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The City and County of Honolulu operated Kalaheo Sanitary Landfill, located near Kawainui Marsh, Kawainui, Oahu, Hawaii, from March 1986 until March 1990. During the 4-yr period of operation an estimated 2.8×10^6 yd^3 (2.14×10^6 m^3) of municipal and commercial solid waste was deposited at the site. As was the case for the nearby Kapaa Sanitary Landfill, concern was raised about the possible adverse effects of the landfill operation on the ecological and environmental aspects of Kawainui Marsh, located approximately 1,000 ft (305 m) away. Analysis of samples obtained from the leachate collection manhole did clearly indicate that the leachate generated from the Kalaheo Sanitary Landfill site would be considered as being relatively weak. The results of the study are intended to serve as a preliminary baseline until additional monitoring sites are established in accordance with the closure plan presently being formulated.

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LEACHATE EVALUATION AND MONITORING PROJECT, KALAHEO SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

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ABSTRACT

The City and County of Honolulu operated the Kalaheo Sanitary Landfill, located near Kawainui Marsh, Kawainui, O'ahu, Hawai'i, from March 1986 until March 1990. During the four-yr period of operation, an estimated 2.8×10^6 yd^3 (2.14×10^6 m^3) of municipal and commercial solid waste was deposited at the site. As was the case for the nearby Kapaa Sanitary Landfill, concern was raised about the possible adverse effects of the landfill operation on the ecological and environmental aspects of Kawainui Marsh, located approximately 1,000 ft (305 m) away. Analysis of samples obtained from the leachate collection manhole did clearly indicate that the leachate generated from the Kalaheo Sanitary Landfill site would be considered as being relatively weak. The results of the study are intended to serve as a preliminary baseline until additional monitoring sites are established in accordance with the closure plan presently being formulated.

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INTRODUCTION

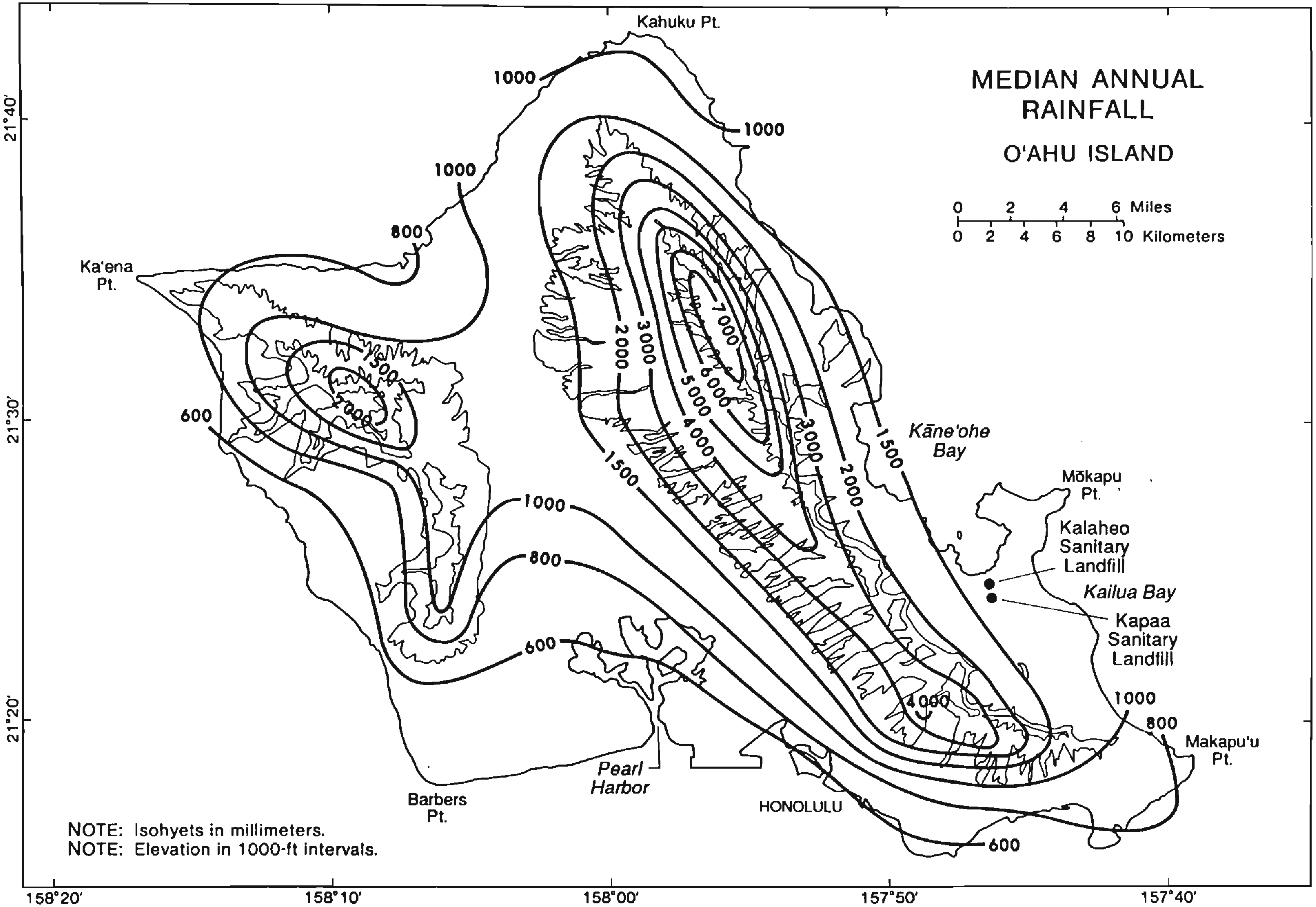
The Kalaheo Sanitary Landfill, located in windward O'ahu (Fig. 1), is adjacent to Interstate Route H-3 and near Kawainui Marsh, as shown in Figure 2. The Kalaheo facility was operated by the Division of Refuse Collection and Disposal, Department of Public Works, City and County of Honolulu from March 1986 until it reached its height limitation, set at an elevation of 250 ft (76.2 m), in March 1990. The height limitation was established by the Hawaii State Department of Land and Natural Resources when the Conservation District Use Permit was issued. The approximately 55 acre (2.23×10^5 m^2) landfill area, indicated in Figure 2, received an estimated 2.8×10^6 yd^3 (2.14×10^6 m^3) of solid waste from municipal and commercial solid waste (refuse) sources during the four years of operation.

A subsurface leachate collection system (pipes and receptacle), included in the design of the landfill, will be further discussed in a subsequent section of this report. The intent of the leachate collection system was to enable collection of leachate, which could potentially reach adjacent Kawainui Marsh by surface and/or subsurface flows, and to haul it to a wastewater treatment facility for treatment and disposal.

The City and County of Honolulu has had a long-standing concern regarding leachate production from Kapaa Sanitary Landfill, in operation since 1964, and more recently Kalaheo Sanitary Landfill, and its potential for affecting the adjacent 750 acre (3.04×10^6 m^2) Kawainui Marsh (Fig. 2). This concern is evident by the number and diversity of the studies, commencing since the early 1970s.

The first study of potential leachate generation and movement from Kapaa Sanitary Landfill, conducted by Burbank (1972), was a short-duration study of only three sites; two surface-water sites and one shallow well. Two 1977 studies (Bowles and Mink 1977; EMCON Associates 1977) were based on reviews of the existing literature on the hydrogeology of the region and on leachate production reported elsewhere. All three investigations concluded that the sanitary landfill operation at Kapaa did not adversely affect the quality of the waters of Kawainui Marsh by way of leachate production and migration, nor would the expansion considered at that time (which was implemented and is nearing full utilization) be expected to create unacceptable and adverse impacts. The City and County of Honolulu also funded a baseline study by Smith (1978) of the vegetation in and near Kawainui Marsh.

Even though the three previous investigations strongly suggested that leachate migration to Kawainui Marsh would not be expected to create undesirable consequences, the paucity of actual field data collection and analysis prompted the City and County of Honolulu to take a precautionary approach and establish a baseline sampling and monitoring program. To this end, an intensive two-yr baseline study was established with six sampling sites each for



SOURCE: Giambelluca, Nullet, and Schroeder (1986).

Figure 1. Kalaheo and Kapaa sanitary landfill sites and median annual rainfall, Kawainui, O'ahu, Hawai'i

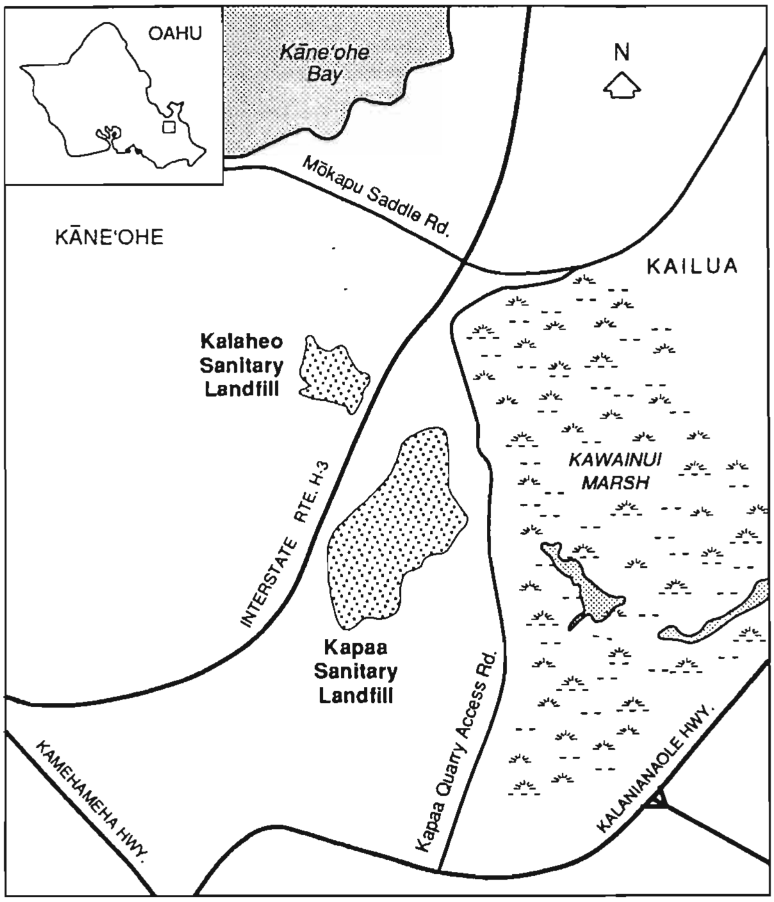


Figure 2. Specific site locations for Kalaheo and Kapaa sanitary landfills, Kawainui, O'ahu, Hawai'i

surface water and groundwater, followed by an ongoing, low-level (limited sample sites and analyses) monitoring program (Chun and Dugan 1981). A monitoring program to test for explosive gases near buildings close to Kapaa Sanitary Landfill was also conducted during the baseline study phase. The analyses conducted for the baseline study were for typical surface water and leachate parameters. The low-level monitoring program consisted of an annual analysis of the array of constituents used for the baseline study at selected sampling sites (three leachate monitoring wells, four surface-water stations, and one manhole servicing the in-place horizontal underdrain collection system), followed by monthly sampling at the three monitoring wells and one surface-water station for chemical oxygen demand (COD), chlorides, and pH (Dugan 1991).

Leachate, as used in this study, implies liquid that has percolated through the influence of solid waste from which dissolved and/or suspended materials have been extracted. Some of these materials are readily soluble, while others are by-products of biological degradation of solid waste or products of biochemical actions of leachate.

PURPOSE AND SCOPE

The purpose of this report is to evaluate the analytical results of samples of leachate collected from the leachate collection system at the Kalaheo Sanitary Landfill. The results of the study are intended to serve as a preliminary baseline until additional monitoring sites are established in accordance with the closure plan presently being formulated.

PHYSICAL SETTING

The Kalaheo and Kapaa sanitary landfills, both of which are located near and mauka of Kawainui Marsh, are in Maunawili Valley, an 18 mile^2 (46.6 km^2) basin that drains into Kailua Bay on the windward side of O'ahu, Hawai'i. The geologic features of this valley were principally formed by the lava flows of the Koolau and Kailua Volcanic Series. The Koolau Volcanic Series formed high cliffs along the southwestern side of the basin, while the rocks of the Koolau and Kailua Volcanic Series formed two ridges that strike north-eastward and separate the area from Waimanalo to the southwest, and Kāne'ohe to the northwest (Takasaki, Hirashima, and Lubke 1969).

At the base of the high cliffs deep in the valley, older alluvium forms an apron, while the lower part of the valley is underlain by younger alluvium. This younger material forms an important geographic feature of the valley—namely, Kawainui Marsh, the largest freshwater marsh in Hawai'i. Test borings in the marsh have revealed pockets of silty clay and clayey marl interbedded with coral detritus and alluvium extending to depths of more than 100 ft (30.5 m) (Takasaki, Hirashima, and Lubke 1969).

It has been suggested that Kawainui Marsh was once a freshwater lake that has been transformed by siltation into the present marsh. Along the front of this marsh area, as well as along the entire coastline, dune sand beach deposits and sparse outcrops of coralline limestone occur. The marsh is presently designated as a flood-control and conservation area. Greater attention to the ability of the marsh to help control floods resulted from the New Year's 1988 flood of Coconut Grove, a housing subdivision adjacent to the marsh.

Groundwater in Maunawili Valley is principally high-level and dike-confined, located generally at elevations above 650 ft (198.1 m). The height of the basal water is less than 2 ft (0.61 m), and the near-shore water is brackish. Groundwater near the crest probably moves northeastward, due to geologic constraints, and discharges at numerous points as springs at elevations of about 600 ft (182.9 m). These springs feed Kawainui Marsh and the area's two stream systems, Maunawili and Kahanaiki. The dependable yield of this groundwater reservoir is estimated to be 6.7 mgd (0.294 m^3/s), of which approximately 2.7 mgd (0.118 m^3/s) feed the two systems (Takasaki, Hirashima, and Lubke 1969).

Groundwater in the dike compartment aquifer at the inland margin of Kawainui Marsh overflows into the marsh rather than through the vertical face, as is common in aquifer hydraulics. Thus, leachate would tend to flow along the water table surface instead of undergoing deep mixing in the aquifer. The surface of Kawainui Marsh is the surface of the general groundwater table in the region (Takasaki, Hirashima, and Lubke 1969).

Of the two stream systems draining into Kawainui Marsh, Maunawili is the larger, with flow steadily increasing downstream to a maximum at the upper edge of the marsh. Takasaki, Hirashima, and Lubke (1969) reported an estimated long-term average daily flow of 7.8 mgd (0.342 m^3/s) for Maunawili Stream and 1.0 mgd (0.044 m^3/s) for Kahanaiki Stream at the upper marsh edge. However, about 2.0 mgd (0.088 m^3/s) are diverted from the area by the Maunawili Ditch system, which intercepts water from Makawao Stream, a tributary of Maunawili Stream. The net flow of Maunawili Stream is therefore estimated to be 5.8 mgd (0.254 m^3/s) at the upper boundary of the marsh. The median annual rainfall at the Kapaa and Kalaheo sanitary landfills is about 47 in. (1 194 mm), whereas it is over 100 in. (2 540 mm) near the crest where the principal groundwater recharge occurs (Fig. 1). The projected intensity of the 100-yr, 24-hr frequency-duration storm for the Kapaa and Kalaheo sanitary landfill areas is approximately 13 in. (330 mm) (Giambelluca, Nullet, and Schroeder 1984).

Mean monthly temperatures range from about 73°F (22.8°C) during the coldest month to approximately 79°F (26.1°C) during the warmest month, while the average monthly relative humidity ranges between approximately 50% and 80% (Schmitt 1988). The predominantly cool trade winds modify the effect of the warm temperatures and high humidity.

Kawainui Marsh

In discussing the biological conditions of Kawainui Marsh, various aspects must be considered. The marsh is presently a flood-control facility for most of the Kailua area and serves as a buffer zone and sink for sediment and nutrients that are produced by natural and human activities upstream of the marsh, including overland runoff. The marsh is also a receptacle for a small quantity of treated sewage effluent and, possibly, leachate from the landfill; however, most of the treated sewage effluent that once flowed into Kawainui Marsh is now diverted to the Kailua Wastewater Treatment Plant (WWTP). Because of its size and location adjacent to an urban area, the marsh is desired by developers for housing, commercial ventures, and active recreation, and by conservationists for a wildlife sanctuary.

No pristine vegetation exists in Kawainui Marsh because the area has been used, altered, and exploited since the discovery of the islands by Europeans. The vegetation that exists today is the result of past stresses on the system, and if the nature of these stresses changes, the vegetation and other biological aspects of the marsh will adjust accordingly (Smith 1978).

The biological aspects of the baseline study in and around Kawainui Marsh incorporated information on the vegetative (flora) considerations of Smith (1978), and on the fauna aspects reported by Ford (1975). The report by Ford and a previous document by Bienfang (1974) addressed the environmental and biological conditions of the marsh ecosystem, but not in relation to the expansion of the landfill operation, one of the main objectives stated in the report by Smith (1978).

A large portion of the permanently flooded area of the lower part of Kawainui Marsh is a floating bog, with layers of plants, roots, and peat floating over water. In general, wetlands such as Kawainui Marsh are not thought to be very sensitive to small environmental changes, inasmuch as they have an adaptive resistance to the harsh conditions under which they exist. Thus, wetlands do not serve well as sensitive bioindicators. In view of this, it is important to ascertain how plant species are distributed in the marsh and to monitor these aspects over time (Smith 1978).

Smith (1978) inventoried the entire marsh and found that the vegetation can be segregated into two types: woody (forest) and marsh meadow. Both are considered secondary because they are composed of plants that became established in previously disturbed areas. In general, the woody vegetation area's location is not considered to be potentially affected by the landfill operation. Thus, the main emphasis was placed on the marsh meadow.

No rare or endangered plants were found in Kawainui Marsh. Bulrush and sawgrass dominated the lower, permanently flooded portions of the marsh, while California grass, with scattered strands of cattail and bulrush, dominated the upper, temporarily flooded portion of the marsh (Smith 1978).

In some ways, the biological aspects of Kawainui Marsh can be expressed by the "black box" concept, inasmuch as the actual biophysical-chemical relationships within the marsh are poorly understood at best. Only a portion of the inputs and outputs can be measured. Nevertheless, it is generally agreed that water depth is the major factor governing the distribution of wetland plants and that sedimentation is closely related. An increase in the nutrient load appears to have little effect on plant species distribution; however, little is known about the effects of heavy metal loadings and much less about nutrient decreases (Smith 1978).

Leachate obtained from refuse landfill operations may contain significant to high concentrations of heavy metals, particularly iron. In the case of heavy metals, the concern is not particularly with the uptake within the plants themselves, but with the potential biomagnification (leading to toxicity) in the overall food chain. Water hyacinth and duckweeds are known to accumulate heavy metals, which are subsequently passed up the food chain.

An interesting aspect of the marsh in terms of what is usually the most prominent heavy metal constituent in landfill leachate, iron, is that the marsh receives iron-rich clays in the incoming sediment. Thus, the fact that the plants do not presently show any toxic effects from iron is probably the best indication that the vegetation would not be affected if the iron concentration increased (Smith 1978).

Ford (1975) conducted an aquatic and estuarine fauna survey at sixteen stations established in the Kawainui Marsh and Maunawili Stream system; however, only the first seven stations (A–G) are within the marsh itself, and thus correspond generally to the area surveyed by Smith (1978).

Evidently, individuals and agencies have conflicting data on the abundance and distribution of water birds within the marsh (Ford 1975). In general, the marsh serves as habitat and feeding grounds for four endangered water-bird species: the Hawaiian coot, which appears to be the most prevalent of the rare species; the Hawaiian duck or *koloa (Anas wyvilliana)*; the gallinule *(Gallinula chloropus sandvicensis)*; and, occasionally, the Hawaiian stilt *(Himantopus himantopus knudseni)* (Ford 1975). The coot and *koloa* were observed in the area of the lake at Kawainui Marsh stations E and F. An inventory of the estuarine fauna is, as was the vegetative list, also included in the project's baseline technical report (Chun and Dugan 1981).

PROJECT DESIGN

The storm water drainage for the surface area covering Kalaheo Sanitary Landfill is diverted through ditches and pipes into an approximately 0.5 acre (2.0×10^3 m^2) rectangular shaped silting basin, which was positioned downstream of the landfill and about 1,000 ft (305 m) from the edge of Kawainui Marsh. An approximately 740 ft (225.6 m) long, 8 in. (203 mm) diameter perforated subsurface drainage pipe, with four branches totaling another 790 ft (240.8 m), is positioned over the natural clay stratum that protects the underlying groundwater, and under the landfill deposited material to collect leachate and pipe it to the collection manhole located above and near the edge of the silting basin. The last 200-ft (61.0-m) portion of the leachate collection pipe, prior to discharging into the collection manhole, is not perforated. Leachate is generated whenever rainfall percolates beyond the root zone and/or capillary zone, which is primarily when rainfall exceeds evaporation. Initial water contained in the landfill's deposited solid waste and/or percolating water absorbed by the solid waste could also potentially affect the quantity of leachate produced.

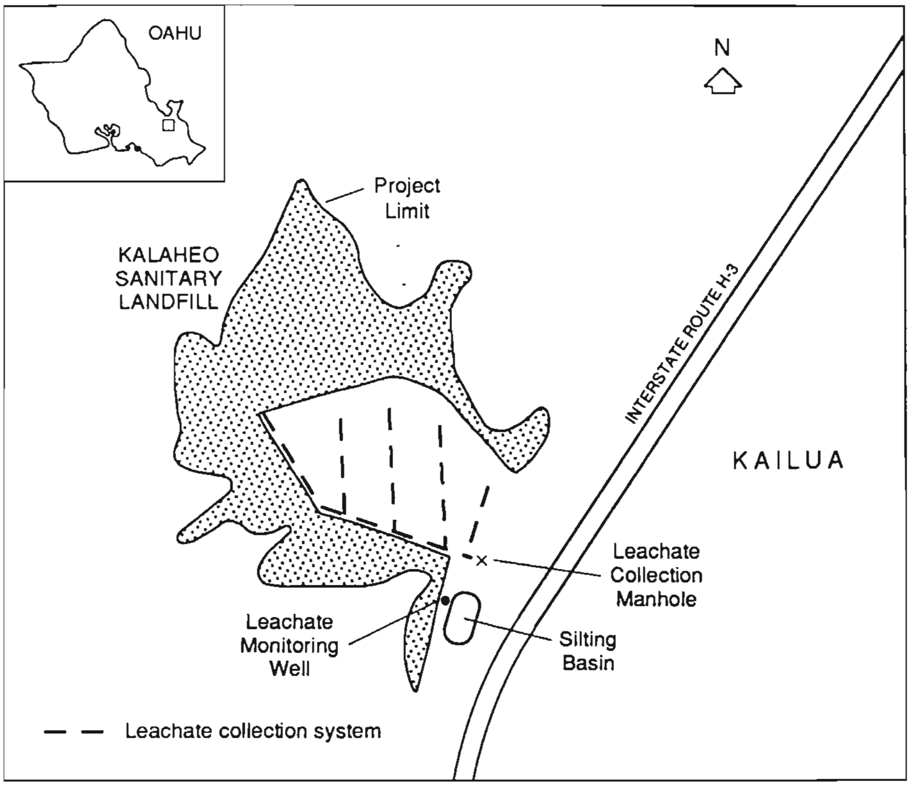
The inside dimensions of the leachate collection manhole are 4.0 ft × 4.0 ft × 8.5 ft deep (1.22 × 1.22 × 2.59 m), with a 2.0 ft (0.61 m) diameter steel manhole cover. The manhole was designed to be pumped out whenever it was full or nearly full of leachate, which generally occurred during significant rainfall events. The total volume of the leachate collection manhole is 136.0 ft^3 or 1,017 gal (3.85 m^3). A 6.0 ft (1.8 m) high chain link fence with 8.0 ft (2.4 m) side dimensions, and a side gate, surround the manhole.

The locations of the leachate collection manhole and silting basin in relation to the excavation area where solid waste was disposed at Kalaheo Sanitary Landfill are shown in Figure 3.

The leachate samples for analysis were obtained the day after leachate was completely removed from the collection manhole, in order to have relatively fresh leachate samples, or samples which had not undergone potential sedimentation and biochemical reactions. The Division of Refuse Collection and Disposal personnel at the Kapaa and Kalaheo Sanitary Landfill site coordinated their pumping activities with the University of Hawaii Water Resources Research Center, whose responsibility was the collection and analysis of the leachate samples.

The manhole cover was removed and a "thief sampler" dropped to mid-depth to obtain the sample. Then, the temperature and dissolved oxygen of the leachate were measured and recorded before the leachate was transferred to collection containers, placed in an ice chest, and transported to the water quality laboratories in Holmes Hall, University of Hawaii at Manoa campus. Once the samples were delivered to the water quality laboratories they were analyzed immediately or properly preserved and stored for later analysis, following the recommendations of *standard methods* (APHA, AWWA, and WPCF 1989).

The selection of individual chemical and physical water quality parameters for the project was based in part on the high concentrations of the parameters reported for typical leachate and on their value as groundwater and surface water quality indicators in routine water quality studies. The water quality parameters included dissolved oxygen (DO), pH, temperature, conductivity, alkalinity, chloride (Cl), chemical oxygen demand (COD), total dissolved solids (TDS), total suspended solids (TSS), nitrite and nitrate nitrogen (NO_2 + NO_3-N), phosphate phosphorus (PO_4-P), sulfate (SO_4), and metals: silver (Ag), arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), magnesium (Mg), manganese (Mn), sodium (Na), lead (Pb), selenium (Se), and zinc (Zn). The laboratory methods utilized to determine the preceeding individually listed constituents are contained in Appendix Table A.1.



NOTE: Excavation and stockpile area boundaries represent the pre-project designated boundaries.

Figure 3. Sampling locations and project limits of Kalaheo Sanitary Landfill, Kawainui, O'ahu, Hawai'i

RESULTS AND DISCUSSION

Unexpected problems encountered at the Kalaheo Sanitary Landfill limited the intended sampling scope of the project. The leachate collection manhole was covered by approximately 1.0 ft (0.3 m) of sediment, the probable result of a landslide prior to the initiation of the project. After several months the Division of Refuse Collection and Disposal personnel were able to clean and renovate the site, uncover the manhole, and pump out the collected water and sediment. After renovation, leachate sampling from the collection manhole commenced in May 1990.

The goal of the sampling procedure was to collect samples from the leachate collection manhole approximately once a month on the day after the manhole was pumped out, and to transport the contents to a wastewater treatment facility for treatment and disposal. The sampling procedure and sequence occurred as planned (except for a miscommunication for the July 1990 sampling) until November 1990, when a landslide once again occurred and prevented access as well as covered the leachate collection manhole. The Division of Refuse Collection and Disposal personnel had planned to clean up the site to enable access to the manhole, but a series of landslides periodically occurred before the site had dried out sufficiently to allow convenient excavation within the Division's and sampling project's timetable. During the summer of 1992, the site around the leachate collection manhole was re-excavated to lessen the occurrence of landslides and the quantity of collected leachate was checked on a daily basis and pumped out as necessary.

From the foregoing it is obvious that the number of leachate samples collected from the Kalaheo Sanitary Landfill site is somewhat limited. Nevertheless it is conceived that the samples collected and the subsequent analysis do give an indication of the potential quality of leachate generated from the operation of the landfill, and, thus, represent a preliminary baseline until additional monitoring sites are established in accordance with the closure plan presently being formulated.

A tabulation of typical wastewater/leachate parameters is presented in Table 1, while analysis for the leachate's metals are shown in Table 2. Also included in Tables 1 and 2 are storm runoff and silt basin sample values. Leachate generation from a particular landfill site is apparently site specific, and up to the present time the federal government has not specified effluent standards for leachate quality (Zolten 1991).

Hydrologic techniques were developed during the 1970s to estimate the production of leachate, if any, when the magnitude of precipitation is greater than evapotranspiration and water storage within the solid waste itself (U.S. EPA 1975; Mather and Rodriguez 1978). If the input of precipitation in comparison to evapotranspiration and storage is not great enough over a given time period, then no leachate will be produced. If precipitation is greater, then the quantity of leachate per unit area can be calculated.

Daily precipitation and evaporation values are obviously desirable for the hydrologic technique. Daily rainfall records are available from a nearby U.S. Weather Bureau Station, Kokokahi (Sta. No. 781.6), located less than a mile northwest of the Kalaheo Sanitary Landfill site, but no convenient nearby evaporation sites are available. In addition, the limited number of leachate samples from Kalaheo Sanitary Landfill, and the lack of any consistent correlation from the hundreds of analyses and rainfall data collected over a 12-yr period for the Kapaa Sanitary Landfill operation curtailed further investigation into this matter (Dugan 1991). Daily rainfall records from the Kokokahi (Sta. No. 781.6) rainfall recording site for the period January 1989 through April 1990, except for two relatively short time periods, are tabulated in Appendix Table B.1. Data for the two missing time periods are supplemented by rainfall data from the nearby Nohouani Weather Station (Sta. No. 781.80).

TABLE 1. COMPOSITION OF LEACHATE FROM COLLECTION MANHOLE, KALAHEO SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

Date	D.O. (mg/l)	pH	Temp. (°C)	Cond. (μmhos/cm)	Alk. as $CaCO_3$	Cl	COD	TDS	TSS	NO_2+ NO_3-N	PO_4-P	SO_4
					(mg/l)							
05/03/90	....	.....	...	7,460	2,420	....	....	5,037	21	2.7	0.98	.....
05/22/90	....	.....	...	10,660	1,810	1,879	1,200	5,043	39	1.3	0.62	.....
06/28/90	1.9	7.35	25	8,550	1,449	1,866	1,000	5,220	104	2.1	0.82	15.0
08/20/90	1.4	7.98	28	7,585	1,608	1,612	962	5,119	14	1.2	0.47	15.2
09/25/90	1.6	7.28	27	737	116	119	52	442	6	0.7	0.03	44.5
10/25/90	3.0	7.63	26	3,870	263	866	453	2,377	15	1.2	0.20	19.5
05/01/91*	....	8.01	...	....	.....	.....	1,651	......	...	....	.....	.....
05/02/91†	....	8.20	...	....	.....	.....	121	......	...	....	.....	.....

NOTE: Refer to Appendix Table A.1 for description of method of analysis.
NOTE: D.O. = dissolved oxygen; Cond. = electrical conductivity; Alk. = total alkalinity; Cl = chloride; COD = chemical oxygen demand; TDS = total dissolved solids; TSS = total suspended solids; NO_2+NO_3-N = nitrite plus nitrate nitrogen; PO_4 = phosphate phosphorus; SO_4 = sulfate

*Storm runoff prior to flowing into silting basin (Fig. 3).
†Silting basin.

Interestingly, a major storm occurred on March 20, 1991, with a recorded rainfall of 9.01 in. (228.9 mm) (App. Table B. 1). The preceding day 1.02 in. (25.9 mm) was measured, while 3.17 in. (80.5 mm) was recorded the following day. Thus, depending on the storm pattern, it is possible that >9.01 in. occurred within a given 24-hr period. For reference a storm of 9.01 in. would be expected to statistically occur approximately once every 10 yr, as can be noted in Table 3. Unfortunately, no leachate samples were collected during this time period since the manhole was covered over with sediment.

Numerous studies on the concentration of solid waste leachate have been conducted and reported in the literature over the past nearly three decades. Some of these have been laboratory and pilot plant studies, while others, particularly in recent years, have been actual in-situ measurements at landfill sites. Over an approximately 12-yr period, hundreds of groundwater samples were collected from the monitoring wells at the adjacent Kapaa Sanitary Landfill site to measure potential leachate generation and movement (Dugan 1991).

Subsurface leachate collection pipes positioned over a natural clay stratum barrier, or within a system of natural and/or synthetic liners, and above the groundwater table, help alleviate the concern with groundwater pollution. As previously indicated, leachate production is a function of precipitation, evaporation, and to some degree the moisture content of the deposited solid waste. Consequently, during heavy storm events large "slugs" of leachate could move through the soil column. From the foregoing, it is understandable that there would be a wide difference in the quality of leachate reported in the literature from various landfill operations. Such is the

TABLE 2. METAL ANALYSIS OF LEACHATE, STORM RUNOFF AND SILT BASIN LIQUID, KALAHEO SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

SOURCE	DATE	METALS§ (mg/l)													
		Ag	As	Ba	Cd	Cr	Cu	Fe	Hg	Mg	Mn	Na	Pb	Se	Zn
Primary DWR*		0.05	0.05	1.0	0.010	0.05	....	....	0.002	.....	.....	.....	0.05	0.01	....
Secondary DWR†		......	......	....	....	......	1.0	0.3	....	.....	0.05	.....	......	......	5.0
Industrial Wastewater Discharge Provision‡		0.43	0.5	....	0.69	2.77	3.38	....	0.5	.....	.....	.....	0.6	2.0	2.61
UNFILTERED															
Leachate Manhole	05/03/90	0.021	1.244	0.031	0.0034	0.016	0.015	0.939	<0.001	277.2	0.0144	95.8	0.044	0.540	0.587
Leachate Manhole	05/22/90	0.225	0.179	0.040	0.0047	0.013	0.021	0.825	<0.001	104.8	0.155	131.4	0.101	0.572	0.423
Leachate Manhole	06/28/90	0.022	1.020	0.349	0.0104	0.022	0.018	1.477	<0.001	161.0	3.02	119.0	0.125	0.540	0.636
Leachate Manhole	08/20/90	0.007	0.164	0.390	0.001	0.044	0.015	1.690	0.002	197.3	3.35	112.6	0.155	0.694	0.572
Leachate Manhole	09/25/90	<0.001	0.033	0.163	<0.001	0.009	0.031	0.697	0.003	56.7	3.40	73.4	0.081	0.048	0.461
Leachate Manhole	10/25/90	0.003	0.068	0.727	<0.001	0.021	0.027	0.563	<0.001	192.8	3.77	87.8	0.052	0.231	0.243
Storm Runoff	01/26/91	0.004	0.107	0.894	0.002	0.052	......	......	<0.001	......	.....	.....	0.033	0.266	......
Silting Basin	01/26/91	0.001	0.029	0.161	<0.001	0.015	......	......	<0.001	......	.....	.....	0.047	0.037	......
Storm Runoff	05/01/91	0.003	0.209	0.752	0.001	0.099	......	......	0.007	......	.....	.....	0.043	0.868	......
Silting Basin	05/02/91	<0.001	0.007	0.132	<0.001	0.006	......	......	<0.001	......	.....	.....	0.057	0.109	......

NOTE: Refer to Appendix Table A.1 for description of method of analysis.
*Primary Drinking Water Regulations (Department of Health 1981).
†Secondary Drinking Water Regulations (U.S. EPA 1979).
‡Division of Wastewater Management (1985).
§Ag = silver; As = zrsenic; Ba = barium; Cd = cadmium; Cr = chromium; Cu = copper; Fe = iron; Hg = mercury; Mg = magnesium; Mn = manganese; Na = sodium; Pb = lead; Se = selenium; Zn = zinc

TABLE 3. RAINFALL FREQUENCY FOR 24-HR STORMS AT KALAHEO SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

Recurrence Interval (yr)	Rainfall Intensity (in.)	(mm)
2	5.4	137
10	9.1	231
50	13.0	325
100	13.5	338

SOURCE: Giambelluca, Nullet, and Schroeder (1984).

case as can be observed in the two sources tabulated in Table 4, which is a compilation of reported leachate quality values from various sources over the years. One is from the somewhat "classical" Lovelace (1970) publication, the other is a 1991 (Zolten) reported source.

The Lovelace (1970) source of Table 4 lists typical leachate quality values as well as the reported range, while the Zolten (1991) values only includes the range. In general, considering the span in years of the reported results, their similar quality values are relatively comparable, except for magnesium, which is approximately a magnitude more, respectively, in the Zolten (1991) report.

Also included in Table 4 are the range and median values for leachate collected from the project's leachate collection manhole. One outstanding characteristic of leachate, as shown in Table 4, is the high COD values. Although the range does drop to 40 mg/l in the Zolten results, the 18,000 mg/l typical value reported by Lovelace (1970) is considered a reasonable mid-line value.

The project's median COD value (Table 4) is only approximately 5% of the typically reported COD value. On a relative basis, this is also true for the median values for total suspended solids, nitrate, orthophosphorus, sulfate, and iron. The project's sodium value was approximately 20% of the typical reported value, while alkalinity and magnesium were 50%, however, chloride was over three times the typical value. As previously indicated, the magnesium in the Zolten (1991) report was a magnitude higher than the typical value by Lovelace (1970), thus it is conceivable that based on Zolten's values, the project's magnesium value could be closer to 5%.

The project's median values for alkalinity, sodium, and chloride are well within the upper report limits of the Lovelace and Zolten results given in Table 4. Potentially, a significant portion of the increase in sodium and chloride values could be attributed to the close proximity of the landfill to the ocean, in terms of ocean spray being carried by rainfall and winds to the

TABLE 4. REPORTED LANDFILL LEACHATE COMPOSITION VS. LEACHATE FROM COLLECTION MANHOLE, KALAHEO SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

CONSTITUENT	REPORTED LANDFILL LEACHATE COMPOSITION (mg/l)*			LEACHATE COLLECTION MANHOLE		
	Range†	Typical†	Range‡	No. of Samples	Range	Median
Chemical Oxygen Demand	3,000–45,000	18,000	40–89,520	5	52–1,200	962
Total Suspended Solids	200–1,000	500		6	6–104	18.2
Organic Nitrogen	10–600	200				
Ammonia Nitrogen	10–800	200	0–1,106			
Nitrate	5–40	25	0.2–10.29§	6	0.74–2.7§	1.25§
Total Phosphorus	1–70	30	0–130			
Orthophosphorus	1–50	20		6	0.03–0.98	0.55
Alkalinity (as $CaCO_3$)	1,000–10,000	3,000	0–20,850	6	116–2,240	1,529
pH	5.3–8.5	6	3.7–8.5	4	7.28–7.98	7.49‖
Calcium	200–3,000	1,000	60–7,200			
Magnesium	50–1,500	250	17–15,600	6	56.7–277.2	126.9
Potassium	200–2,000	300	28–3,770			
Sodium	200–2,000	500	0–7,700	6	73.4–131.4	104.2
Chloride	100–3,000	500	4.7–2,467	5	119–1,879	1,612
Sulfate	100–1,500	300	1–1,558	4	15.0–44.5	17.4
Total Iron	50–600	60	0–2,820	6	0.563–1.690	0.882

*Except pH.
†From Lovelace (1970).
‡From Zolten (1991).
§Includes nitrite.
‖Arithmetic median.

landfill and the probable additional salt contained in the solid waste that was deposited on the site. However, a mass balance of the latter statement has not been attempted. Based on the preceding presented information, it is apparent that the leachate collected by the collection manhole at Kalaheo Sanitary Landfill is relatively weak.

The leachate collection manhole values for COD and chloride for Kapaa Sanitary Landfill for 1988 and 1989 were respectively, 3,200 and 475 mg/l for COD, and 2,270 and 830 mg/l for chloride (Dugan 1991). No samples were reported for 1990. From the foregoing it appears that the quality of leachates from the Kalaheo and Kapaa sanitary landfills have quite similar characteristics.

Concern for metal concentrations in the leachate (Tables 2, 4) from the Kalaheo Sanitary Landfill is primarily because of its close proximity [approximately 1,000 ft (305 m)] to the 750 acre (3.04×10^6 m^2) Kawainui Marsh into which the groundwater beneath the landfill seeps. Concern for aquatic life prompted the U.S. Environmental Protection Agency (EPA) to issue a series of reports in 1980 on the maximum limit of various heavy metals under different conditions for the protection of aquatic life in a balanced, healthy, aquatic community, with revised criteria issued in 1986 (U.S. EPA 1986). However, these criteria are not considered applicable to the relatively harsh biological conditions that exist in such environments as Kawainui Marsh.

For evaluation purposes, in terms of metals, comparisons are made, where applicable, with the maximum limits specified in the primary drinking water regulations (Department of Health, 1981), secondary drinking water regulations (U.S. EPA 1979), and the City and County of Honolulu Division of Wastewater Management's (1985) industrial wastewater discharge provisions. The latter is the maximum acceptable by the City and County of Honolulu's municipal sewerage system. Such a comparison is obviously only intended for relative purposes. The maximum values listed for these three regulations, which do not apply to the present situation are also listed in Table 2, as are the metal concentrations for storm runoff and silting basin liquid.

When the unfiltered values of Table 2 are compared to the metal values listed for the primary drinking water regulations, all the barium samples are less; only one silver and one cadmium are equal to or greater than, two chromium samples are greater than, three mercury samples are greater than, one-half the lead samples are greater than, and all the arsenic and selenium are greater than the limits. In terms of secondary drinking water regulations, all the copper and zinc samples are less than, all but one of the manganese samples are greater than, and all the iron samples are greater than the limits. Only one arsenic sample exceeded the industrial wastewater discharge maximum limit. These samples, of course, will be extremely diluted and further subjected to the sorption and biological adaption processes and only the leachate, which oversaturates the natural clay stratum barriers and exceeds the capacity of the leachate collection system, will seep to the groundwater table when excess rainfall occurs.

Surprisingly, all the metal concentrations, except one lead and both selenium values, in the silting basin were below the primary drinking water regulations. As can also be noted, the metal concentrations of the liquid samples from the silting basin are significantly lower than those of the storm runoff, although the sample numbers are quite limited. The same statement can be made for the COD values listed in Table 1. The silting basin is apparently quite efficient in removing constituents contained in the storm water runoff.

CONCLUSIONS

Considerable concern has been expressed, since the mid-1970s, over the potential generation of leachate from the City and County of Honolulu's Kapaa Sanitary Landfill and its possible adverse effects on the ecological and environmental aspects of the adjacent 750 acre (3.04×10^6 m^2) Kawainui Marsh. The Kapaa Sanitary Landfill has been in continuous operation since 1964. Between March 1986 to March 1990, the Kalaheo Sanitary Landfill, located about 1,000 ft (305 m) from the edge of Kawainui Marsh and approximately 0.5 mile (805 m) from Kapaa Sanitary Landfill, received an estimated 2.8×10^6 yd^3 (2.14×10^6 m^3) of municipal and commercial solid waste. As was the case for the Kapaa Sanitary Landfill, the potential generation of leachate from the operation of the Kalaheo Sanitary Landfill and its effect on Kawainui Marsh is also of concern, even though its operation has been terminated and the total amount of solid waste deposited on-site is only a fraction of the amount deposited at Kapaa.

The City and County of Honolulu commissioned several studies in the latter part of the 1970s to ascertain the potential for leachate generation from the Kapaa Sanitary Landfill operation in relation to Kawainui Marsh. The most extensive of these involved an intensive 2-yr baseline study of groundwater and surface water in the project area during 1979-1980 (Chun and Dugan 1981) followed by an ongoing low-level monitoring program since 1981 (Dugan 1991). The conclusion of these studies was that any correlation between leachate production and the underlying groundwater quality would have to be considered minor at best.

The present project to study leachate generation from Kalaheo Sanitary Landfill was intended to obtain samples from an on-site leachate collection manhole and to analyze these samples for a series of analytical parameters commonly reported for leachate. The leachate collection manhole was the terminus for a subsurface leachate piping system.

The number of samples collected and analyzed for the project was somewhat limited due to frequent landslides that covered the leachate collection manhole. Nevertheless, the results did demonstrate that the leachate intercepted by Kalaheo's leachate collection system is relatively weak in comparison to nationally reported typical leachate concentrations. The results obtained from the study are intended to serve as a preliminary baseline until additional monitoring sites are established in accordance with the closure plan presently being formulated.

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APPENDIX CONTENTS

Appendix Tables

APPENDIX TABLE A.1. ANALYTICAL METHODS

1.	Dissolved Oxygen	The measurements were always conducted in situ. The instrument used was the YSI Model 51B Dissolved Oxygen Meter.
2.	pH	The measurements were conducted in the laboratory upon return to campus. The instrument used was the ORION Model 811 microprocessor pH/millivolt meter 811.
3.	Temperature	The measurements were conducted in situ. The instrument used was the YSI Model 51B D.O. Meter.
4.	Conductivity	The measurements were conducted in the laboratory and in accordance with *Standard Methods* (17th ed., Sec. 2510 Conductivity, pp. 2-57 to 2-61). The instrument used was the YSI Model 31A Conductivity Bridge.
5.	Alkalinity	The measurements were conducted in the laboratory and in accordance with *Standard Methods* (17th ed., Sec. 2320 Alkalinity, pp. 2-35 to 2-39). The specific method was by Section 2320B Filtration Method.
6.	Chloride	The measurements were conducted in the laboratory and in accordance with *Standard Methods* (17 ed., Sec. 4500-Cl Chloride, pp. 4-67 to 4-70). The specific method was by Section 4500-Cl C. Mercuric Nitrate Method.
7.	Chemical Oxygen Demand	The measurements were conducted in the laboratory. Sample days 22 May 1990 and 28 June 1991 were performed according to *Standard Methods* (17th ed., Sec. 5220 Chemical Oxygen Demand, pp. 5-10 to 5-16). The specific method was according to 5220 B Open Reflux Method. The later measurements were conducted according to Sec. 5220 D, Closed Reflux, Colorimetric Method. The instrument used was HACH Model 45600 COD Reactor, in conjunction with the HACH DR/3000 spectrophotometer.
8.	Total Dissolved Solids	The measurements were conducted in the laboratory and in accordance with *Standard Methods* (17th ed., Sec. 2540 Solids, pp. 2-71 to 2-76). The specific method used was Sec. 2540C, Total Dissolved Solids dried at 180°C.
9.	Total Suspended Solids	The measurements were conducted in the laboratory and in accordance with *Standard Methods* (17th ed., Sec. 2540 Solids, pp. 2-71 to 2-76). The specific method used was Sec. 2540D, Total Suspended Solids Dried at 103-105°C.
10.	Nitrate+Nitrite Nitrogen	The measurements were conducted in the laboratory and were performed according to the HACH Company DR/3000 test procedures for procedure code N.6 Nitrogen, Nitrate, Medium Range: 0-5.0 mg/l, Cadmium Reduction Method; and procedure code N.9 Nitrogen, Nitrite, Low Range: 0-0.350 mg/l, Diazotization Method.

NOTE: *Standard Method* (American Public Health Association, American Water Works Association, and Water Pollution Control Federation 1989).

11. Phosphorus

The measurements were conducted in the laboratory and in accordance with *Standard Methods* (17th ed., Sec. 4500-P Phosphorus, pp. 4-116 to 4-181). The specific methods used consisted of two parts: (1) a sample preparation technique performed according to Sec. 4500-P B, 5 Persulfate Digestion Method; and (2) a colorimetric procedure performed according to the HACH Company DR/3000 Test Procedures. The specific method used was procedure code P.4 Phosphorus, Reactive (Orthophosphate), low range: 0-2.00 mg/l, Ascorbic Acid Methods.

12. Sulfate

The measurements were performed in the laboratory and in accordance with HACH Company DR/3000 Test Procedures for procedure code S.6 Sulfate, Low Range: 0-50 mg/l Sulfate, SulfaVer 4 Method.

13. Metals

a) Metals were preserved according to *Standard Methods* (17th ed., Sec. 3010B Sampling and Sample Preservation, pp. 3-1 to 3-2).

b) All metals except mercury were analyzed by the Perkin-Elmer atomic absorption spectrophotometry. The specific method was by Graphite Furnace.

c) Mercury was analyzed by the cold vapor technique using Model 61 spectrophotometry by Perkin-Elmer.

APPENDIX TABLE B.1. ANNUAL RAINFALL AT U.S. WEATHER BUREAU STATION KOKOKAHI (STA. NO. 781.6), KAWAINUI, O'AHU, HAWAI'I, JANUARY 1989 THROUGH APRIL 1991

1989	MONTHLY RAINFALL (in.)											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	.....	tr	1.94	0.18	0.11	1.00	.....	0.04	0.07	0.36	.....	.....
2	.....	0.31	1.40	0.10	0.01	1.74	.....	0.36	0.10	0.01	.....	.....
3	0.07	2.83	1.60	0.05	tr	.....	tr	0.03	0.12	0.63	.....	.....
4	0.27	tr	0.23	1.44	0.04	.....	0.02	0.16	0.17	3.99	.....	tr
5	0.02	0.10	0.12	2.74	tr	0.23	0.11	.....	tr	0.05	0.08	tr
6	.....	0.14	0.57	0.13	0.36	0.16	0.24	.....	0.01	0.34	.....	.....
7	0.07	0.04	0.15	2.28	0.02	tr	0.05	0.08	0.12	0.09	0.03	.....
8	0.25	0.07	0.01	2.25	.....	0.06	.....	.....	0.04	0.01	0.02	.....
9	0.02	0.01	0.01	4.50	0.06	0.08	.....	.....	0.16	0.55	tr	1.42
10	0.58	0.53	0.05	0.18	0.13	.....	0.09	.....	0.02	1.14	tr	0.33
11	0.54	1.44	0.07	tr	.....	.....	0.16	.....	.....	0.03	.....	.....
12	1.50	1.33	0.07	0.54	0.01	.....	0.08	.....	0.06	.....	.....	.....
13	0.63	0.22	tr	1.58	0.05	.....	0.20	0.01	0.05	.....	0.06	0.20
14	0.20	0.01	.....	0.06	0.01	.....	0.06	.....	.....	0.30	0.76	.....
15	0.02	.....	.....	0.03	0.09	.....	0.46	.....	0.02	0.64	0.66	.....
16	0.09	.....	0.13	.....	.....	.....	.....	0.01	.....	0.38	0.39	.....
17	0.02	.....	0.19	.....	tr	.....	0.19	0.07	0.05	0.02	.....	.....
18	0.01	.....	0.17	.....	.....	0.12	.....	tr	.....	0.14	.....	.....
19	.....	0.11	.....	.....	0.40	0.01	0.01	0.25	0.06	0.03	0.04	.....
20	0.18	0.07	.....	0.01	0.19	0.02	0.17	0.21	0.19	0.18	.....	2.28
21	tr	1.76	.....	.....	0.01	0.12	2.62	1.52	.....	0.04	0.07	0.04
22	.....	0.07	tr	0.04	0.03	0.18	0.38	0.07	tr	0.02	tr	tr
23	.....	0.34	......	0.12	.....	0.01	0.30	tr	0.08	0.02	0.01	0.01
24	.....	0.08	0.04	0.01	0.04	0.05	tr	0.04	0.02	tr	.....	tr
25	0.01	0.04	0.01	.....	0.02	.....	0.12	0.06	0.01	0.04	.....	tr
26	.....	.....	0.66	0.01	.....	.....	0.03	0.03	.....	0.02	.....	0.02
27	0.05	.....	0.01	0.23	0.02	.....	0.01	0.02	.....	.....	0.01	0.06
28	0.10	0.24	tr	0.84	0.01	0.02	0.02	.....	0.14	0.16	tr	0.21
29	0.50	.....	0.02	0.28	tr	tr	0.25	0.83	0.01	1.24	.....	0.03
30	.....	.....	0.08	0.15	0.05	.....	0.02	.....	0.22	0.01	0.14	0.04
31	.....	.....	0.02	.....	0.18	.....	0.01	0.02	.....	0.04	.....	0.16
Monthly Total	5.13	9.74	7.55	17.75	1.84	3.80	5.60	3.81	1.72	10.48	2.27	4.80
Annual Total						74.49						

APPENDIX TABLE B.1—*Continued*

1990	MONTHLY RAINFALL (in.)											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.*	Dec.*
1	0.02	0.33	2.78	0.01	0.24	0.03	0.03	.....	tr	0.16	.....	0.13
2	0.30	0.10	0.91	0.02	0.10	0.02	0.04	0.06	0.01	0.04	0.32	0.23
3	0.02	0.32	0.02	0.09	0.35	.....	0.01	.....	.....	0.01	0.01	0.03
4	tr	0.03	.....	.....	0.06	tr	0.06	0.06	0.16	0.20	0.04	.....
5	0.02	0.04	0.05	0.01	0.08	.....	0.05	0.03	0.04	0.10	.....	2.75
6	.....	0.06	0.08	0.10	tr	0.01	.....	0.01	0.13	.....	.....	0.01
7	tr	0.04	0.55	0.20	0.11	.....	.....	.....	tr	.....	0.05	.....
8	.....	0.01	0.15	0.14	0.02	.....	0.08	0.05	0.40	.....	.....	0.01
9	.....	tr	0.04	0.60	tr	.....	0.33	.....	1.02	.....	.....	0.25
10	.....	0.12	0.01	tr	0.01	.....	.....	.....	0.05	0.10	.....	.....
11	.....	0.12	0.01	.....	0.01	tr	0.09	tr	.....	0.27	.....	tr
12	.....	0.02	0.02	.....	.....	0.02	0.02	0.03	0.03	0.04	1.99	0.02
13	.....	.....	0.07	.....	.....	tr	0.19	0.10	0.03	tr	2.30	tr
14	.....	.....	0.03	.....	0.40	0.02	.....	0.04	0.07	0.04	1.03	0.02
15	0.83	0.01	0.04	.....	0.11	.....	0.01	0.10	0.07	.....	tr	tr
16	1.09	.....	0.01	.....	0.01	0.03	.....	0.04	.....	.....	0.02	0.01
17	1.80	0.06	.....	.....	0.18	0.43	0.01	0.01	0.21	0.38	1.99	tr
18	0.15	0.28	.....	.....	0.12	0.10	0.36	.....	0.44	0.03	3.03	0.62
19	1.20	0.03	0.01	0.03	0.14	0.04	0.06	0.18	0.03	0.02	.....	1.64
20	2.71	0.35	0.17	.....	0.11	0.09	.....	0.60	0.20	0.03	0.17	0.71
21	0.10	0.01	0.07	0.01	0.10	0.04	tr	0.04	0.31	.....	0.95	0.42
22	0.06	tr	0.01	tr	.....	tr	0.16	0.07	tr	0.26	.....	0.15
23	0.08	.....	.....	0.01	0.60	0.06	.....	0.02	0.05	0.09	0.46	1.16
24	0.60	0.01	.....	0.08	0.22	0.01	0.01	0.07	0.16	0.07	.....	0.57
25	0.09	2.04	0.06	0.01	.....	0.17	0.12	0.04	0.01	0.01	.....	0.38
26	0.06	2.12	0.01	.....	0.02	0.01	.....	0.04	0.07	.....	.....	1.08
27	0.09	0.09	1.22	0.01	.....	0.19	0.13	0.07	0.02	0.01	.....	0.02
28	tr	0.39	0.27	.....	.....	0.01	0.75	0.02	.....	0.03	.....	0.04
29	0.10	.....	0.06	.....	tr	0.01	0.01	.....	0.04	0.11	0.32	0.02
30	0.01	.....	0.05	.....	0.03	0.04	0.02	0.01	0.24	0.44	0.07	.....
31	0.02	.....	0.02	.....	.....	.....	0.02	.....	.....	0.14	.....	.....
Monthly Total	9.35	6.58	6.72	1.32	3.02	1.33	2.56	1.69	3.79	2.58	12.75	7.52
Annual Total						59.21*						

APPENDIX TABLE B.1—*Continued*

1991	MONTHLY RAINFALL (in.)			
	Jan.	Feb.*	Mar.*	Apr.*
1	.....	.....	.....	0.03
2	.....	.....	.....	0.03
3	.....	0.43	0.03	0.10
4	.....	0.02	.....	0.07
5	0.15	.....	.....	0.10
6	0.05	tr	.....	.....
7	0.46	.....	0.11	.....
8	0.05	.....	0.11	0.05
9	0.03	tr	0.45	0.85
10	tr	tr	0.06	0.88
11	0.04	0.03	0.45	0.02
12	tr	0.03	1.27	tr
13	0.03	1.06	0.15	.....
14	0.20	0.03	0.03	.....
15	0.10	0.05	0.11	0.16
16	0.02	.....	0.36	0.15
17	0.16	.....	0.05	0.05
18	0.09	0.33	0.10	.....
19	0.03	1.08	1.02	.....
20	.....	0.29	9.01	.....
21	.....	0.20	3.17	0.02
22	.....	0.01	0.06	0.02
23	0.13	0.02	.....	.....
24	0.03	.....	3.00	.....
25	0.01	0.31	0.09	0.11
26	0.01	.....	0.03	0.21
27	1.42	.....	0.23	.....
28	0.07	.....	0.07	0.09
29	.....	0.02	0.02	0.08
30	.....	.....	.....	0.06
31	.....	.....	.....	.....
Monthly Total	3.04	3.96	19.98	3.10
Annual Total	NA			

NOTE: Records maintained at Division of Water Resource Management, Dept. Land and Natural Resources, State of Hawaii, Honolulu, HI 96813.

*Missing data from 19 Nov. through 5 Dec. 1990 and from 29 Feb. through 10 April 1991. Supplemented by data from nearby Sta. No. 781.80 (Nohouani, Kaneohe).