WATER QUALITY OF KAPALAMA CANAL

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Technical Report No. 59

September 1972

Partial Technical Completion Report

for

POLLUTION IN HAWAIIAN WATERSHEDS

OWRR PROJECT NO. A-027-HI, GRANT AGREEMENT NO. 14-31-0001-3211

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PROJECT PERIOD: July 1, 1970 to June 30, 1971

The programs and activities described herein were supported in part by funds provided by the United States Department of the Interior as authorized under the Water Resources Act of 1964, Public Law 88-379.

ABSTRACT

A water quality survey of the Kapalama Canal was undertaken in 1970 - 1971 to obtain baseline data for evaluation of the pollution potential of that surface drainage channel. The survey included the stretch of canal between the residential area below School Street to the tidal waters downstream of the pineapple canneries effluent discharge ditch. Chemical and bacteriological characteristics of the Canal were assessed through the measurement of the following parameters: pH, DO, alkalinity, hardness, chlorides, total solids, total nitrogen, total phosphorus, BOD_5, total coliforms, fecal coliforms, fecal streptococci and Pseudomonas aeruginosa.

Results of the survey show that levels of all parameters except pH and alkalinity increased in a downstream direction with high levels particularly noted downstream of the tidal dam, probably due to the effects of effluent discharge from the pineapple canneries outfall ditch. A significant diluting effect was noted during periods of wet weather streamflow.

The state water quality standards were exceeded for several parameters: pH, DO, nitrogen and phosphorus in the Class A waters, and total coliforms in both the Class A and Class 2 waters. The average FC:FS and FC:TC ratios for the Class 2 waters were 5.2:1 and 0.25:1, respectively. The high FC:FS ratio indicates that human wastes as well as animal feces are entering Kapalama Canal.

Pseudomonas aeruginosa organisms were found in the canal waters and were observed in densities greater than attributed to stormwater runoff in the literature.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Knowledge of river water quality assumes importance today because of the extensive use of surface waters for domestic water supply, recreation, growth and propagation of fish and wildlife, and, in many instances, for agricultural and commercial purposes. Soil erosion resulting from man's activities is a significant factor in agricultural and urban runoff. Chemical wastes discharged into river basins may result in fish kills and loss of esthetic value. Toxins produced during blooms of certain marine organisms and enrichment of streams and lakes from domestic waste discharges and land runoff result in impairment of wildlife propagation.

To preserve these water resources and control quality-related problems and their threat to environmental quality, the Federal Water Quality Act was passed by the Congress in 1965, and in accordance with that Act, the Hawaii State Department of Health established water quality standards for all the state's receiving waters (Department of Health, 1968). These standards are established to include both coastal waters and fresh streams and make it essential that baseline data on the quality of these waters be available so that the system of enforcement of the Standards can be implemented.

Water quality tests between June and November 1970 by the State Health Department disclosed that Kapalama Canal is the most polluted stream on Oahu. Honolulu's major pineapple canneries are considered the prime contributors to the deterioration of the quality of Kapalama Canal during the summer when the canning season is at its peak (Department of Health, 1970).

The Canal, one of the important streams on Oahu which receives raw industrial waste and land runoff, discharges into the ocean at Pier 39 in Honolulu Harbor, Kapalama Canal, downstream of the tidal dam constructed in 1944, has been for many years subjected to waste loads of cannery effluent, oil, other industrial wastes and general municipal trash. The dam itself, was constructed to prevent the movement of accumulated waste upstream to residential areas during periods of high tide.

Pollution of the Canal is significant from not only an esthetic standpoint but also from the direct impact it has on Honolulu Harbor. Three moderate to heavy fish kills have occurred in the Kapalama Canal (Cox and Gordon, 1970). The first, in May 1963, and the third, in September 1966, involved mainly forage species, and were attributed to "food and kindred products". The cause of the second, in July 1965 involving an estimated 100,000 fish, was undetermined. Fish kills have also been recorded for Keehi Lagoon into which some of the Canal waters flow through the Kalihi Ship Channel. Keehi Lagoon and Honolulu Harbor were ranked in 1965 as the second and fifth largest producers, respectively, of bait fish for the aku industry (Department of Health, 1966). Thus deterioration of water quality in the Canal can result in serious consequences at the highest levels in the aquatic food chain, with the possibility of severe economic impact. Therefore it is important that chemical and bacterial water quality levels should be determined and evaluated over a long-term period. Thus this Canal was selected for study in the first year of the three-year "Pollution in Hawaiian Watersheds Project" of the Water Resources Research Center (Hahn, S. D., 1971; Ells, M. D. 1971).

STUDY AREA

The Kapalama drainage basin is located on the southern coast of the island of Oahu within the limits of the City of Honolulu. The basin extends from the leeward slopes of the Koolau Range to the coastal plain ranging from approximately 1800 feet in elevation to sea level. The coastal area encompasses the shoreline to the vicinity of School Street and is relatively flat (0 - 10% slope). However, the upper drainage areas between School Street and Kamehameha School have steep slopes (11 - 30%) and 30+% near the slopes of the Koolaus.

The soil in the basin is mainly of volcanic origin and is composed of alluvial sediments, consolidated lavas and silty-clay material. Mean annual rainfall over the basin is approximately 60 inches ranging from 30 inches along the coastline to 75 inches in higher elevations. The climate is mild and dry with temperatures varying between 60 to 80° F throughout most of the year.

Land use activities in the basin include forested areas, residential areas, light-commercial areas and industrial areas. The Honolulu forest reserve watershed extends from the slopes of the Koolaus to the vicinity of Kamehameha School. Light residential activity begins from Kamehameha School to School Street and intensifies between School and King Streets. Below King Street, light commercial and industrial activities can be found along Kapalama Stream till Pier 39. Industrial activities include mainly a gas company and pineapple canning and processing plants. Commercial activities include small shops, gas stations, and small restaurants. School and recreational areas in the basin include Kamehameha Schools, Kapalama School, Damien High School, and Alewa Playground above School Street and Bishop Museum, Farrington High School, Likelike School, and Honolulu Community College below School Street.

The drainage area for the Kapalama Stream and Canal is approximately 1172 acres or 1183 square miles. The drainage area above School Street is approximately 902 acres or 1.4 square miles and the drainage area till the tidal dam is approximately 1121 acres or 1.75 square miles.

The Kapalama Canal (Fig. 1), which serves to route storm and flood water runoff from Kapalama Stream, Kamehameha Heights, and the Palama area to the sea is channelled through Kapalama Basin, Kalihi Channel, and Honolulu Harbor. The Canal is located approximately at 21°18' N, 157°52' W. The system has a total of 2.6 miles of closed storm drains and open canal that collect the storm runoff from a drainage area of 1145 acres (Cox, D. C. and L. C. Gordon, 1970).

North of School Street, the system consists of 5200 lineal feet of buried storm drains. South of School Street, the system consists of approximately 4600 lineal feet of open canal. Three small concrete-lines canals serve to divert collected flows from Kapalama Stream, Kamehameha Heights, and the Palama area into the main canal just north of Lunalilo Freeway as shown in Figure 1. The Canal then runs parallel to Kohou Street for the rest of its length until it reaches Kapalama Basin.

Kapalama Canal not only carries storm water runoff, it also serves as a receiving water for the bland wastes from the Dole Corporation pineapple processing plant, Del Monte Corporation, and Honolulu Gas Company.

The canal waters are under two classifications in the Water Quality Standards (Department of Health, 1968), Classes A and 2. The waters below the tidal dam shown in Figure 1 are Class A and those above it are Class 2.

METHODOLOGY

Although sampling stations for the Kapalama study area were chosen for ease of sample collection, they were spaced far enough apart to obtain a

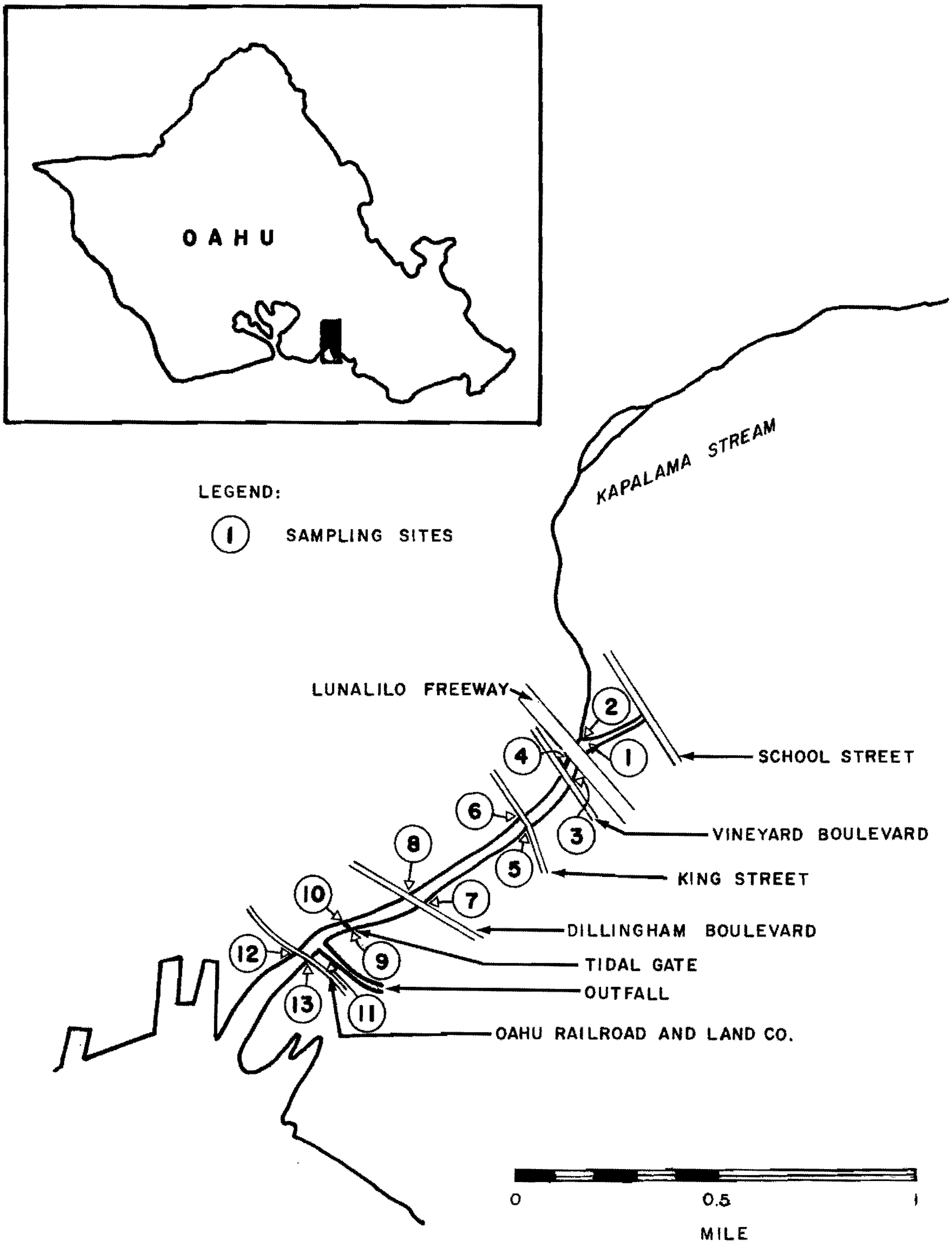

FIGURE 1. LOCATION OF STUDY AREA AND SAMPLING SITES, KAPALAMA CANAL, OAHU.

descriptive variation of the contamination levels. Twelve sampling stations above the mouth of Kapalama Canal and one station was established at the drainage ditch carrying discharge from Dole Corporation, Del Monte Corporation, and Honolulu Gas Company.

Chemical and biological characteristics of Kapalama Canal were assessed by measuring the following parameters: pH, DO, alkalinity, BOD_5, hardness, chlorides, total solids, total nitrogen, total phosphorus, total coliforms, fecal coliforms, fecal streptococci, and *Pseudomonas aeruginosa*.

The *Ps. aeruginosa* organisms were of interest because of their pathogenicity to humans (it is the only pseudomonas of medical importance). They are a source of skin and middle ear infections and possibly "summer diarrhea" (Anderson, 1966) and thus are a hazard in recreational or water-contact areas. Because of the possible input of Canal waters to Keehi Lagoon with its recreational areas, it was considered that this study would provide an excellent opportunity to attempt to isolate the pseudomonas from drainage waters.

Samples for bacterial analyses were collected in clean, 8 oz. screw-cap glass bottles that had been autoclaved at 18 psi and 121° C for 15 minutes. The bottles were submerged to depth of 4 to 6 inches and filled to the two-thirds mark. Samples for chemical analyses were collected in one-gallon plastic pails and field tests for pH, dissolved oxygen were performed at the collection site. The samples were then transferred to sample bottles and transported to the laboratory in an ice cooler. All remaining analytical work was performed in the laboratory. All chemical and bacterial analyses were performed as per Standard Methods (American Public Health Association, 1970). However, in the test for pseudomonas, the fermentation tubes were observed under ultraviolet light, a step not included in Standard Methods.

There is little existing data on the discharge through Kapalama Canal into Honolulu Harbor. The Kapalama Stream, in its upper reaches, is not perennial and there is no flow measuring gage on it. Cox and Gordon (1970) reported the flow through the Dole Corporation ditch at about 16.8 mgd and the dry-weather flow through the canal at about 20 mgd. Approximate flow measurements were made in this study on a velocity-area basis by measuring the flow area and estimating the surface velocity at Stations 1, 2, and 11. Four such measurements were made between February and April, 1971. At Station 1 the flow ranged from 0.7 to 1.0 cfs with an average of 0.8 cfs (0.5

mgd). At Station 2 the flow varied from 3.1 to 4.9 cfs, with an average of 3.8 cfs (2.05 mgd). The flow at Station 11 ranged from 20.1 to 27.3 cfs, with an average of 22.7 cfs (14.6 mgd) which compares favorably with that reported by Cox and Gordon (1970). The total flow data in this study was taken as the equivalent of the sum of flow through these three stations and averaged about 18 mgd for the measured data. Two other sets of flow measurements were made in November and December 1971. The November survey yielded flows of 0.57 cfs at Station 1, 1.52 cfs at Station 2, and 9.6 cfs at the tidal dam. The December survey yielded flows of 0.79 cfs at Station 1, 0.36 cfs at Station 2, and 2.7 cfs at the tidal dam.

RESULTS AND DISCUSSION

In general, the concentrations of the chemical and bacterial parameters were higher in the stations downstream of the tidal dam and lower upstream, with only slight differences between each of the two stations at the same bridge (Tables 1 and 2). In the stream distance covered in this study, Stations 1 through 8 are in the zone of Class 2 waters and Stations 9 through 13 are in a zone of Class A waters. Table 3 summarized the specific standards according to the State Water Quality Standards (Department of Health, 1968).

During wet weather flow between October and January, storm water and runoff lowered the chemical and bacterial concentrations measured during the 20 sampling surveys. From Station 9 to Station 13 general indicators were affected by not only storm water and runoff, but also by cannery operations. Levels of concentration were higher during cannery operating periods and lower during the off-season periods.

The pH variations observed for all stations ranged from 4.6 to 9.0 during the survey period. The pH values at Stations 1 and 2 were higher than the other stations, with averages of 8.0 and 8.1, respectively (Table 1). This was due to shallow flow depth, allowing high reaeration because of turbulence, and also much algae growth resulting in supersaturated DO, higher carbonate levels and pH.

Between Stations 3 and 10 the average pH ranged from 7.0 to 7.5. However, the average pH values at the cannery outfall (Station 11) and downstream Stations 12 and 13 decreased to 6.4 as a result of the effluent of the

TABLE 1. MEAN VALUES OF CHEMICAL PARAMETERS IN KAPALAMA CANAL, 1970-71.

		PARAMETER mg/1							
STATION	pH*	ALKALINITY	HARDNESS	DISSOLVED O_2	BOD_5	CHLORIDES	TOTAL SOLIDS	TOTAL N	TOTAL P
1	8.0	99	100	10.5	3	52	250	0.4	0.33
2	8.1	102	125	11.1	2	97	390	0.6	0.42
3	7.4	117	380	6.4	3	750	1,120	0.6	0.54
4	7.4	107	370	6.3	4	685	1,090	0.8	0.55
5	7.0	121	1,390	4.6	5	3,570	5,460	1.4	0.67
6	7.3	117	1,320	4.4	5	3,200	5,910	1.3	0.62
7	7.5	121	1,620	5.0	7	4,740	8,150	1.3	0.67
8	7.3	123	1,670	5.3	8	4,800	8,610	1.9	0.78
9	7.2	113	2,400	3.7	22	7,330	14,060	1.5	0.84
10	7.2	109	2,300	3.6	32	7,090	13,900	1.6	0.84
11	6.4	94	2,340	1.8	264	7,560	14,600	12.5	2.44
12	6.5	99	3,190	1.7	170	9,540	19,890	7.1	1.57
13	6.4	94	2,830	1.7	177	9,060	17,130	7.8	1.42

* pH IN pH UNITS

TABLE 2. MEAN VALUES OF BACTERIOLOGICAL PARAMETERS IN KAPALAMA CANAL, 1970-71.

STATION	TOTAL COLIFORM x 10^3/100 ml	FECAL COLIFORM x 10^3/100 ml	FECAL STREPTOCOCCUS x 10^3/100 ml	FECAL COLIFORM/ FECAL STREP. RATIO	*PS. AERUGINOSA* no./100 ml
1	2,200	20	11	1.8	460
2	3,800	18	16	1.7	390
3	2,400	38	15	2.5	240
4	2,000	33	25	1.3	50
5	3,800	17	9.8	1.7	520
6	6,000	410	80	5.1	130
7	4,800	75	4.9	15.3	280
8	4,900	94	8.7	10.8	1,050
9	6,700	350	660	0.5	770
10	7,000	540	450	1.2	250
11	260,000	14,000	80,000	0.18	420
12	70,000	14,000	120,000	0.12	230
13	120,000	5,500	650,000	0.01	230

TABLE 3. A SUMMARY OF THE SPECIFIC HAWAII WATER QUALITY STANDARDS ACCORDING TO CLASSIFICATION.

CLASS	SPECIFIC STANDARDS				
	pH-UNITS	DO mg/1	TOTAL N mg/1	TOTAL P mg/1	BACTERIA, COLIFORM/100 ml
AA	8.0-8.5	6.0	0.10	0.020	MEDIAN 70 230 ANYTIME
A	7.0-8.5	5.0	0.15	0.025	MEDIAN 1,000, 10% 2,400
B	7.0-8.5	4.5	0.20	0.030	FECAL COLIFORM 200 FOR 30-DAY PERIOD 10% 400 400 FOR 30-DAY PERIOD
1	NONE	NONE	NONE	NONE	10% 1,000 MEDIAN 1,000, 10% 2,400 FECAL COLIFORM 200 FOR 30-DAY PERIOD 10% 400
2	6.5-8.5	5.0	NONE	NONE	MEDIAN 1,000, 10% 2,400 FECAL COLIFORM 200 FOR 30-DAY PERIOD 10% 400

cannery outfall.

In general, the average pH observation during 20 surveys at all of the stations was within the Water Quality Standards for Class A and Class 2 waters except at Stations 11, 12, and 13.

The average alkalinity observations, in general, for all stations showed no significant variations, with a range only from 94 to 123 mg/1 (Table 1). However, alkalinity concentrations for two surveys during wet weather flow (January 13 and 18, 1971) decreased due to dilution, to between 30 and 88 mg/1. At the cannery outfall (Station 11) there was the greatest range of alkalinity, from a low of 3 to a high of 222 mg/1. This probably is an indication that both strongly basic and acidic wastes were discharges at that point.

The average hardness concentration increased downstream from 100 mg/1 at Station 1 to 3190 mg/1 at Station 12 (Table 1). The hardness decreased markedly during wet weather flow at all stations, with Stations 11, 12, and 13 showing decreased from 4410, 5680, and 5100 to 860, 735, and 970 mg/1, respectively. High concentrations of hardness in downstream stations probably resulted from a pseudohardness effect due to sea water.

During wet weather flow between October and January, DO at Stations 1 and 2 decreased from 18.7 to 8.2 mg/l and 14.8 to 8.5 mg/l, respectively, while at Station 11 and Stations 12 and 13, the DO increased from 0.3 to 5.2 mg/l and from zero to 6.7 mg/l, respectively. This trend is considered to be due to the dilution effect of stormwater and the minimum flow from the cannery outfall in off-season operations.

Dissolved oxygen levels observed at the cannery outfall were always higher than at Stations 12 and 13 due to the aerators installed by the Dole Corporation in the outfall ditch. Although the aerators were operating in summer, the minimum dissolved oxygen was 0.2 mg/l, with an average of 1.8 mg/l at the outfall. This means that the aeration was inadequate to stabilize the organic load from the outfall effluent during the cannery operating season. Dissolved oxygen levels at Stations 11, 12, and 13 persisted at near zero, ranging from zero to 6.4 with an average of 1.7 mg/l. This indicates that anaerobic conditions occasionally may exist in the canal below the tidal dam.

The average DO concentrations observed at Stations 1 through 4 and at Stations 7 and 8 met the standards established for Class 2 waters, while the mean values for Stations 5 and 6 and 9 through 13 failed to meet the Standards for either Class 2 or Class A waters, respectively (see Fig. 2).

Increased rainfall and stormwater runoff generally lowered the BOD_5 concentrations at all of the stations. During wet weather flow the average BOD_5 at Stations 11, 12, and 13 decreased from 480, 360, and 345 mg/l to 48, 10, and 18 mg/l, respectively, due to the dilution effect of stormwater and off-season operation of the canneries. Higher BOD_5 levels at Stations 11, 12, and 13 were considered to be primarily due to the large quantity of sugars in the waste from the canneries (Table 1 and Figure 3).

The average calculated BOD_5 load at the outfall and of Stations 7 and 8 upstream from it were 32,300 and 200 lbs/day, respectively. The total BOD_5 load discharged through the canal into Kapalama Basin and Honolulu Harbor was determined as 32,500 lbs/day. The calculations of BOD_5 loadings were based on four sets of approximate flow values obtained for dry weather conditions. This type of evaluation should be continued to further define the BOD_5 contribution of the canal to the harbor.

Chloride concentrations increased in a downstream direction from 52 mg/l at Station 1 to 9540 mg/l at Station 12 (Table 1). The large increase in

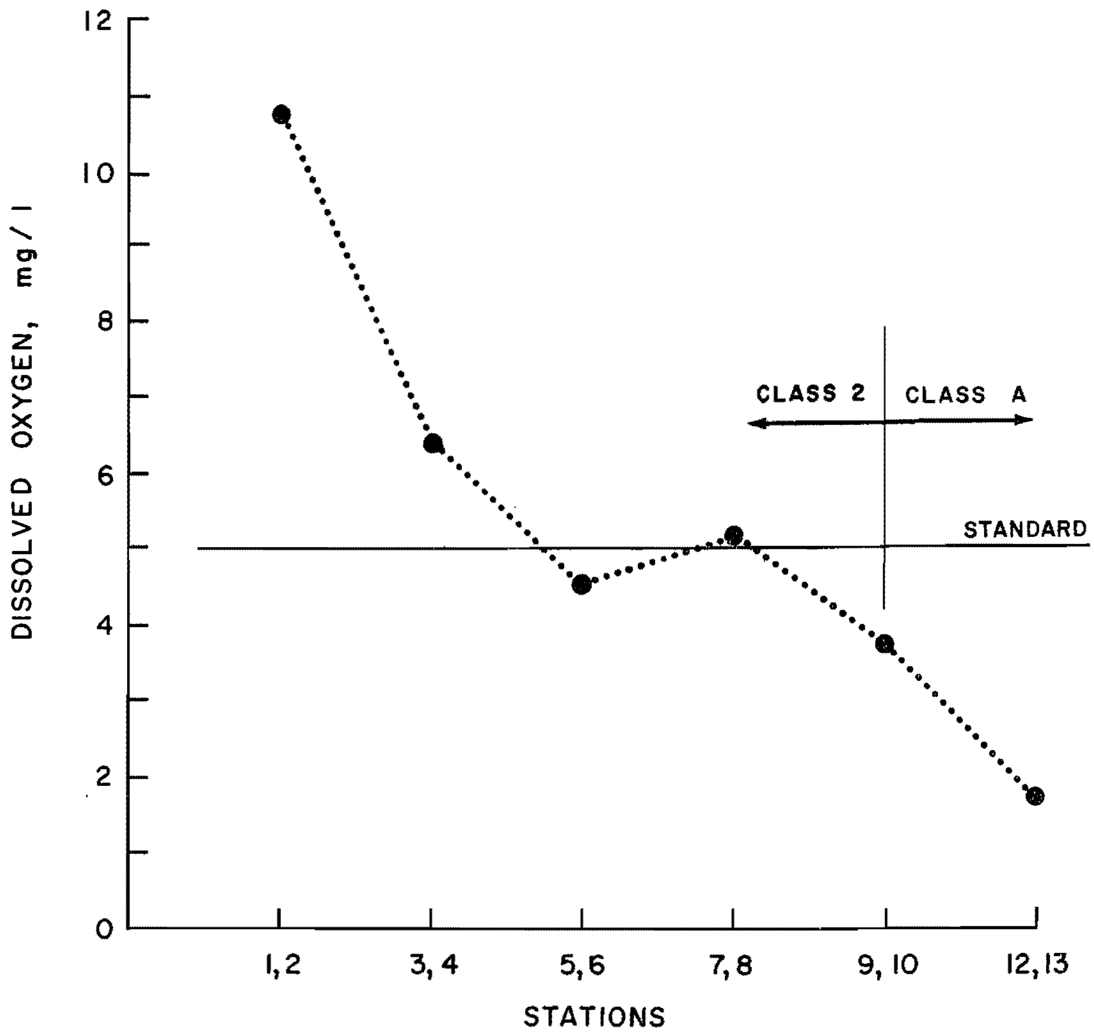

FIGURE 2. CHANGE IN DISSOLVED OXYGEN WITH STREAM DISTANCE, KAPALAMA CANAL, JULY, 1970 - JUNE, 1971.

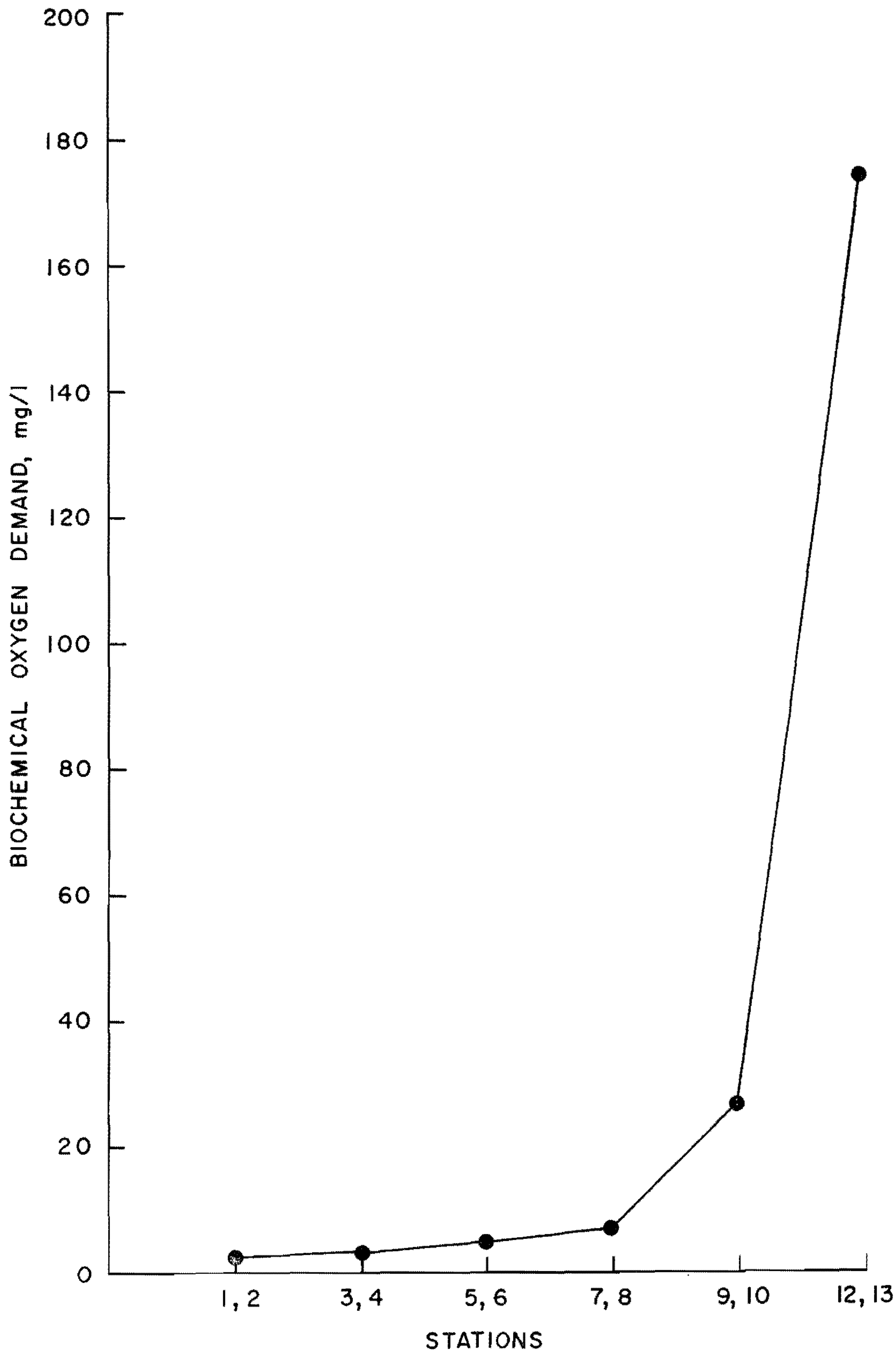

FIGURE 3. CHANGE IN BIOCHEMICAL OXYGEN DEMAND WITH STREAM DISTANCE, KAPALAMA CANAL, JULY, 1970 - JUNE, 1971.

chloride concentration between Stations 7 and 8 and the dam at Stations 9 and 10 confirms the effectiveness of that dam in preventing the upstream flow of seawater and the waste effluent from Station 11. High seasonal variations at Stations 11, 12, and 13 are considered to be due to the result of tidal variations, dilution by runoff during wet weather, and the seasonal discharge pattern through the cannery outfall.

The high increase of total solids downstream from the dam was considered to be due primarily to total influence, similar to that for chlorides. The total solids content at Stations 3 and 4 and Stations 11, 12, and 13 ranged from 305 to 2940 mg/l, 1490 to 23,860 mg/l and 4230 to 35,450 mg/l, respectively. The Health Department survey yielded results similar to these data.

The highest concentration of total nitrogen was 54.9 mg/l at Station 11. There was little variation in this parameter at stations upstream of the barrier, with a range from zero to 1.9 mg/l. At Station 11, the concentration of total nitrogen ranged from 1.0 to 54.9 mg/l, with an average of 12.5 mg/l. At Stations 12 and 13, the total nitrogen content increased greatly due to effluent contribution. Other sources of nitrogen in the canal were fecal material, refuse, and litter that had been dumped illegally into the canal, as some of these types of materials were observed during the sampling surveys. The average concentrations of total nitrogen determined for each station failed to meet the State Standards for Class A waters (see Fig. 4).

During this study the mean level of total coliforms for the Class 2 waters of the Canal was 39×10^5/100 ml. The mean for the Class A waters was 8×10^7/100 ml. Mean values increased from 22×10^5/100 ml at Station 1 to 48×10^5/100 ml at Stations 7 and 8 (Table 2). At the tidal dam the total coliform density increased to 67×10^5/100 ml and from there increased to 26×10^7/100 ml near the mouth of the canal. The high levels of the total coliforms suggest contamination in surface runoff from cesspool leakage or from household sewage connections draining into the canal.

The mean total coliform levels for the Class 2 water decreased from 4×10^5/100 ml during dry weather flow between July and September to 8×10^5/100 ml during wet weather flow between October and February. However, the levels for the Class A waters of the canal ranged from 3×10^7 to 1×10^7/100 ml for the same seasonal periods. This compares with a range of from 0.3 to

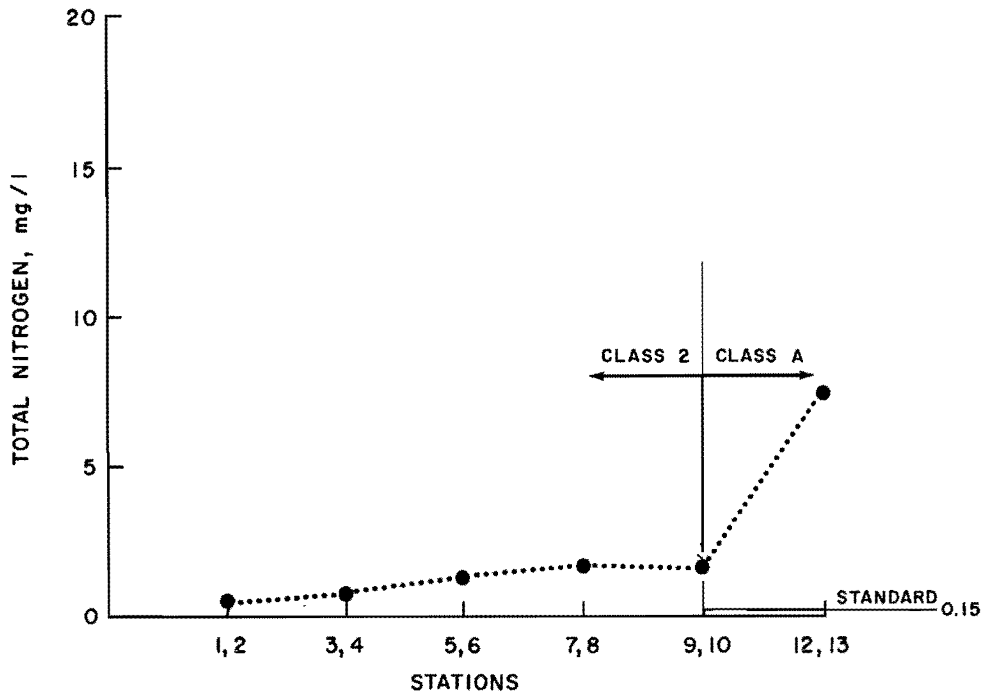

FIGURE 4. CHANGE IN TOTAL NITROGEN WITH STREAM DISTANCE, KAPALAMA CANAL, JUNE 1970 - JULY 1971.

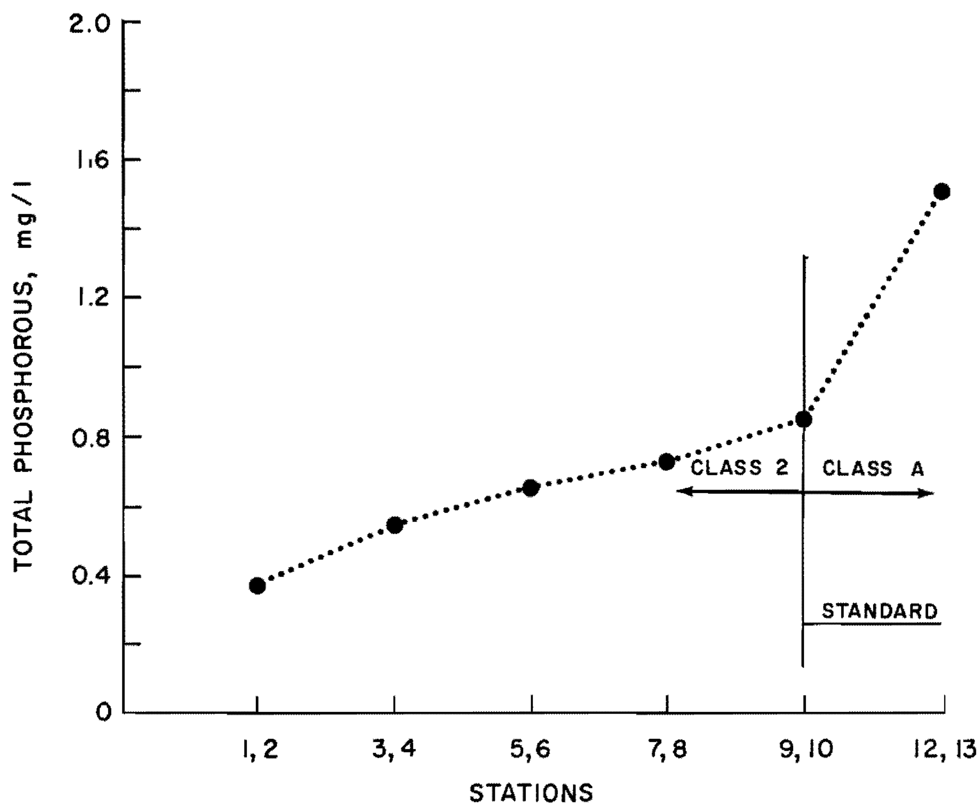

FIGURE 5. CHANGE IN TOTAL PHOSPHORUS WITH STREAM DISTANCE, KAPALAMA CANAL, JUNE 1970 - JULY 1971.

$22x10^7$/100 ml obtained in a survey in July 1968 at the mouth of the Canal (Ultramar, 1968). Total coliform levels at all stations failed to meet the requirements of the State Standards for Class 2 or Class A waters (see Figure 6).

The mean level of fecal coliform organisms for the waters of the canal designated as Class 2 was $1x10^5$/100 ml, while the mean for the waters designated as Class A waters was $8x10^6$/1000 1 (Table 2). The highest concentration of fecal coliforms was at Station 11 with $14x10^6$/100 ml, and the lowest was at Station 2 with $18x10^3$/100 ml. The mean levels for the fecal coliform for the Class 2 designated waters, as with the total coliform, decreased slightly from $16x10^3$/100 ml during dry weather flow to $8x10^3$/100 ml in wet weather flow. However, the mean for the Class A designated waters decreased from $36x10^6$/100 ml to $47x10^4$/100 ml for the same seasonal periods. This change was probably due to the large number of organisms being discharged through the cannery ditch during dry weather flow, the off-season cannery operations, and dilution effects of stormwater during wet weather flow. A range of 0.6 to $227x10^6$/100 ml was obtained during a July 1968 survey (Ultramar, 1968). The density of fecal coliforms observed at each station exceeded the state standards for Class 2 waters (see Figure 6).

The mean value of fecal streptococcus density for the Class 2 designated waters was $32x10^3$/100 ml, while the mean for the Class A designated waters was $4x10^7$/100 ml. The mean level of fecal streptococcus density for the Class 2 designated waters, as with the fecal coliform, decreased from $44x10^4$/100 ml in dry weather flow to $6x10^4$/100 ml in wet weather flow, while the mean for the Class A designated waters decreased from $75x10^5$/100 ml to $95x10^4$/100 ml. There is no standard for fecal streptococcus levels in the State Water Quality Standards.

The ratio of fecal coliforms to total coliforms (FC:TC) in the Ohio River (Ohio River Valley Water Sanitation Commission, 1971) was 0.14:1. Burm and Vaughn (Burm, R. J. and R. D. Vaughn, 1966) also reported a ratio of 0.2:1 in combined sewage. In the present study, ratios of FC:TC and FC:FS (fecal coliforms to fecal streptococci) based on the mean densities observed in the Class 2 waters of the canal were 0.25:1 and 5.2:1, respectively. Geldreich and Bernard (Geldreich, D. D. and A. K. Bernard, 1969) reported ratios of FC:FS in wastes of human origin as 4.4:1 and greater, and in animal wastes as 7.7:1 or less. At Stations 1 and 2, the mean value

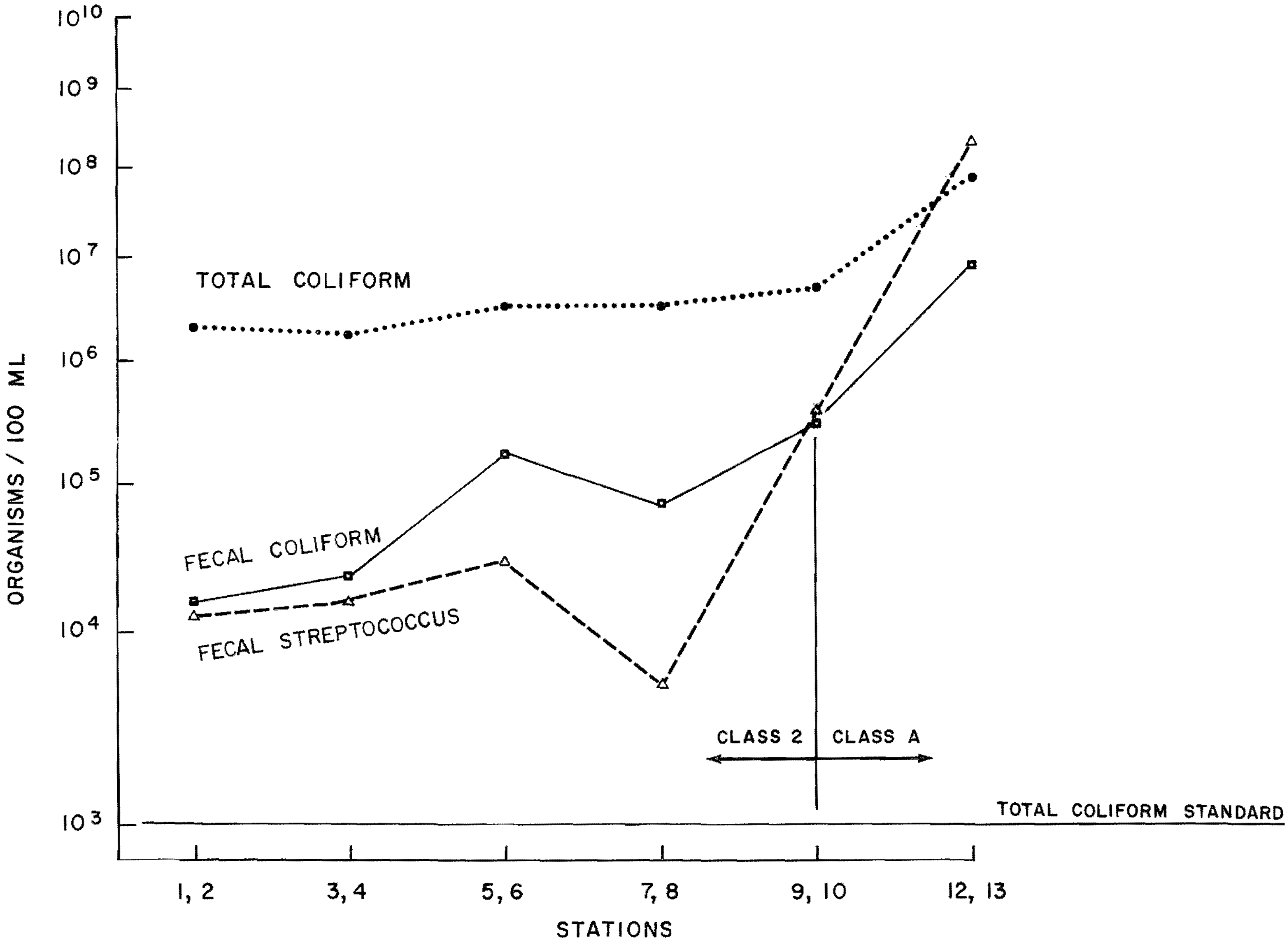

FIGURE 6. CHANGE IN COLIFORM AND STREPTOCOCCUS WITH STREAM DISTANCE, KAPALAMA CANAL, JUNE 1970-JULY 1971.

for FC:FS was determined to be 1.5:1. In view of the indications by Geldreich, these results suggest that raw human sewage as well as animal feces were entering the canal in the drainage from the Palama area.

The mean FC:FS ratio for Stations 2 and 4 was 2.0:1. At Stations 5 and 6 the mean ratio increased to 9.0:1. This rapid increase suggests the possibility of cesspool or sewer leakage into storm drains and subsequently into the Canal. The mean ratio for Stations 7 and 8 decreased to 6.0:1 from the high level at Stations 5 and 6. The cause of the decrease in organisms may be just a natural die-off. Below the tidal dam, the ratio of FC:FS decreased to 0.5:1. The cause of the rapid decrease of the organisms is unknown and suggests that further study needs to be done with these organisms and their relationships over a continuous, long-term period.

Concentrations of *Ps. aeruginosa* organisms observed in the Kapalama Canal were found to fluctuate (see Fig. 7). There was, however, a gradual increase in densities in the upstream to downstream direction that may be due to natural growth of the organisms and not to the addition of organism inflow from stormdrains. In dry weather flow, the mean density observed for the Class 2 designated waters was 112/100 ml, while in the Class A designated waters, it was 1000/100 ml. During wet weather flow the mean densities for the respective water classifications were 85 and 277/100 ml.

The major source of *Ps. aeruginosa* reaching the environment is man. In the U.S., 11 percent of the healthy adult population can be expected to harbor the organism (Hoadley, 1968). Similar carrier rates were reported for Israel with slightly lower rates for England and Hungary. Bonde (1963) was the first investigator to suggest a link between the presence of the organism in polluted water samples and water supplies as signifying recent and substantial pollution.

Hoadley (1968) found that besides man, only young calves were found to execute the organism, and only until they were weaned. The organism is rarely isolated from soils and it appears only among animals associated with man, and only in low densities. In runoff from two stormwater outfalls, densities of 4.9 and 2.0 organisms/ml were found, and the source of the organism was thought to be ruminants.

The occurrence and density of *Ps. aeruginosa* in surface waters varies considerably but Hoadley (1968) reports only 1 to 10 organisms/100 ml in streams of low contamination. Other reported values range between 100 to

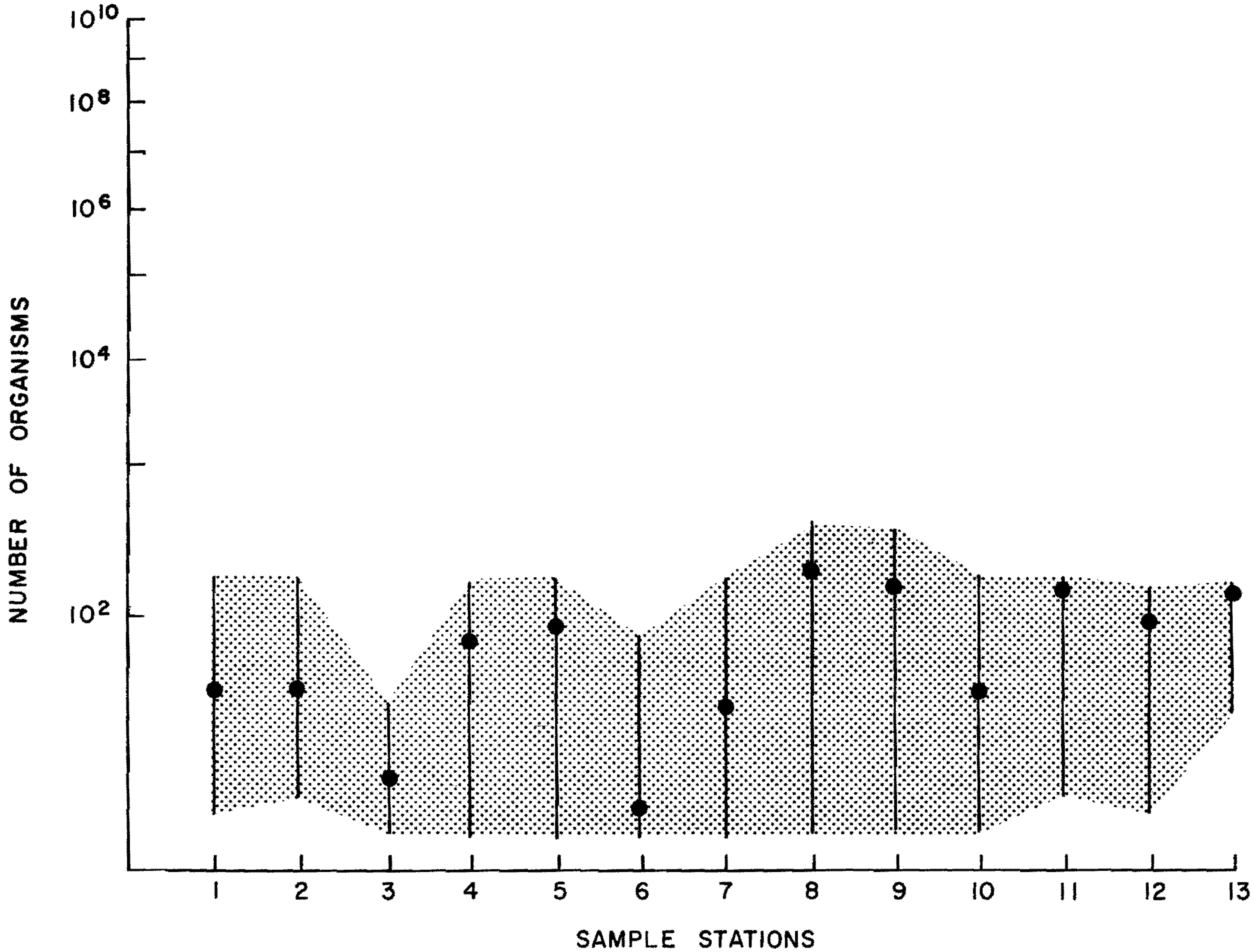

FIGURE 7. HIGH, MEAN, AND LOW *PSEUDOMONAS AERUGINOSA* VALUES OBSERVED PER 100 ML IN THE KAPALAMA CANAL, OAHU - MARCH 11-JULY 10, 1971.

1000/100 ml. Stream samples below a primary sewage treatment plant discharge were found to contain 7 to 92/ml with a median density of 13/ml, while samples below a secondary sewage treatment plant discharge contained a median content of 95/ml with a maximum of 2400/ml, indicating that the latter type of treatment may have favorable effect on the organism.

Since the occurrence of *Ps. aeruginosa* in Hawaiian streams has never previously been determined, it was interesting to find the canal waters to be transporting the organisms. In 1968, Hoadley (Hoadley, A. W., 1968) reported finding *Ps. aeruginosa* in concentrations of 4.9 and 2.0/ml in stormwater runoff, and the data from the present study is generally higher than Hoadley's results. The periodic variation of these organisms in the canal may be an indication of periodic discharges of raw sewage. It is also interesting to note that the mean density observed at Station 11 was 1400/ml, with a range of 220 to 2200/ml. It is possible, therefore, that the effluent discharge through Station 11 may also contain human wastes.

CONCLUSIONS

Based upon the results of surveys performed in the Kapalama Canal between July 1970 and June 1971, the following conclusions are drawn:

1. The concentrations of all parameters, with the exception of pH and alkalinity, increased in a downstream direction.

2. During wet weather streamflow, between October and February, increased surface runoff and rainfall resulted in a significant dilution effect on all the parameters measured.

3. The concentrations of all parameters analyzed increased definitely downstream of the tidal dam, probably due to the effluent from the pineapple canneries' outfall ditch.

4. The mean pH values of the State Standards were met by the Class 2 designated waters but was exceeded by the Class A designated waters. Supersaturated DO conditions were observed at Stations 1 and 2. Mean values obtained for DO for Class 2 waters met the standards, but the Class A waters exceeded the standards.

5. The calculated total BOD_5 load in the canal was 32,500 lbs/day. Of this total load, 99 percent was discharged into the canal at Station 11, the cannery outfall ditch.

6. The two nutrients measured, total nitrogen and phosphorus, increased greatly in dry weather flow downstream of the tidal dam. The levels of both nutrients at all stations failed to meet the State Water Quality Standards.

7. The average FC:FS and FC:TC ratios for the Class 2 waters were 5.2:1 and 0.25:1, respectively. The FC:FS ratio indicates that human wastes as well as animal feces are entering the Kapalama Canal.

8. The total coliform levels at all stations failed to meet the State Standards for either the Class 2 or Class A waters.

9. *Pseudomonas aeruginosa* organisms were found in the canal waters and were observed in densities greater than has been attributed to storm water runoff in the literature. During periods of wet weather flow, when levels of coliform and streptococci increase, the level of *Ps. aeruginosa* decreases.

REFERENCES

American Public Health Association. 1970. *Standard Methods for the Examination of Water and Wastewatèr.* 13th edition, The Association, Washington, D. C.

Anderson, W. A. D., ed. 1966. *Pathology*, Vol. I. St. Louis. (5):766 p.

Bonde, G. J. 1963. "Bacterial indicators of water pollution, a study of quantitative estimation." *Teknisk Forlag.* Copenhagen. 422 p.

Burbank, D. C., Jr. and J. S. Kumagai. 1965. "A study of pineapple cannery waste." *Proceedings of the 20th Industrial Waste Conference.* Purdue University, Engineering Extension Series No. 118. 365-397.

Burm, R. J. and R. D. Vaughn. 1966. "Bacteriological comparison between combined and separate sewage discharges in Southern Michigan." *Journal Water Pollution Control Federation.* 38:400-409.

Cox, D. C. and L. C. Gordon. 1970. *Estuarine Pollution in the State of Hawaii, Vol. I.: Statewide Study.* Technical Report No. 31, Water Resources Research Center, University of Hawaii.

Department of Health, State of Hawaii. 1966. *Public Hearings Nos. II & IV on Water Uses and Standards of Water Quality for Oahu's Water.*

Department of Health, State of Hawaii. 1968. "Water pollution control." *Public Health Regulations: Chapter 37.*

Department of Health, State of Hawaii. 1968. "Water quality standards." *Public Health Regulations: Chapter 37-A.*

Department of Health, State of Hawaii. 1970. *A Report on the Water Quality of the Kapalama Canal.*

Ells, M. D. 1971. *Bacterial Indicators in Kapalama Canal, Oahu with Special References to Pseudomonas Aeruginosa.* M.S. Thesis, University of Hawaii.

Geldreich, E. E. and A. K. Bernard. 1969. "Concepts of fecal streptococci in stream pollution." *Journal Water Pollution Control Federation.* 41:R336-R351.

Hahn, S. D. 1971. *Some Aspects of Water Quality in the Kapalama Stream.* M.S. Thesis, University of Hawaii.

Hoadley, A. W. 1968. *On the Sanitary Significance of Pseudomonas Aeruginosa in Surface Waters.* New England Water Works Association. LXXXII (2):99-111.

Ohio River Valley Water Sanitation Commission (ORSANCO). 1971. "Total coliform: fecal coliform ratio for evaluation of raw water bacterial quality." *Journal Water Pollution Control Federation.* 43(4):630-640.

Ultramar Chemical Water Laboratory. 1968. *Water Quality Study: Honolulu Harbor, Keehi Lagoon and Nearshore Waters from Kewalo Basin to Ahua Point, Island of Oahu.* Contract No. 10415 for Department of Health, State of Hawaii.