MARINE PROJECT REPORT SUBMITTED TO
THE UNIVERSITY OF HAWAII MARINE OPTION PROGRAM

Sewage Pollution in Kapoho Tide Pools
(preliminary study)

Duration of Study
September 11 - November 15, 1989

Project Leader

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Advisors

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December 5, 1989

ABSTRACT

This is a study to determine the presence and degree of sewage pollution in the tide-pools of Vacationland subdivision, in Kapoho, disrict of Puna, Hawaii Island.

The tide-pools in Vacationland subdivision may be prone to sewage contamination due to to groundwater infiltration and subsequent leaching of nearby residents' cesspools.

Fecal coliform and enterococci were chosen as biological indicators of sewage pollution.

Three tide-pools were studied with varying degrees of influence from the open ocean.

All three tide-pools show a high degree of sewage pollution posing a serious threat to human health.

INTRODUCTION

Kapoho, located in the district of Puna Hawaii, is thirty kilometers southeast of Hilo at Cape Kumukahi, the eastern-most point of Hawaii Island. Kapoho is the site of several large tide-pools that are frequently used for recreation (swimming, fishing, snorkeling, etc.) by residents and visitors alike.

The tide-pools in Vacationland subdivision may be prone to sewage contamination due to groundwater infiltration subsequent leaching of nearby residents' cesspools. Drs. Dudley and Hallacher are currently studying the distribution and dispersion of sewage pollution in the Hilo Bay area. My project is an ancillary investigation correlating to Dr. Dudley and Dr. Hallacher's project.

Sewage pollution poses a serious threat to human health. Many debilitating, even potentially fatal human pathogens can be found in conjunction with sewage pollution including polio, hepatitis, leptospirosis, tuberculosis, and gastroenteritis (Table 1).

It has been suggested by Dr Hallacher that certain environmental parameters, such as tide level and recent rainfall, may influence the levels of contamination in the tide-pools.

As a means of determining the degree of contamination, and the influence of environmental conditions in the Kapoho tide-pools, I have collected samples from three tide-pools with varying degrees of direct influence from the open ocean (all of the tide-pools rise and fall regularly with tide level). Samples were collected weekly for a period of ten weeks (September 11,

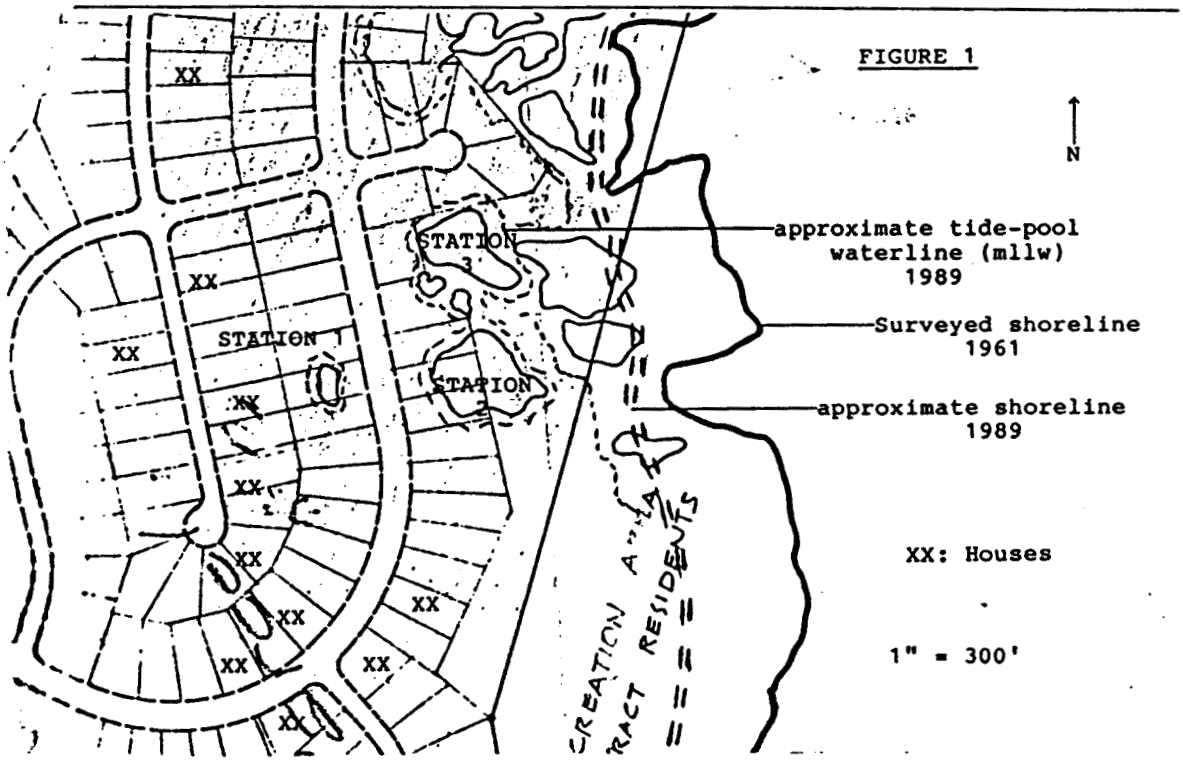
through November 13, 1989). Tidal changes and in situ measurements of water temperature, salinity, wind speed and direction, and recent rainfall, as well as in-laboratory procedures to determine the concentration of fecal bacteria (enterococci and fecal coliform), have been executed according to the accepted standards and the results compiled.

Table 1.

DISEASES KNOWN TO BE ASSOCIATED WITH UNTREATED SEWAGE:

Amoebic dysentery
Salmonella
Cholera
Polio
Staphylococci infection
Hepatitis
Shigellosis
Enteropathogenic E. Coli. infections
Leptospirosis (Leptospira sp.)
Tuberculosis and Enteritis (Mycobacterium sp.)

[source: Yeager and O'Brien, 1983]



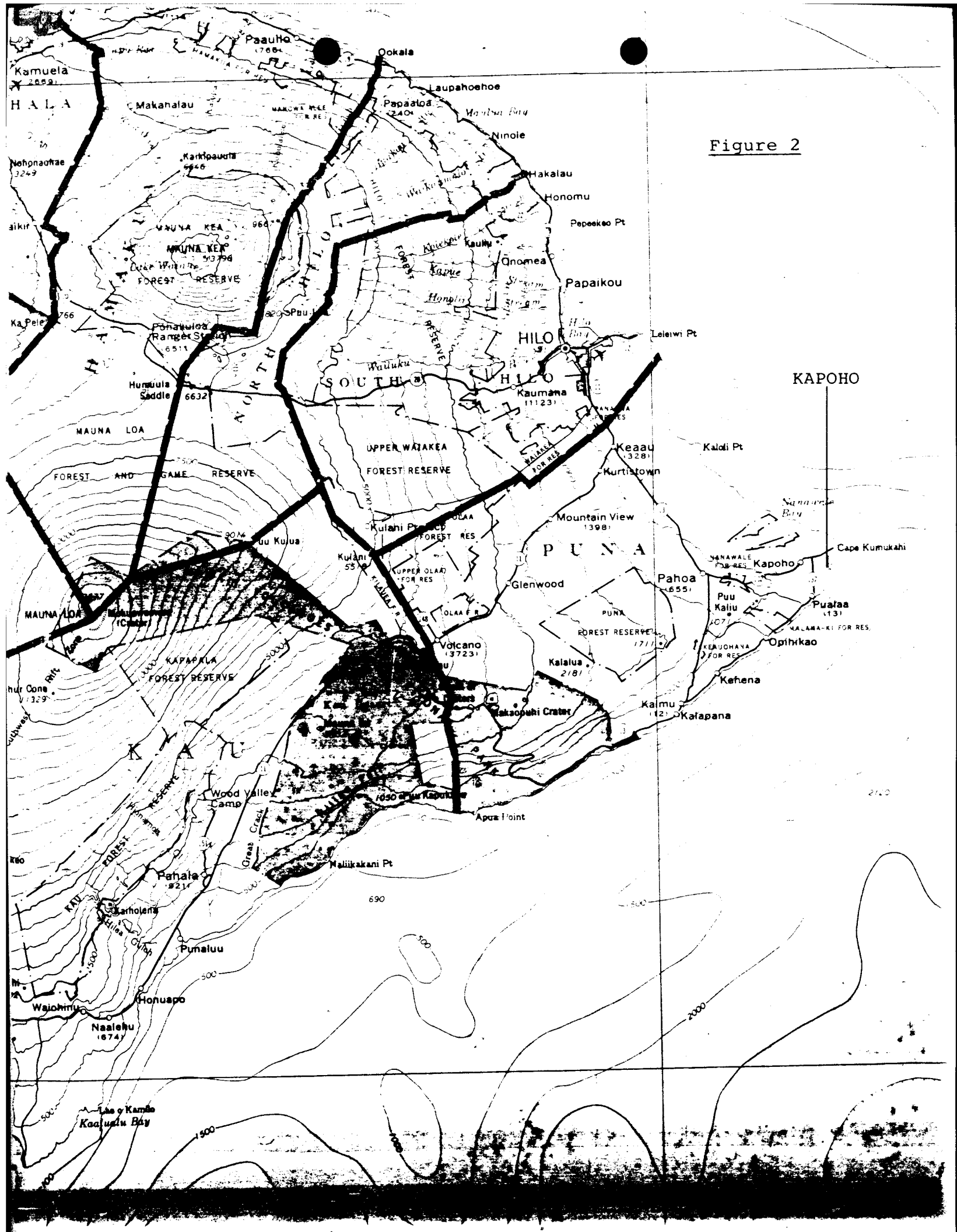


Figure 2
Paauilo
Ookala
Kamuela
Laupahoehoe
Papaaloa
Ninole
Makanalau
Hakalau
Honomu
Pepeekeo Pt
Kaumu
Onomea
Papaikou
Hilo Bay
Leleiwi Pt
HILO
KAPOHO
Kaumana
Humuula Saddle
MAUNA LOA
UPPER WAIAKEA FOREST RESERVE
FOREST AND GAME RESERVE
Keaau
Kaloli Pt
Kurtistown
Mountain View
Kulani
Glenwood
PUNA
Pahoa
Kapoho
Cape Kumukahi
Puu Kaliu
Puaiaa
Opihikao
Volcano
Kalalua
Kehena
Kalapana
KAPAPALA FOREST RESERVE
Wood Valley Camp
Apua Point
Pahala
Naalehu
Punaluu
Honuapo
Waiohinu
Kaalualu Bay

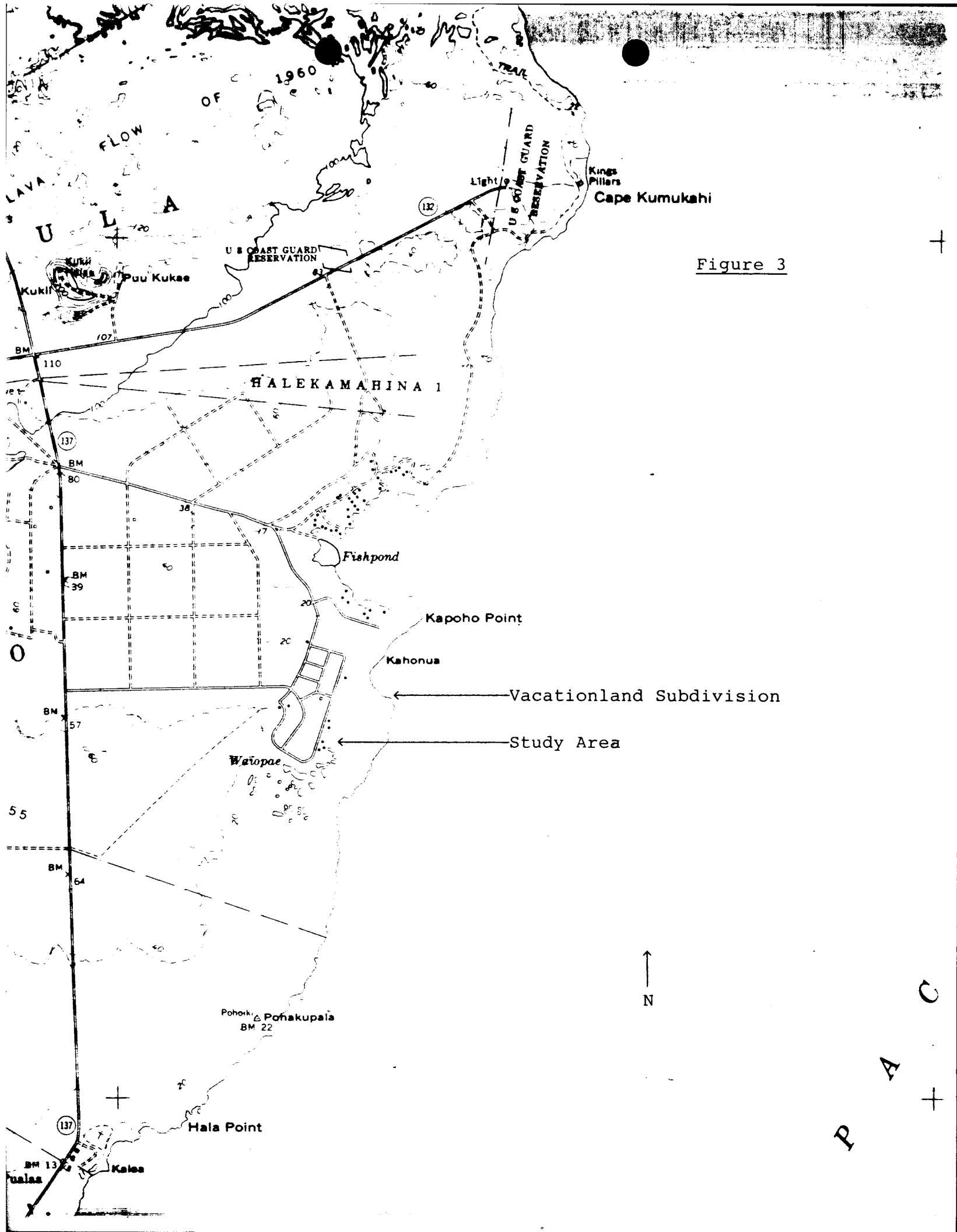

1960
OF
FLOW
LAVA
U L A
U S COAST GUARD RESERVATION
Light
Kings Pillars
Cape Kumukahi
Kukii
Puu Kukae
Kukii
U S COAST GUARD RESERVATION
BM
110
HALEKAMAHINA 1
137
BM
80
38
47
Fishpond
BM
39
20
Kapoho Point
20
Kahonua
O
Vacationland Subdivision
BM
57
Study Area
Waiopae
55
BM
64
N
Pohakupala
BM 22
P A C
Hala Point
137
BM 13
Kalea

Figure 3

MATERIALS AND METHODS

Sample locations (tide-pools) were chosen according to their inferred degree of influence from the open ocean, and relative close proximity to homes (Figure 1).

Fecal coliform and enterococci were chosen as biological indicators of sewage pollution. These bacteria are associated with the digestive systems of warm-blooded animals (enterococci being specific to humans), and are therefore good indicators of sewage pollution. Fecal coliform are currently the most widely used indicator.

To test for these bacteria, samples were collected in pre-sterilized, pre-labeled nalgene bottles and transported on ice to the MBRS (Minority Biomedical Research Station) lab at the University of Hawaii--Hilo for immediate filtration. The samples were filtered using the millapore membrane filtration method as outlined in the EPA's Standard Methods for the Examination of Water and Wastewater--Sixteenth edition--1985. The recovered bacteria were placed in petri dishes on selective media and then incubated.

Enterococci were incubated in a dry incubator at 41.5 (c) and cultured on m-E agar for 48 hours. Colonies were identified by their characteristic red coloration and verified in situ on esculin iron agar.

Fecal coliform were placed on a recovery media (M-FC broth) in petri dishes and sealed with parafilm. The petri dishes were then placed in heat-sealed bags and incubated in a water bath at

44.5 (c) for 24 hours. The colonies in each dish were then identified by their characteristic blue coloration, counted and recorded.

For each site 50 mL (milliliter) and 5 mL volumes were diluted to 100 mL, the accepted standard volume for bacterial colony analysis. Actual colony counts and volumes filtered were entered on the computer for calculation and standardization (geometric mean and arithmetic mean).

Physical parameters were recorded during sampling including time, water temperature, wind speed and direction, general weather conditions, and human activity. Recent precipitation was monitored near the site (a rain gauge stationed in a friends yard) and recorded for 24, 48, and 72 hours prior to sampling time. Salinity was determined using a YSI salinometer. Tidal information, wind and rain data were also obtained from NOAA (National Oceanic and Atmospheric Administration).

RESULTS

As a means of distinguishing between sampling locations the tide-pools were simply labeled Kapoho 1, Kapoho 2, and Kapoho 3. Kapoho 1 being the furthest inshore and therefore the least interaction with the open ocean; Kapoho 2 is intermediate; Kapoho 3 being closest to the shoreline and subject to the greatest amount of mixing by regular tidal influx.

All three tide-pools show high degrees of sewage pollution.

Kapoho 1 was consistently the most contaminated, with fecal coliform (mean) colony counts as high as 7380 (36.5 times greater than EPA standard dangerous level of 200 colonies per 100 mL), with a range of 89 to 7380, and on many occasions too numerous too count. Enterococci (mean) colony counts ranged from 52 to 2200 with a geometric mean of 287 (41 times greater than EPA standard of 7--corresponding to 19 illnesses per 1000 swimmers).

Kapoho 2 fecal coliform (mean) colony counts ranged from 0 to 1130 with a geometric mean of 198 (EPA standard dangerous level 200). Enterococci (mean) colony counts ranged from 2 to 1200 with a geometric mean of 71 (10 times greater than EPA standard of 7).

Kapoho 3 fecal coliform (mean) colony counts ranged from 4 to 328 with a geometric mean of 53. Two of the ten days sampled (20%) resulted in counts exceeding the 200 level. Enterococci (mean) colony counts ranged from 0 to 82 with a geometric mean of 14 (2 times greater than the EPA standard of 7).

DISCUSSION

The physical parameter that showed the most significant correlation with the data was rainfall. Generally high rainfall within 24 hours of sampling resulted in lower bacterial counts, for both enterococci and fecal coliform. Generally high rainfall within 72 hours of sampling, and low rainfall within 24-48 hours resulted in the highest colony counts for fecal coliform, but this did not correlate with results for enterococci colonies in Kapoho 1 which were lowest in enterococci counts during these periods although still at the high end of the scale). (See appendix).

Analysis of the remainder of the data in relation to physical parameters showed no significant correlation to bacterial colony counts.

In some cases the fecal coliform counts may have been recorded as being erroneously low, due to competition from some other micro-organisms that populated the recovery media, resulting in yellowish confluent and isolated colonies.

There is an inverse correlation between bacterial counts and Salinity.

Tidal flow scale showed some correlation with the data. In some cases bacterial counts were generally higher when tidal flow was at a minimum. (See appendix).

Sewage pollution is a serious problem in the Kapoho tide-pools. Due to the absence of other probable polluters (livestock, etc.) in the Kapoho area, my hypothesis is that the source of the pollution is the nearby residents cesspools (which is nothing

more than a cement capped hole in the ground) into which the raw sewage is flushed. The highly porous basaltic substrate is an effective aquifer, therefore after periods of high rainfall the cesspools are effectively leached and the sewage contaminates the groundwater,
which ultimately flows to the fresh water saline interface of the tide-pools.

The inverse correlation between salinity and bacterial colony counts, I perceive to be a direct relation to recent rainfall.

The Kapoho area has been undergoing subsidence causing a significant recession of the shoreline and enlargement of the tide-pools (see figure 1).

The results of this study clearly show that the degree of sewage pollution in Kapoho is extremely high, posing a threat to human health. In order to deal with the situation adequately some drastic changes will have to be made in dealing with sewage treatment and disposal in coastal residential areas such as Kapoho. In the near future many more people will be moving into this area and the problem is likely to get worse before it gets better.

REFERENCES

Greenberg, Arnold E., Chairman Joint Editorial Board 1985 Standard Methods for the Examination of Water and Wastewater, Sixteenth Edition. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington D.C.

Yeager, J.G. and R.T. O'Brian 1983. Irradiation as a means to minimize public health risks from sludge-borne pathogens. Journal Water Pollution Control Federation 57(5): 977-983.

Maps courtesy of Hawaii County Public Works -- Hilo Hawaii

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A P P E N D I X

KAPOHO SEWAGE POLLUTION STUDY

Kapoho 1
Fecal coliform
Arithmatic Mean = 2808
Geometric Mean = 1532

Date	Time Hrs.	Time Mins.	Mean Colony Count	Sal.	Temp.	RAIN 24HR	RAIN 48HR	RAIN 72HR	Tide (ft)	Tide Scaled Flow
11SEP89	7	0	1000	9.5	26.5	0.10	0.10	0.10	0.40	0.3
18SEP89	7	10	660	9.5	25.5	0.40	1.50	1.90	2.69	-0.7
25SEP89	7	25	780	6.5	28.0	0.10	0.10	2.40	0.60	-0.1
02OCT89	7	15	4900	4.0	27.0	0.20	0.70	1.40	2.34	-3.4
09OCT89	7	43	89	2.5	28.0	0.90	0.90	2.30	1.13	5.1
16OCT89	7	34	4550	9.5	27.5	0.00	0.00	0.20	2.62	-6.0
23OCT89	7	41	4220	4.0	26.0	2.20	2.20	2.20	0.98	3.3
30OCT89	7	19	7380	6.0	26.0	0.00	0.30	1.00	1.78	-6.9
06NOV89	7	45	570	4.5	27.0	1.40	1.40	1.40	2.14	4.1
13NOV89	7	27	3930	8.0	26.5	0.10	0.10	0.10	1.79	-9.3

FECAL COLIFORM
KAPOHO 1
Bacterial Count Worksheet

Date	Vol.(ml) Filtered Series 1	Colony Count Rep 1a	Colony Count Rep 1b	Vol.(ml) Filtered Series 2	Colony Count Rep 2a	Colony Count Rep 2b
11SEP89	50	*	8	5	**	50
18SEP89	50	*	*	5	39	27
25SEP89	50	*	*	5	37	41
02OCT89	50	*	*	5	242	248
09OCT89	50	22	67	5	**	**
16OCT89	50	*	*	5	252	203
23OCT89	50	*	*	5	202	220
30OCT89	50	*	*	5	369	*
06NOV89	50	*	*	5	29	28
13NOV89	50	*	*	5	215	178

* too numerous to count
** insufficiant data

Kapoho 1
Enterocci
Arithmatic Mean = 589
Geometric Mean = 307

Date	Time Hrs.	Time Mins.	Mean Colony Count	Sal.	Temp.	RAIN 24HR	RAIN 48HR	RAIN 72HR	Tide (ft)	Tide Scaled Flow
11SEP89	7	0	153	9.5	26.5	0.10	0.10	0.10	0.40	0.3
18SEP89	7	10	156	9.5	25.5	0.40	1.50	1.90	2.69	-0.7
25SEP89	7	25	420	6.5	28.0	0.10	0.10	2.40	0.60	-0.1
02OCT89	7	15	420	4.0	27.0	0.20	0.70	1.40	2.34	-3.4
09OCT89	7	43	60	2.5	28.0	0.90	0.90	2.30	1.13	5.1
16OCT89	7	34		9.5	27.5	0.00	0.00	0.20	2.62	-6.0
23OCT89	7	41		4.0	26.0	2.20	2.20	2.20	0.98	3.3
30OCT89	7	19	2200	6.0	26.0	0.00	0.30	1.00	1.78	-6.9
06NOV89	7	45	120	4.5	27.0	1.40	1.40	1.40	2.14	4.1
13NOV89	7	27	1180	8.0	26.5	0.10	0.10	0.10	1.79	-9.3

ENTEROCOCCI KAPOHO 1
Bacterial Count Worksheet

Date	Vol.(ml) Filtered Series 1	Colony Count Rep 1a	Colony Count Rep 1b	Vol.(ml) Filtered Series 2	Colony Count Rep 2a
11SEP89	50	72		5	12
18SEP89	50	76		5	10
25SEP89	50	*		5	21
02OCT89	50	*		5	21
09OCT89	50	26		5	7
16OCT89	50	*		5	*
23OCT89	50	*		5	*
30OCT89	50	*		5	110
06NOV89	50	60		5	**
13NOV89	50	*		5	59

* Too numerous to count
** insufficiant data

KAPOHO SEWAGE POLLUTION STUDY

Kapoho 2
Fecal coliform
Arithmatic Mean = 435
Geometric Mean = 198

Date	Time Hrs.	Time Mins.	Mean Colony Count	Sal.	Temp.	RAIN 24HR	RAIN 48HR	RAIN 72HR	Tide (ft)	Tide Scaled Flow
11SEP89	7	10	860	15.0	28.0	0.10	0.10	0.10	0.41	0.9
18SEP89	7	12	670	16.5	26.5	0.40	1.50	1.90	2.69	-0.8
25SEP89	7	27	1130	10.5	28.0	0.10	0.10	2.40	0.60	0.0
02OCT89	7	18	1	27.5	27.0	0.20	0.70	1.40	2.33	-3.5
09OCT89	7	48	700	7.0	28.0	0.80	0.90	2.30	1.15	5.2
16OCT89	7	40	76	29.5	27.0	0.00	0.00	0.20	2.58	-6.2
23OCT89	7	44	0	9.0	27.0	2.20	2.20	2.20	0.99	3.4
30OCT89	7	25	510	14.0	28.0	0.00	0.30	1.00	1.73	-7.0
06NOV89	7	48	93	12.0	28.0	1.40	1.40	1.40	2.15	4.0
13NOV89	7	30	310	16.0	28.0	0.10	0.10	0.10	1.76	-9.3

FECAL COLLIFORM
KAPOHO 2
Bacterial Count Worksheet

Date	Vol.(ml) Filtered Series 1	Colony Count Rep 1a	Colony Count Rep 1b	Vol.(ml) Filtered Series 2	Colony Count Rep 2a	Colony Count Rep 2b
11SEP89	50	*	*	5	43	**
18SEP89	50	*	*	5	36	31
25SEP89	50	*	*	5	66	47
02OCT89	50	0	0	5	1	0
09OCT89	50	*	*	5	30	40
16OCT89	50	38	38	5	**	**
23OCT89	50	0	0	5	0	0
30OCT89	50	*	*	5	25	26
06NOV89	50	30	**	5	21	**
13NOV89	50	155	158	5	15	13

* too numerous too count
** insufficiant data

KAPOHO SEWAGE POLLUTION STUDY

Kapoho 2
Enterococci

Arithmatic Mean = 251
Geometric Mean = 71

Date	Time Hrs.	Time Mins.	Mean Colony Count	Sal.	Temp.	RAIN 24HR	RAIN 48HR	RAIN 72HR	Tide (ft)	Tide Scaled Flow
11SEP89	7	10	115	15.0	28.0	0.10	0.10	0.10	0.41	0.9
18SEP89	7	12	25	16.5	26.5	0.40	1.50	1.90	2.69	-0.8
25SEP89	7	27	200	10.5	28.0	0.10	0.10	2.40	0.60	0.0
02OCT89	7	18	2	27.5	27.0	0.20	0.70	1.40	2.33	-3.5
09OCT89	7	48	70	7.0	28.0	0.90	0.90	2.30	1.15	5.2
16OCT89	7	40	22	29.5	27.0	0.00	0.00	0.20	2.58	-6.2
23OCT89	7	44	660	9.0	27.0	2.20	2.20	2.20	0.99	3.4
30OCT89	7	25	200	14.0	28.0	0.00	0.30	1.00	1.73	-7.0
06NOV89	7	48	13	12.0	28.0	1.40	1.40	1.40	2.15	4.0
13NOV89	7	30	1200	16.0	28.0	0.10	0.10	0.10	1.76	-9.3

ENTEROCOCCI KAPOHO 2
Bacterial Count Worksheet

Date	Vol.(ml) Filtered Series 1	Colony Count Rep 1a	Colony Count Rep 1b	Vol.(ml) Filtered Series 2	Colony Count Rep 2a
11SEP89	50	52		5	11
18SEP89	50	14		5	0
25SEP89	50	*		5	10
02OCT89	50	1		5	0
09OCT89	50	35		5	**
16OCT89	50	11		5	1
23OCT89	50	*		5	33
30OCT89	50	*		5	10
06NOV89	50	7		5	0
13NOV89	50	*		5	60

* Too numerous to count
** insufficiant data

KAPOHO SEWAGE POLLUTION STUDY

Kapoho 3
Fecal coliform
Arithmatic Mean = 103
Geometric Mean = 53

Date	Time Hrs.	Time Mins.	Mean Colony Count	Sal.	Temp.	RAIN 24HR	RAIN 48HR	RAIN 72HR	Tide (ft)	Tide Scaled Flow
11SEP89	7	12	107	17.0	25.0	0.10	0.10	0.10	0.41	1.0
18SEP89	7	13	60	31.0	26.5	0.40	1.50	1.90	2.69	-0.9
25SEP89	7	29	328	12.0	28.0	0.10	0.10	2.40	0.60	0.0
02OCT89	7	20	5	27.5	26.5	0.20	0.70	1.40	2.32	-3.6
09OCT89	7	52	108	7.0	26.5	0.90	0.90	2.30	1.18	5.3
16OCT89	7	41	21	29.5	27.0	0.00	0.00	0.20	2.57	-6.3
23OCT89	7	45	4	28.5	26.5	2.20	2.20	2.20	1.00	3.4
30OCT89	7	26	92	21.5	27.0	0.00	0.30	1.00	1.73	-7.0
06NOV89	7	50	98	24.0	27.0	1.40	1.40	1.40	2.16	4.0
13NOV89	7	31	204	19.0	27.0	0.10	0.10	0.10	1.75	-9.3

FECAL COLIFORM
KAPOHO 3
Bacterial Count Worksheet

Date	Vol.(ml) Filtered Series 1	Colony Count Rep 1a	Colony Count Rep 1b	Vol.(ml) Filtered Series 2	Colony Count Rep 2a	Colony Count Rep 2b
11SEP89	50	104	5	5	6	3
18SEP89	50	**	30	5	**	**
25SEP89	50	169	161	5	18	13
02OCT89	50	3	2	5	1	0
09OCT89	50	54	**	5	**	**
16OCT89	50	11	8	5	1	3
23OCT89	50	3	1	5	0	0
30OCT89	50	40	52	5	**	**
06NOV89	50	46	54	5	4	4
13NOV89	50	106	99	5	7	12

** insufficiant data

KAPOHO SEWAGE POLLUTION STUDY

Kapoho 3
Enterococci
Arithmatic Mean = 27
Geometric Mean = 14

Date	Time Hrs.	Time Mins.	Mean Colony Count	Sal.	Temp.	24HR RAIN	48HR RAIN	72HR RAIN	Tide (ft)	Tide Scaled Flow
11SEP89	7	12	40	17.0	25.0	0.10	0.10	0.10	0.41	1.0
18SEP89	7	13	5	31.0	26.5	0.40	1.50	1.90	2.69	-0.9
25SEP89	7	29	82	12.0	28.0	0.10	0.10	2.40	0.60	0.0
02OCT89	7	20	4	27.5	26.5	0.20	0.70	1.40	2.32	-3.6
09OCT89	7	52	52	7.0	26.5	0.90	0.90	2.30	1.18	5.3
16OCT89	7	41	0	29.5	27.0	0.00	0.00	0.20	2.57	-6.3
23OCT89	7	45	4	28.5	26.5	2.20	2.20	2.20	1.00	3.4
30OCT89	7	26	11	21.5	27.0	0.00	0.30	1.00	1.73	-7.0
06NOV89	7	50	2	24.0	27.0	1.40	1.40	1.40	2.16	4.0
13NOV89	7	31	67	19.0	27.0	0.10	0.10	0.10	1.75	-9.3

ENTEROCOCCI KAPOHO 3
Bacterial Count Worksheet

Date	Vol.(ml) Filtered Series 1	Colony Count Rep 1a	Colony Count Rep 1b	Vol.(ml) Filtered Series 2	Colony Count Rep 2a
11SEP89	50	18		5	4
18SEP89	50	2		5	1
25SEP89	50	41		5	**
02OCT89	50	0		5	2
09OCT89	50	26		5	**
16OCT89	50	0		5	0
23OCT89	50	2		5	0
30OCT89	50	6		5	0
06NOV89	50	1		5	0
13NOV89	50	36		5	1

** insufficiant data