbers. At 22 m large amounts of bagasse piled along reef cliff base (see Fig. 4). Turbid water at this depth.
13	11	---	15	--	25/--	flat, rocky, gentle slope to shore.	5 miles west of outfall, 700 yds NW. Puu Poa Pt. abundant coral, some cane stalks seen.
14	12	5.9	6	--	25/29.2	soft, fine, black mud at least ½ m thick.	In Hanalei Bay 750 yds due north of the mouth of the Hanalei River, 6 miles from the outfall.

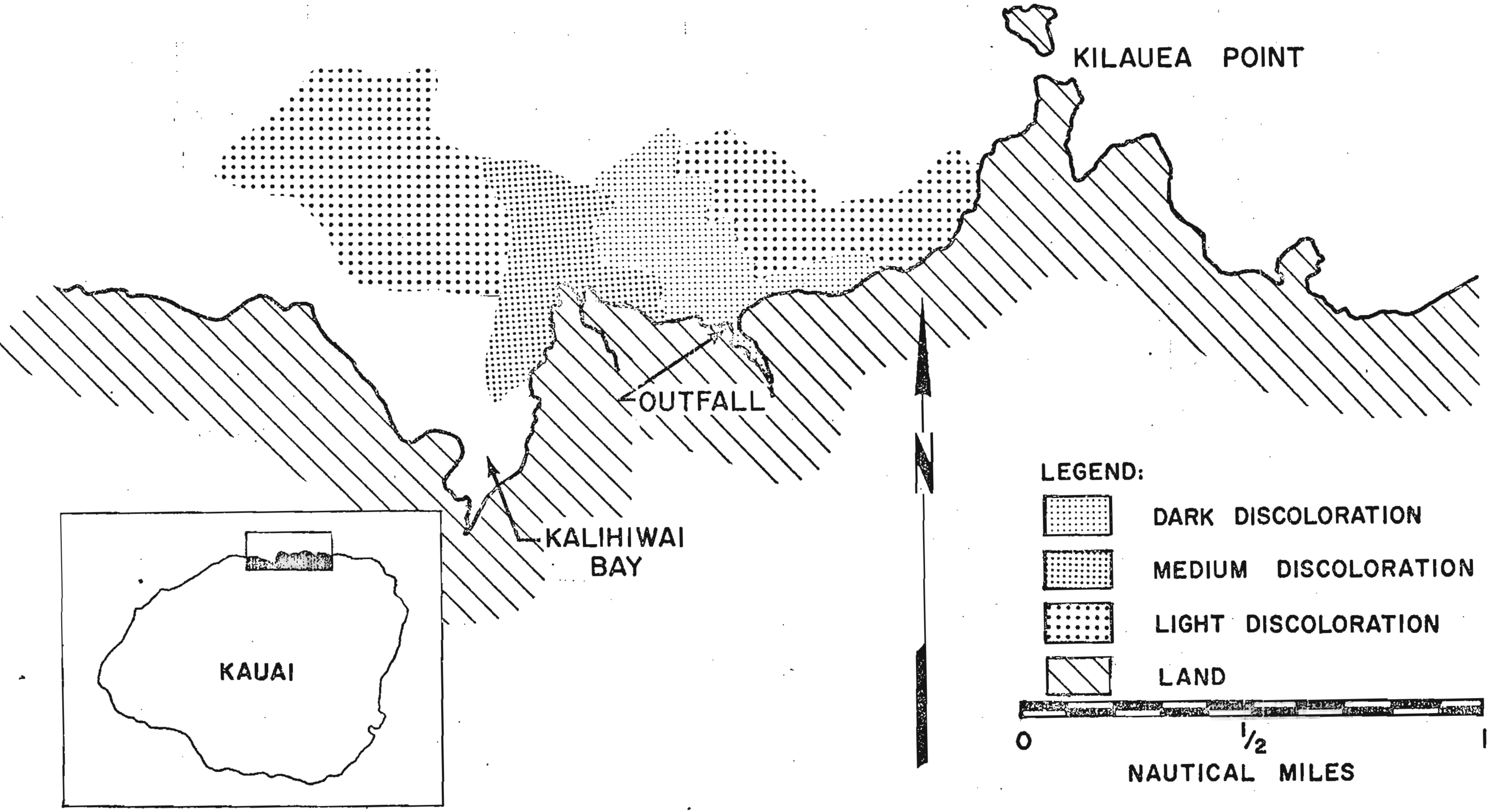

FIGURE 5. AVERAGE PLUME DEVELOPMENT AT THE NIU STREAM OUTFALL: JULY 1971.

METHODS AND MATERIALS

Fourteen major subtidal stations and three stations for reef studies were chosen for detailed underwater observations and six substations for extra turbidity measurements (Figs. 2-4). The major offshore stations were situated at depths of approximately ten m and were spaced about equally along the Kilauea coast between Hanalei Bay and Kilauea Bay. Reef Stations A and B lie in the path of the mill discharge plume and Reef Station C, 2 miles east of Kepuhi Point and 6 miles from the outfall, was chosen as a control. At each major station, the depth was recorded with a standard Navy depth gauge and temperature readings were taken with a standard centigrade thermometer.

A gallon jar set in a burlap bag was lowered to the bottom and opened by divers to fill the jar with bottom water. The sample water was analyzed for dissolved oxygen content with a YSI oxygen meter and for salinity with a salinity titration kit (mfr. LaMotte Chemical Corporation, Model POL-H). Three titrations were made and averaged for each water sample. The remainder of the samples were put into plastic bags and placed in appropriate glass or metal containers for analysis at the University of Hawaii.

Turbidity measurements were made using a 12-inch diameter Secchi disc. Eighteen stations were monitored. Turbidity measurements were taken at all major stations and substations on the same day, July 15, 1971 for comparison. Substations provided not only supplementary data, but they were continuously monitored.

Horizontal visibility was measured at six stations utilizing a 50-meter transect line marked every meter with tape. While one diver remained stationary on one end, the other diver moved along the line until the first disappeared. At two of the stations horizontal visibility was estimated by sight.

At stations where coral was present and the visibility not limiting, estimates of the percent of coral coverage were made by dropping a one m^2 quadrat along the transect line at random intervals at the same depth. Five to ten quadrats were averaged and the area was designated heavy, medium or sparsely covered depending on whether there was greater than 80 percent, 50-80 percent, or less than 10 percent coral coverage, respectively. Where no coral was visible, zero was recorded. In addition, the presence or absence of echinoderms, especially sea urchins, was recorded. All recording was done on white plastic sheets mounted on a clip board. The presence or absence of bagasse, cane stalks, silt, and estimates of fish were also recorded, subject to the diver's interpretation of heavy or sparse concentrations (Fig. 6).

Three transects were made across the reef at stations A, B, and C during low tide. A 50-m transect line was placed on the reef parallel to shore. A one m^2 quadrat was centered over pre-selected random points and the density of sea urchins was determined. This method not only gives estimates of abundance but also of frequency and distributional pattern (Grigg, 1970).

Photographs were taken at most stations with a Nikonos II underwater camera. The focal length needed to fill one frame with one meter square was predetermined and some of the photos were taken at this focal length. This technique not only facilitates counting of organisms per unit area, but gives a permanent pictorial record of the ocean bottom at a specific site. Samples of bottom sediments at all major stations were analyzed at the University of Hawaii.

DISCUSSION OF THE RESULTS

Dissolved oxygen, temperature, and salinity measurements for the major offshore stations are tabulated in Table 3. Oxygen readings tended to be fairly constant over 9 of the 11 stations sampled. The mean oxygen tension was 5.9 ppm (standard deviation = 0.32, standard error = 0.09). Stations 3 and 7 showed readings which were significantly different from the mean (t-distribution A = 0.01). The saturation value for dissolved oxygen in sea water at 26° C and 36.1‰ salinity is 4.78 ml/l or 6.85 ppm (Sverdrup, *et al.*, 1942), hence, 5.9 ppm O_2 represent 86 percent saturation value.

Salinities did not change significantly from station to station except for low values at Stations 12 and 14. Station 14, situated in Hanalei Bay, indicated relatively fresher water due to discharge into the Bay from three rivers.

Turbidity, measured as depth of clarity, decreased sharply as the

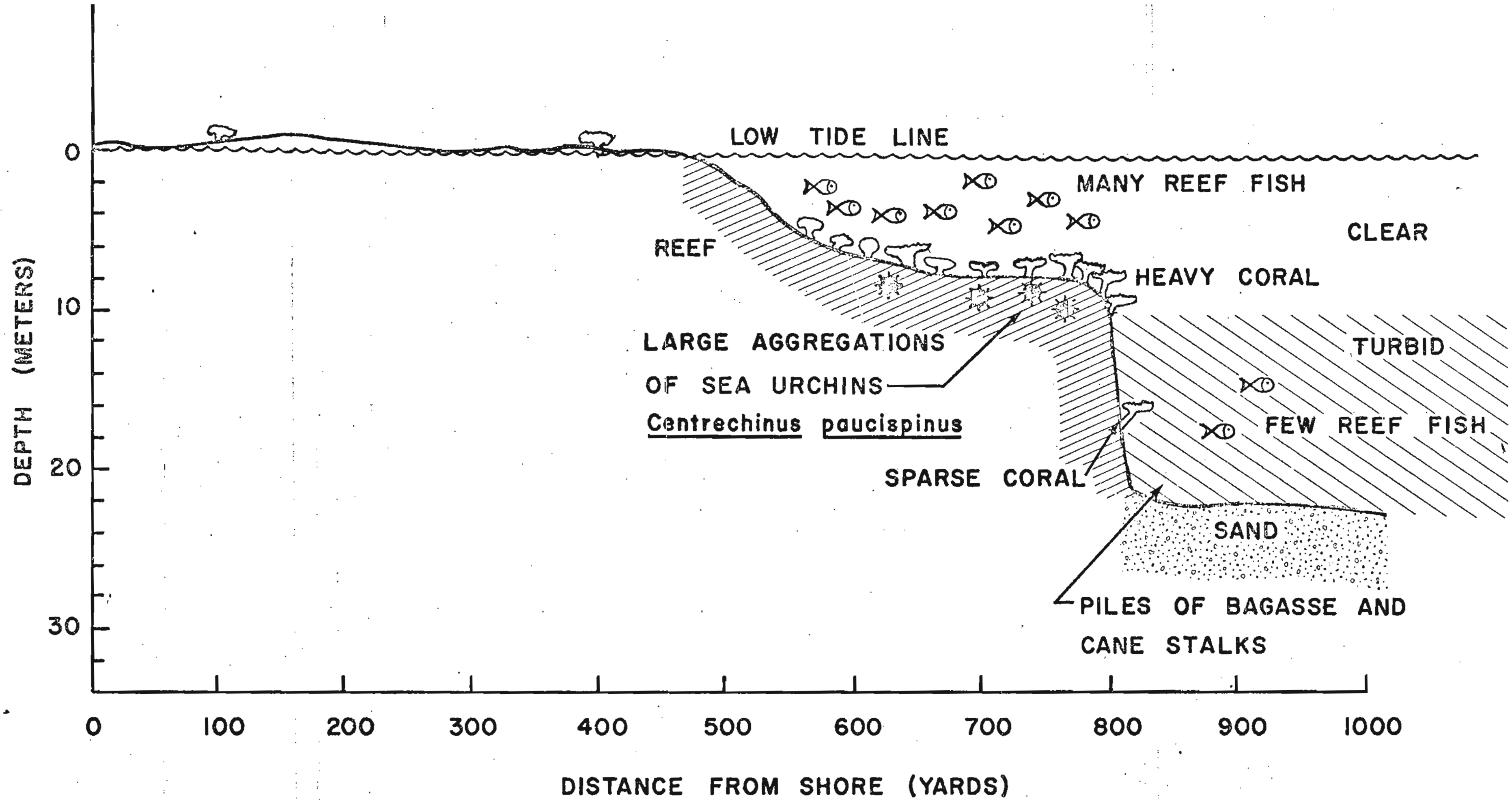

FIGURE 6. PROFILE OF STATION 12.

horizontal distance to the outfall decreased (Fig. 7). Using 15 meters as the control depth of clarity, relative turbidity increased thirty-fold from Station 1 to Station 4A (Fig. 2). Receiving waters more than one mile from the outfall were at maximum or control clarity. These measurements were taken on July 15, 1971 with wind and sea conditions very calm. The discharge plume was not developed extensively compared with all the other days of that month. Off Station 7, the plume was about 300 yards wide during calm seas and extended about one mile west and ¼ mile east of the outfall.

Horizontal visibility tended to increase as distance from the outfall increased. However, in one case, at Station 12 off Anini Reef, turbidity increased sharply below 10 m. A profile of the reef at Station 12 is shown in Figure 6. During several dives a definite turbocline was found to exist at Stations 2, 6, and 7 with visibility rapidly increasing with depth below two to three meters.

The reef stations showed very little or no coral growth (Fig. 8). However, sparse coral growth does not necessarily mean an unhealthy reef condition. For example, the mean relative density in percent of coral coverage on the Waikiki fringing reef is 0.7 and the mean cover is 0.2 with most of the cover being *Hydrolithon* and *Porolithon*, both encrusting coralline algae. Therefore, corals cover less than one percent of this area and are relatively unimportant in overall fringing reef habitats. Normally, crustose coralline algae is the dominant reef building component of Hawaiian reefs (Pollack, 1928; Littler, 1971). The reef edge of Hawaiian fringing reefs tends to be characterized by both encrusting and compact branching corallines. On the Waikiki reef, crustose coralline cover make up 38.9 percent of the total coverage; dead reef, rubble, and sand make up the rest.

The ratio of crustose corallines to coral was 200:1 at Waikiki. This value is considered high, probably due to phosphates from sewage discharge (Littler, 1971). In unpolluted areas, the coral *Porites compressa* was the major coral form between the surface and 30 m.

Sea urchins were seen underwater only at Station 12 (see Fig. 6). In general, sea urchins tend to be found in most coastal areas in Hawaii. In a study of Honaunau Bay (Doty, 1969) and Kealakekua Bay (Doty, 1968), off the island of Hawaii, numerous sea urchins were counted at all depths

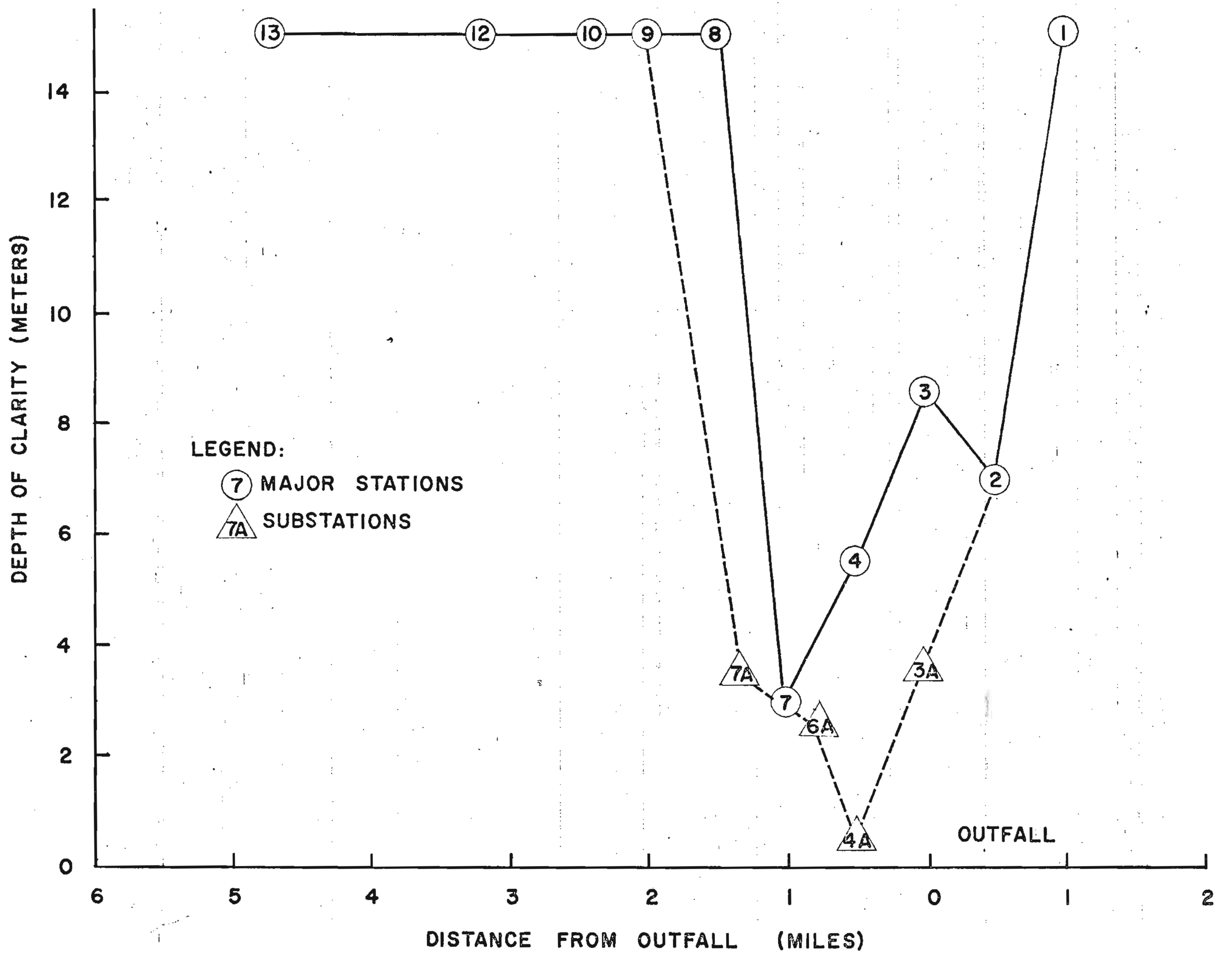

FIGURE 7. HORIZONTAL DISTANCE FROM NIU STREAM OUTFALL VERSUS DEPTH OF CLARITY OF OPEN OCEAN WATERS: JULY 15, 1971.

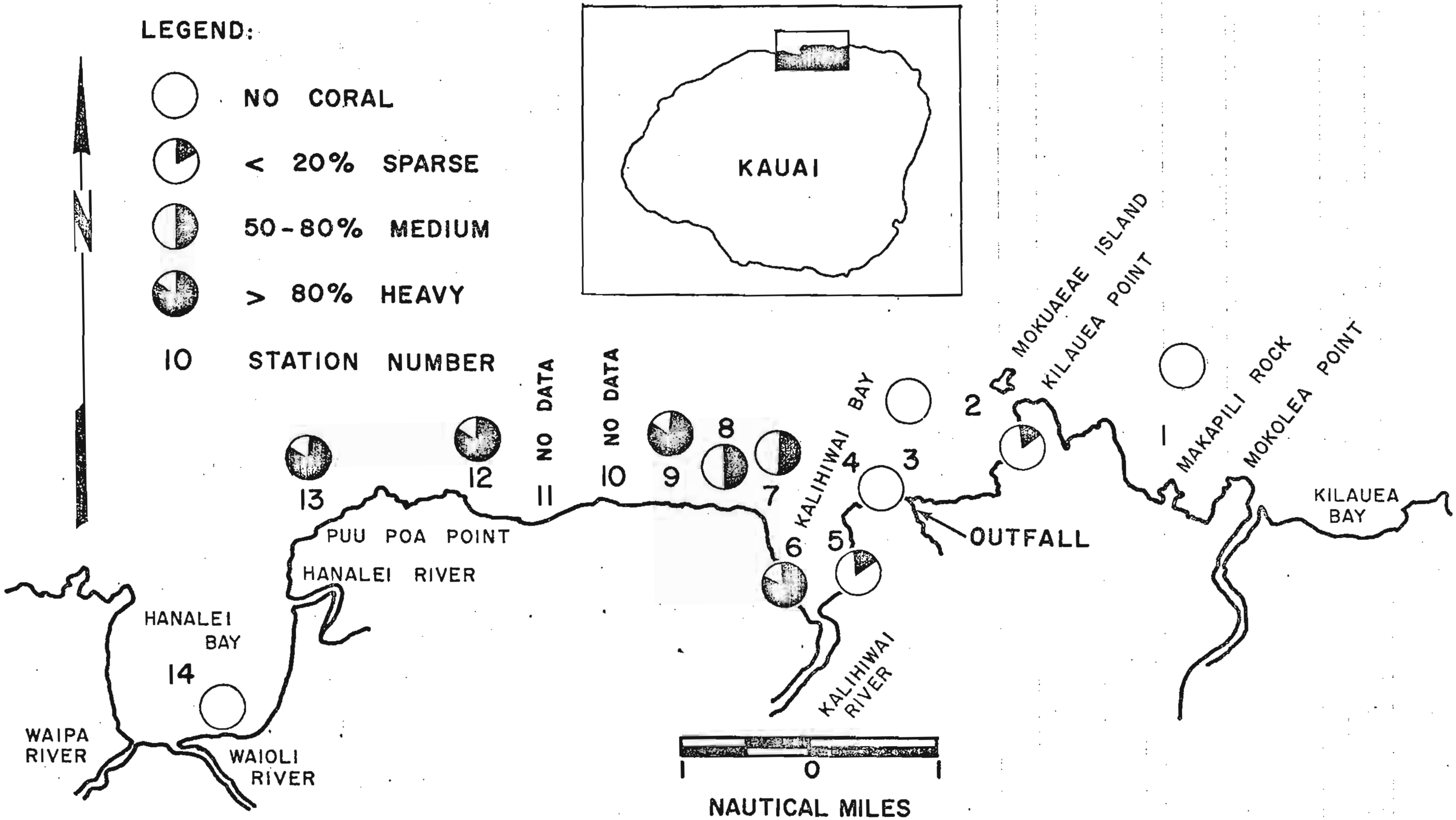

FIGURE 8. PERCENT OF CORAL COVERAGE AT OFFSHORE STATIONS BETWEEN KILAUEA BAY AND HANALEI BAY.

down to 40 feet. On algal reefs in Honaunau Bay densities of up to 400 individuals per m^2 of the sea urchin *Echinometra oblonga* were counted. On algal reefs on Makaha, Oahu, the author has counted over $150/m^2$ of this same species. The most abundant sea urchin found in the current study was *Echinometra mathaei* with a density of $18/m^2$. Sea urchins of the genera *Echinothrix* and *Heterocentrotus* were fairly abundant in Honaunau Bay. None was seen in this study. *Tripneustes gratilla,* second in importance to *Heterocentrotus mammilatus* for the Kona coast of the island of Hawaii, was seen in very small numbers only at station C. Exposure to the open sea is correlated with numbers of sea urchins (Doty, 1968) and in general, density decreases in open exposed coasts.

PRELIMINARY OBSERVATIONS AND CONCLUSIONS

Offshore Stations

The discharge from the Kilauea Sugar Co. discolors the receiving waters, sometimes extending one mile east to the Kilauea lighthouse and two to three miles to the west to Station 10. Associated with this discoloration is a definite increase in turbidity as the outfall is approached (Fig. 7). Deposits of bagasse and cane stalks indicate that, even though the receiving waters may become clear two or three miles from the outfall, debris is carried by currents as far as 5 miles to the west of the outfall (see photographs of Station 13 in Appendix B).

Mill waste enters Kalihiwai Bay at certain times as evidenced by deposits of bagasse at Stations 5 and 6. Part of the general murky condition of the water in Kalihiwai Bay can be attributed to suspended solids from the outfall but the outfall may not be the major contributor. Runoff from adjacent lands into Kalihiwai River bring down to the Bay terrigenous muds, silts, and clays. This runoff, combined with complex inshore and offshore processes, may contribute a significant, if not a major part, in explaining the Bay's turbid nature.

In Hanalei Bay the effect of terrigenous runoff is reflected in the low salinity of Bay waters and the nature of its bottom sediments. Station 14 in Hanalei Bay, the most westerly of all the stations surveyed located 6 miles from the sugar mill outfall, is the sink for three large streams

Hanalei River and Waipa and Waioli Streams. The Bay bottom is partly covered with a ½-meter thick layer of fine black mud. This information coupled with the dissolved oxygen reading of 5.9 ppm suggest short turnover times and good mixing quality of the Bay water.

The dissolved oxygen concentrations at 9 of the 11 stations were fairly constant indicting that the receiving waters off the Kilauea coast have short turnover times and there seems to be no indication of eutrophication. At Station 3 which is more than 500 yards directly seaward of the outfall the DO reading was 5.3 ppm. Waters at this station are constantly subjected to mill discharge even under the calmest conditions. Fauna at the ocean bottom was minimal and deposits of silt were observed. However, at Station 7 where the DO reading was also low, although surface waters were turbid, they were clear at the depth at which samples were taken and flora and fauna were abundant at the ocean bottom.

The nearly constant salinity of the receiving waters near the outfall indicate that mixing of the offshore waters is vigorous and not severely affected by the fresh water from the outfall.

Coral growth seems to have been affected by deposition of silt and by turbidity close to the outfall (Fig. 8). Stations 3 and 4, with rocky substrates amenable to coral growth, were observed to be devoid of most life. Coral growth on the west side of Kalihiwai Bay was anomalously high but diversity was generally low where *Montipora* predominated over other corals. The presence of a suitable reef substrate combined with complex movement of turbid waters in and out of the Bay must be investigated further before any conclusions can be drawn.

Reef Stations

No attempt was made to determine the relative densities of major reef builders for the reef stations at Kilauea (Table 1). Numerous dead coral heads of *Porites* and *Pocillopora* were observed at all three stations. Their presence attests to the fact that at one time coral growth, although minimal in terms of total cover, was fairly luxuriant. At reef Station C, 5 miles east of the outfall, clear waters and the absence of mill trash on the beach and reef indicate no obvious effects from the mill discharge.

However, coral growth is almost nil here. Sea urchins are neither abundant nor frequent (Table 2) and there is abundant growth of the algae *Padina* and *Dictyosphaeria*, an indication that nutrient-rich organic matter is reaching the reef, perhaps, from adjacent sugar cane fields. Algae covered with brown silt were seen frequently at Station C. The Anini reef stations (Stations A & B) are in the direct path of the discharge plume. Large amounts of bagasse and mill trash are deposited on this reef. The only measured difference between the Anini reef and the reef at Station C is the greater abundance of the sea urchin *Echinometra mathaei* at station C (Table 2). Even though a few sea urchins were present on the reefs, there still was a conspicuous absence of these organisms over most of the area studied at Kilauea, in both open and protected waters, parameters other than just exposure to the open sea must account for their scarcity.

RECOMMENDATIONS

A detailed study of the abundance and distribution of benthic and reef micro and macro-communities need to be made. More knowledge of reef-building components of the algal reefs off the Kilauea coast might help in determining the effect of agricultural runoff on coral growth and general reef health. A thorough study of the current patterns, winds, and mixing parameters along the coast and in the bays is needed before the extent of damage, if any, caused by the outfall can be determined. Since the Kilauea Sugar Company is stopping all operations at the end of this year, continuous bottom sampling should be done. Hydrological and geological data are needed to determine the volume of flow of rivers and streams, in the Kilauea coastal area and the suspended loads of the streams at the point of discharge into the ocean. The effect of the Kilauea Sugar Company outfall on the area between Hanalei Bay and Kilauea Bay is also masked by the unknown impact of the natural runoff from adjacent agricultural lands. Further studies are needed before cause and effects can be definitely pinpointed.

ACKNOWLEDGEMENTS

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APPENDICES

APPENDIX A. SUGGEST CHECK LIST INFORMATION FOR Q.C.W. PROJECT CONTROL GROUP - KAUAI

1. LAND AND WATER RELATIONSHIPS

A) Land Area Developed:

The lands in the area between the Kilauea and Kalihiwai Rivers have always been primarily used for agriculture purposes. This area surrounds the Niu Stream in which the present factory waste is now discharged. These lands were planted to sugarcane some 80 years ago. Waste areas such as the uncultivable drains, gulches and swampy areas were left in their natural state. Poorer yielding cane fields were leased out as pastures approximately 30 years ago. These pasture lands do not drain directly into Niu Stream.

Kilauea Sugar Company is in the process of phasing out of sugar operations by the end of 1971. As cane area is phased out of production, corn or sorghum crops are being planted.

The community of Kilauea, the sugar processing facilities, and industrial area complex have been built in this area. Drainage from this ultimately flows through Niu Stream.

Shown below is the land area by uses. The total area is all of Kilauea lands even those which are leased. The Niu Stream area is only that land between Kilauea and Kalihiwai Rivers.

USES	TOTAL AREA	NIU STREAM AREA ONLY
Sugarcane Land	4,800 Acs.	1,780 Acs.
Pasture, Forest Reserve, Unusable	8,423 "	1,100 "
Community & Factory Area	110 "	110 "
	13,333 Acs.	2,990 Acs.

B) Irrigation Practices:

Irrigation in the past was strictly furrow irrigated with infield cane line or furrow grades of one to three percent. Within the past two years, some of the fields adjacent to Niu Stream were converted from furrow to sprinkler irrigation. There are 887 acres which were irrigated in the Niu Stream section. Yearly irrigation water usage for this area is between 0.8 and 1.2 billion gallons. In areas irrigated, "tail water" or underground water finds its way into Niu Stream.

All water used for irrigation originates as mountain run off and is channeled to fields and reservoirs by a network of ditches. At times fields adjacent to Niu Stream were irrigated with factory waste water.

C) Soil and Water Conservation District:

The extreme upper portions of the Kilauea Sugar Company lands are tied in with State Forest Reserve and the natural flora has been left undisturbed. Many of the waste areas were planted with various species of trees. During the 1930's, 30,000 trees (Eucalyptus, paper bark, Albizia, Norfolk Island Pine, etc.) were planted throughout the plantation with a heavy concentration of them in an area known as Kilauea Woods which is looked at as a potential tourist attraction. Ironwood trees were planted along the shoreline as both windbreaks and protection from salt spray drift from the ocean.

Irrigation with its vast network of ditches and reservoirs help tremendously to prevent soil erosion. These ditch channel storm waters from heavy rains to natural drains which are maintained for this purpose. Tied in with irrigation are the contour planting of furrow irrigated fields which in itself prevents much soil erosion.

2. CHEMICALS USED IN PRODUCTION OR PROCESSING

A) Fertilizers:

The usual NPK dry mix fertilizers have been the mainstay since the use of inorganic fertilization. In the past anhydrous ammonia was used for a short time. During the 1950's and 1960's aqua ammonia and NK solutions were used. Recently calcium silicate in the form of TVA slag or Hawaiian Cement was used. Minor elements used were strictly experimental. None were used commercially.

B) Herbicides:

Listed below were those used commercially at Kilauea:

NAME	APPROXIMATE DATE USED	USAGE MAJOR OR MINOR
Arsenicals	1935 - 1950	Major
Oils	1945 - 1965	Major
2,4-D	1945 - 1971	Major
Pentachlorophenol	1950 - 1958	Major
TCA	1950 - 1958	Major
Dalapon	1955 - 1971	Major
Monuron (CMU)	1952 - 1958	Minor
Diuron (DCMU)	1955 - 1971	Major
Simazine	1955 - 1958	Minor
Ametryne	1965 - 1970	Minor
Emulsifiers	1960 - 1970	Major
Lasso	1970	Minor

C) Insecticides, Rodenticides, Fungicides:

Kilauea Sugar Company, Limited

NAME	APPROXIMATE USAGE DATES	USAGE MAJOR MINOR	FUNDAMENTAL USAGE
Thallium Sulfate	1930 - 1945	Major	Rat Control
Zinc Phosphide	1940 - 1945	Major	Rat Control
Warfarin	1945 - 1971	Major	Rat Control
1080	1967	Minor	Rat Control
Thallium Sulfate	1967	Minor	Rat Control
PMA	1950 - 1970	Major	Seed cane dip for fungicide control
Ceresan L	1969 - 1970	Minor	Seed cane dip for fungicide control

Metcalf Farms, Inc. (Corn & Sorghum Operation)

NAME	DATE USED	FUNDAMENTAL USAGE
Shell Gardona	1970	Insecticide, foliar app. - corn
Sevin	1970	"
Metasystox	1970	"
Systox	1970-71	" - corn & sorghum
Diazinon	1970	"
Heptachlor	1970	"
Manzate	1970	Fungicide, Applied to corn seed at plant

D) Others:

Chemicals used in factory operations are magnesium oxide, lime, caustic soda, soda ash, and sulfuric acid.

3. POINTS OF WASTE WATER DISCHARGE

Niu Stream Outfall

4. CHARACTERISTICS OF DISCHARGE

A) Type of Material:

The discharge contains various amounts of silt, bagasse, cane trash, cane stalks, fly ash, factory restroom waste, traces of oils from factory lubricants and sugar.

B) Volume and Rate:

In (A) above the only items that have been measured to any degree are mill cane trash (4.5 tons per 24 hr. operating day) and cane stalks (16.0 tons per 24 hr. operating day); the rest are unknown.

Volume of water through the factory is 5.0 million gallons per operating day.

C) Analysis of Waste Water:

Samples have been taken for the U.S. Army Corps of Engineers and sent to Hazleton Laboratories for analysis. A copy of this analysis is attached.

5. SCHEDULE OF DISCHARGES

Daily except weekends from approximately January 15 through November 1.

Plantation: Kilauea Sugar Company, Ltd.

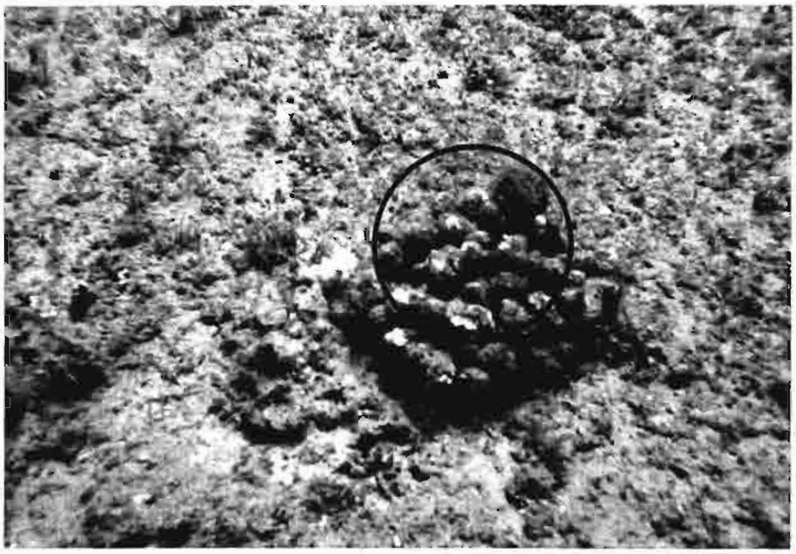
ANALYSIS OF DISCHARGE WATER FOR METALS AND PESTICIDES

	Analysis in ppm for Sample				
	1	2	3	4	5
Arsenic	0.0125				
Mercury	--				
Lead	--				
Thallium	--				
Chromium	--				
Diuron	<0.050				
Atrazine	<0.050				
Ametryne	<0.050				
2,4-D	<0.050				
Dalapon	<0.050				

Note: Where figures are given as "less than" a certain value (e.g. <0.05) this indicates the limit of detection for the method used.

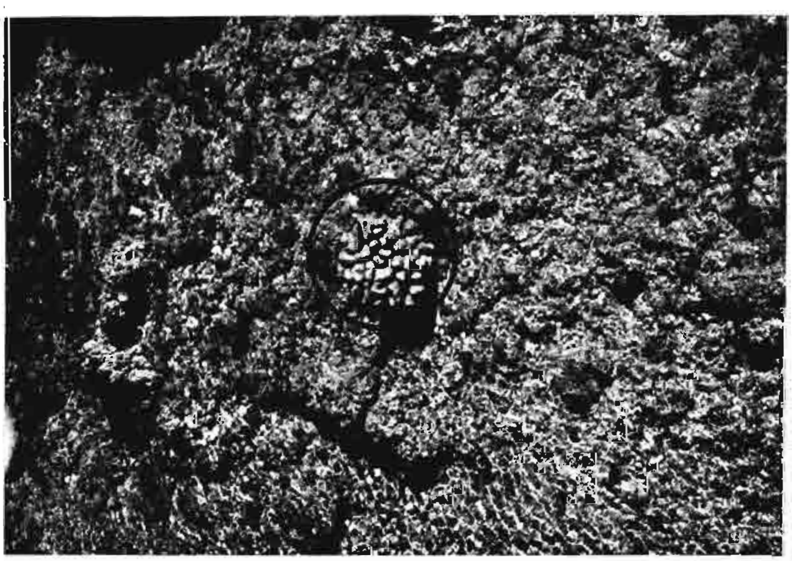
Sample 1. Mill discharge.

APPENDIX B. PHOTOGRAPHS OF REEF AND OFFSHORE STATIONS



Station A. Dead coral *Pocillopora meandrina* (circled) on Anini reef.

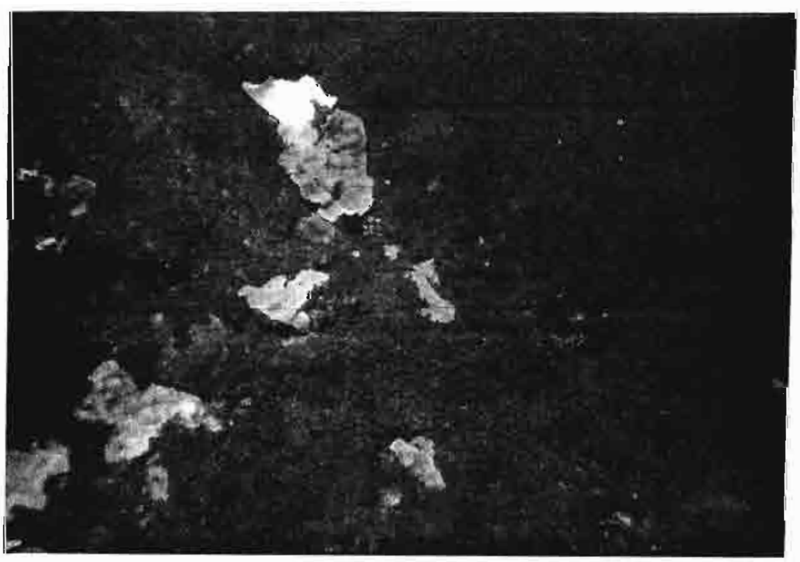
Station C. Algal growth, mostly *Padina* (circled) on reef.



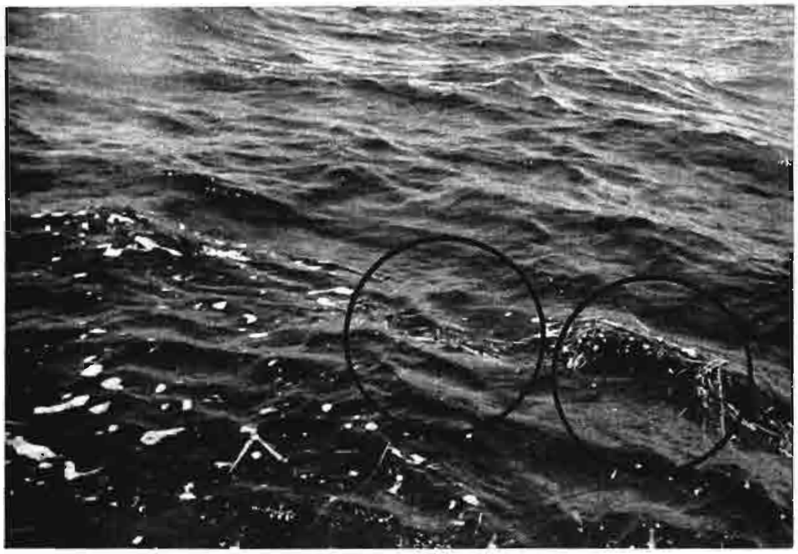
Station C. Solitary coral head of *Pocillopora meandrina* is shown in the circle.

Station 1. Sandy bottom interspersed scoured rocks. Ripple marks at 10m.

Station 2. Dead coral head (in circle) amongst algae covered rocks about 1/2 mile from outfall.



Station 2A. Below Kilauea lighthouse about 100m off-shore, sparse coral coverage, algae laden with silt. Depth 7m distance to outfall 1/2 mile.

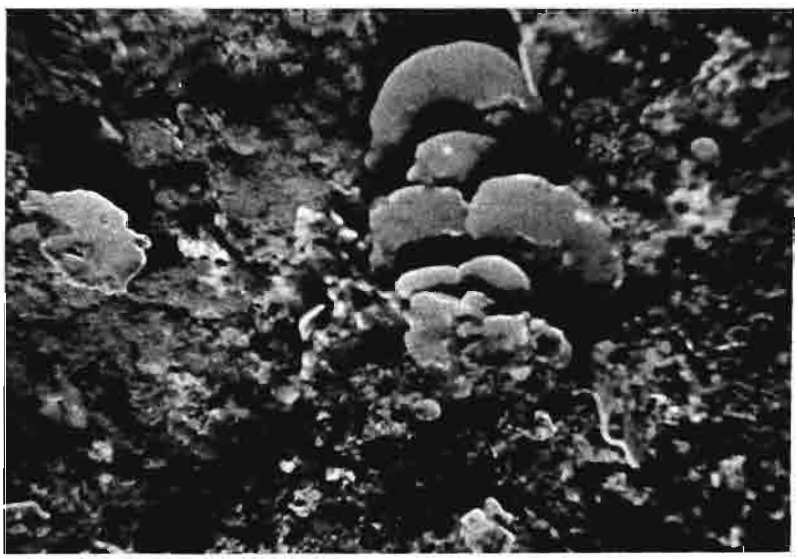


Station 4. Windrows of bagasse (in circles))outside Kalihiwai Bay. Focal length 2m.

Station 6. *Fungia scutaria* (left circle) and *Montipora verrucosa* (right circle) in Kalihiwai Bay.

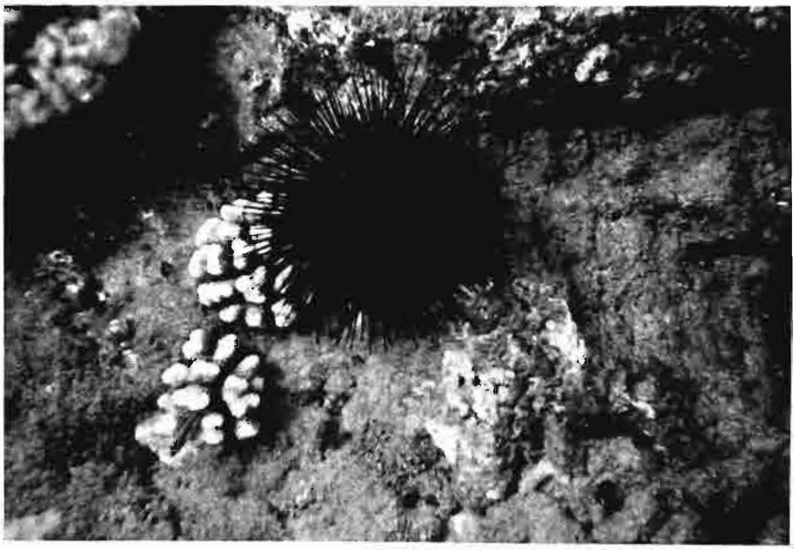
Station 6. Abundant colonies of *Montipora flabellata* at 10m. Photo represents 1 m^2.

Station 7. Photo represents about 3 m^2 of ocean floor. Encircled is a colony of *Montipora flabellata*.



Station 7. More colonies of *Montipora flabellata* at 9-10m. Photo represents about 1 m^2 of ocean floor.

Station 12. Abundant fish and coral (in circle) at 10-m depth.



Station 12. Sea urchin *C. paucispinus* at Station 12 off Anini reef at 11-m depth. Some live *Pocillopora* coral.

Station 12. Cane stalks and debris at 18-m depth off a reef cliff.

Station 13. Cane stalks at 13-m depth, 5 miles from Niu Stream outfall.

Table 3. DESCRIPTION OF MAJOR OFFSHORE STATIONS

STATION NO.	DEPTH (m)	O_2 ppm	DEPTH OF CLARITY (m) July 15, 1971	HORIZONTAL VISIBILITY (m)	T °C/S ‰	SUBSTRATE AND BOTTOM TOPOGRAPHY	LOCATION AND GENERAL DESCRIPTION
1	9	6.1	15	35	27/--	flat sandy bottom with large areas of rock formations	1 mile east of outfall, 300 yds. Devoid of benthic fauna. Some *Padina* observed, bottom surge strong, scour marks noted. No bagasse.
2	10	6.4	7	--	26/35	flat rocky bottom scattered sand pockets	½ mile east of outfall, 400 yds west of Mokuaae Island. Plume well developed, water very turbid. No bagasse.
2A	8	---	--	15	---	flat, rocky	below Kilauea light house ½ mile east of discharge. Medium coral mostly *Montipora* and *Porites*. No bagasse, some silt observed.
3	8	5.3	8.5	2	26/35.2	flat, rocky	900 yds seaward of Niu Stream outfall, some algal growth windrows of bagasse 50 yds long floating on surface, no bottom fauna seen.

STATION NO.	DEPTH (m)	O_2 ppm	DEPTH OF CLARITY (m) July 15, 1971	HORIZONTAL VISIBILITY (m)	T °C/S °/°°	SUBSTRATE AND BOTTOM TOPOGRAPHY	LOCATION AND GENERAL DESCRIPTION
4	8	6.0	5.5	2	26/ 34.9	bare, flat, rocky w/ long crevices running perpendicular to shore.	½ mile to west of outfall, no flora or fauna seen, large amounts of bagasse and cane stalks
5	10	6.0	8.0	3	25/ --	Sand; 50 yds to west reef cliff rising to 5m depth	East side of Kalihiwai Bay, *Montipora* seen on reef cliff, reef flat covered w/ mud and silt bagasse and cane stalks seen. Large numbers of burrows of mud shrimp *Callianassa at 15 m*
6	11	6.0	5.0	1	25/ 34.9	flat, sandy; 100 yds to west reef flat	West side of Kalihiwai Bay, abundant coral of all kinds seen, abundant *Dictyosphaeria* and *Padina* growth, little bagasse.
7	7	5.4	3.2	26	25/ 35.2	rocky reef w/ sand channels parallel to shore	700 yds outside west edge of Kalihiwai Bay, abundant coral (*Montipora*), bagasse and cane stalks seen, 2-3 m plume thickness, clarity of water increased sharply below this layer of suspended solids.
8	9	6.0	15	32	26/ --	rocky, rugged, dissected by many crevices and channels	900 yds off the coast west of Kalihiwai Bay 1½ miles from the outfall, bagasse and cane stalks seen in trace amounts, abundant coral,

STATION NO.	DEPTH (m)	O_2 ppm	DEPTH OF CLARITY (m) July 15, 1971	HORIZONTAL VISIBILITY (m)	T °C/S ‰	SUBSTRATE AND BOTTOM TOPOGRAPHY	LOCATION AND GENERAL DESCRIPTION
9	11	6.2	15	35	26/ --		2 miles west of mill discharge, 900 yds offshore. no bagasse, abundant coral mostly *Montipora*, abundant fish.
10	--------NOT SURVEYED--------						
11	--------NOT SURVEYED--------						
12	8	6.1	15	--	25/34.5	flat, rocky, gentle slope to shore. 800 yds from shore reef drops to 22 m	3½ miles west of outfall and 600 yds NE of Kaweonui Point, abundant coral and fish, sea urchin *C. paucispinus* seen in large numbers. At 22 m large amounts of bagasse piled along reef cliff base (see Fig. 4). Turbid water at this depth.
13	11	---	15	--	25/--	flat, rocky, gentle slope to shore.	5 miles west of outfall, 700 yds NW. Puu Poa Pt. abundant coral, some cane stalks seen.
14	12	5.9	6	--	25/29.2	soft, fine, black mud at least ½ m thick.	In Hanalei Bay 750 yds due north of the mouth of the Hanalei River, 6 miles from the outfall.