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[12] ABSTRACT (PURPOSE, METHOD, RESULTS, CONCLUSIONS)

The operation of the City and County of Honolulu Kapaa Sanitary Landfill, located next to Kawainui Marsh in Kawainui, Oahu, Hawaii, raised concern over the possibility that landfill leachate could have adverse effects on the marsh. Thus, an intensive 2-yr baseline study (1979–1980) was conducted in which six sampling sites each were established for surface water and groundwater; this was followed by an ongoing, low-level monitoring program begun in 1981 and reported herein through 1990. Analyses were conducted for typical surface-water and leachate parameters. There was obvious interchange of the marsh water and groundwater, with the higher mineral constituents of seawater intrusion being more evident in the monitoring wells with lower water level. The outstanding characteristic of leachate, chemical oxygen demand (COD), which was typically reported at a concentration of 18,000 mg/l, was found at only a fraction of this value at the sample stations—the highest annual median COD value of the 12-yr study being only 85 mg/l for one of the sampling wells, and 325 mg/l at a surface-water sampling station. No consistent correlation could be found between individual constituent concentrations of the surface-water stations or monitoring wells and groundwater levels, rainfall, or seasonal and/or annual changes. It is concluded that any correlation between leachate production and the underlying groundwater quality would have to be considered minor at best.

2540 Dole Street • Honolulu, Hawaii 96822 • U.S.A. • (808) 956-7847

AUTHOR:

Dr. Gordon L. Dugan
Professor
Department of Civil Engineering
University of Hawaii at Manoa
2540 Dole St.
Honolulu, Hawaii 96822
Tel.: 808/956-8969

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

Gordon L. Dugan

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WATER RESOURCES RESEARCH CENTER
University of Hawaii at Manoa
Honolulu, Hawaii 96822

ABSTRACT

The operation of the City and County of Honolulu Kapaa Sanitary Landfill, located next to Kawainui Marsh in Kawainui, O'ahu, Hawai'i, raised concern over the possibility that landfill leachate could have adverse effects on the marsh. Thus, an intensive 2-yr baseline study (1979–1980) was conducted in which six sampling sites each were established for surface water and groundwater; this was followed by an ongoing, low-level monitoring program begun in 1981 and reported herein through 1990. Analyses were conducted for typical surface-water and leachate parameters. There was obvious interchange of the marsh water and groundwater, with the higher mineral constituents of seawater intrusion being more evident in the monitoring wells with lower water level. The outstanding characteristic of leachate, chemical oxygen demand (COD), which was typically reported at a concentration of 18,000 mg/l, was found at only a fraction of this value at the sample stations—the highest annual median COD value of the 12-yr study being only 85 mg/l for one of the sampling wells, and 325 mg/l at a surface-water sampling station. No consistent correlation could be found between individual constituent concentrations of the surface-water stations or monitoring wells and groundwater levels, rainfall, or seasonal and/or annual changes. It is concluded that any correlation between leachate production and the underlying groundwater quality would have to be considered minor at best.

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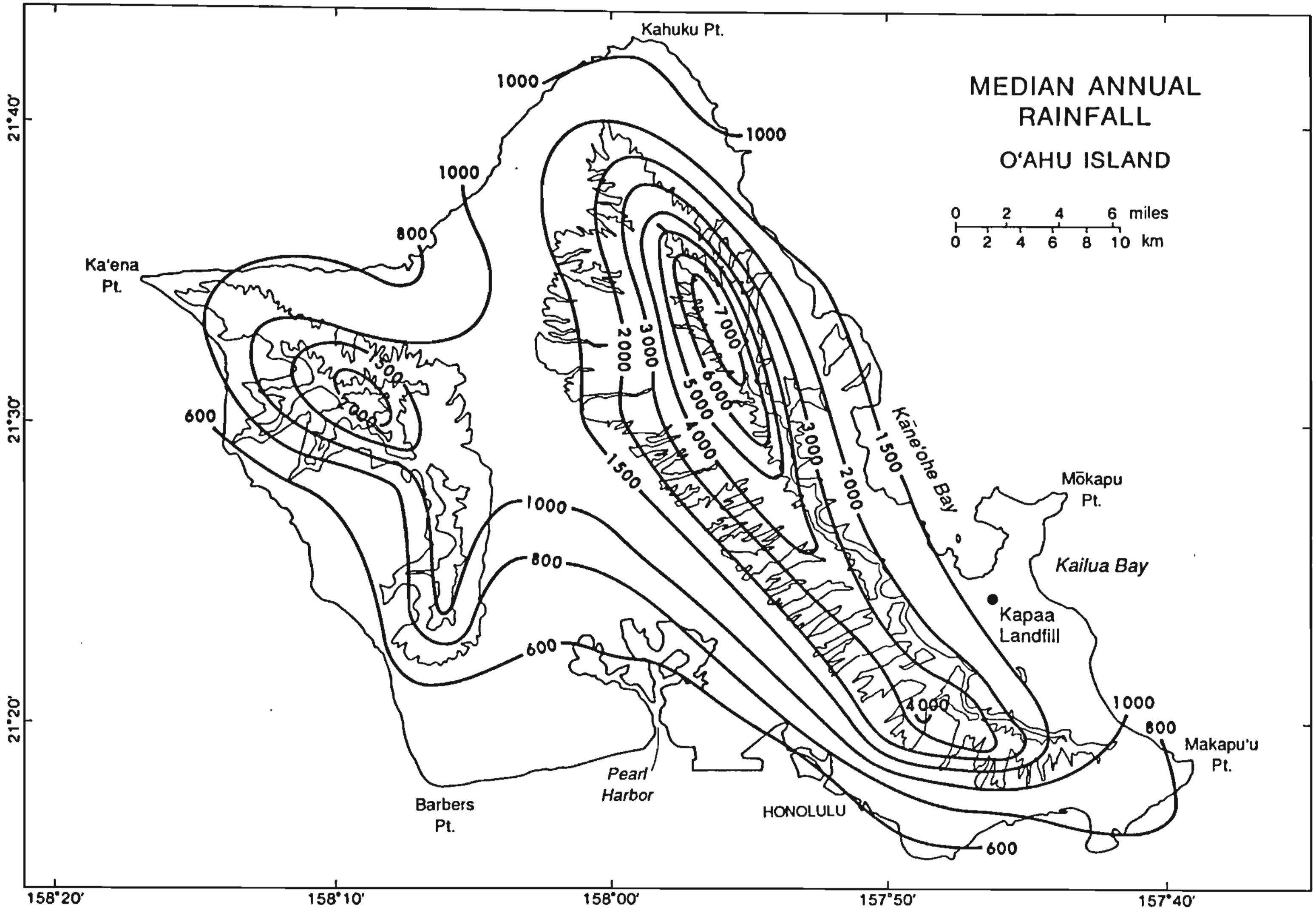
INTRODUCTION

The City and County of Honolulu has funded several projects since the early 1970s involving the possible generation and movement of leachate from the operation of Kapaa Sanitary Landfill, and particularly its potential for affecting the adjacent 750-acre ($3.035 \times 10^6 m^2$) Kawainui Marsh, located near Kailua town in windward O'ahu, as shown in Figures 1 and 2. Kapaa Sanitary Landfill, in operation since 1964, is nearing its capacity. In order to help compensate for the loss of landfill capacity, the Kalaheo Sanitary Landfill, situated a short distance north of the existing Kapaa Sanitary Landfill (Fig. 1), was placed in operation by the Division of Refuse Collection and Disposal from March 1986 to March 1990, its capacity was reached and it was closed. Since March 1986, only individual (noncommercial) delivered refuse has been accepted at the Kapaa Landfill.

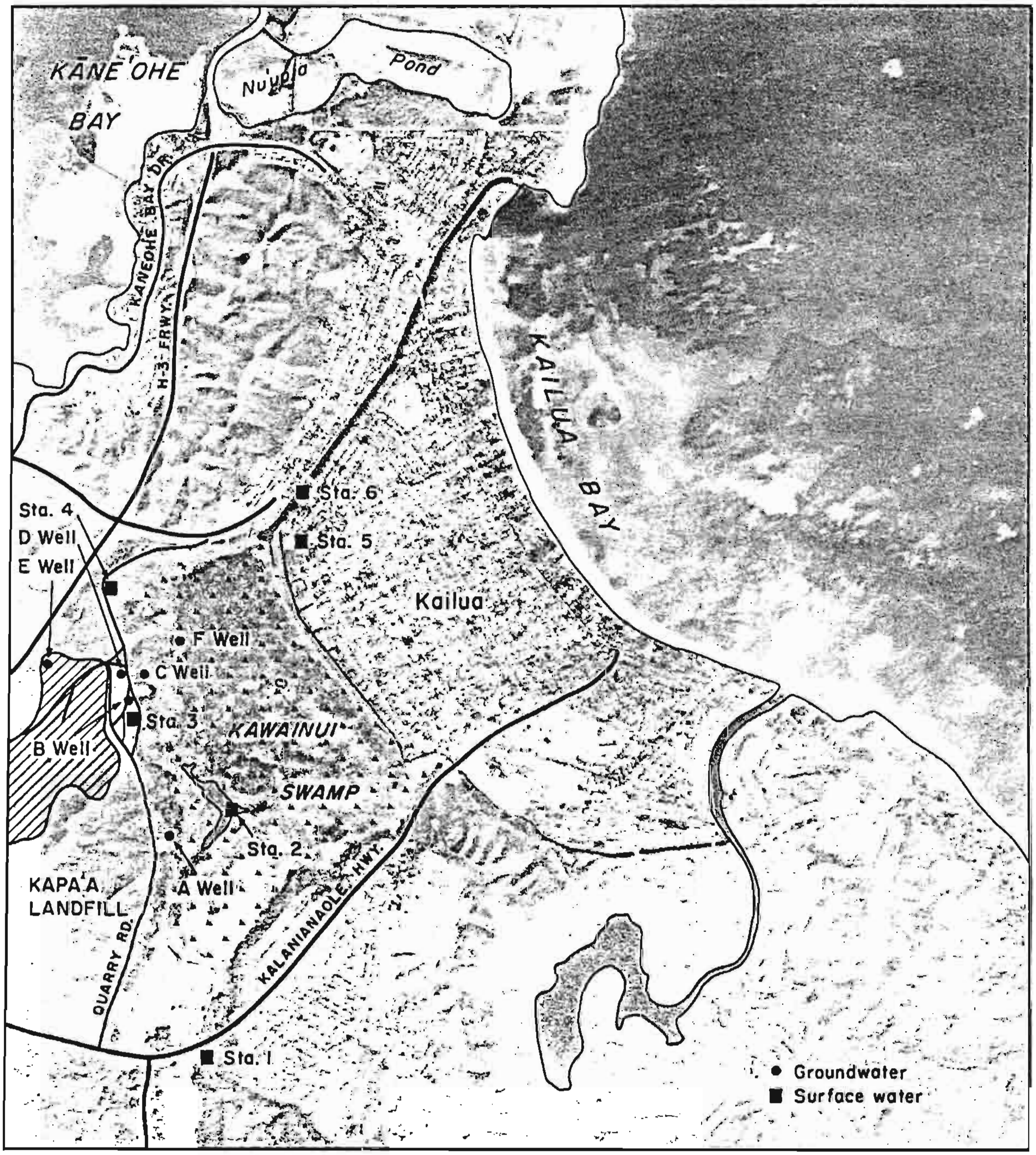
The first study of potential leachate generation and movement from Kapaa Sanitary Landfill, conducted by Burbank (1972), was a short-duration study of only three sites; two surface-water sites and one shallow well. Two 1977 studies (Bowles and Mink 1977; EMCON Associates 1977) were based on reviews of 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 Kapa'a 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 intense 2-yr baseline study was established with six sampling sites each for surface water and groundwater, followed by an ongoing, low-level monitoring program (Chun and Dugan 1981). An explosive-gas monitoring program for buildings near 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.



SOURCE: Giambelluca, Nullet, and Schroeder (1986, p. 73).
NOTE: Isohyets in mm.
NOTE: Elevation in 1,000-ft intervals.

Figure 1. Kapaa Sanitary Landfill site and median annual rainfall, Kawainui, O'ahu, Hawai'i



SOURCE: Chun and Dugan (1981).

Figure 2. Surface-water and well-water sampling sites near Kapaa Sanitary Landfill, Kawainui, O'ahu, Hawai'i

The results of the baseline study revealed that there was obvious interchange of the marsh water and groundwater, with higher mineral constituents of seawater intrusion being more evident in wells with lower water levels. The baseline study also indicated that COD, usually the most outstanding characteristic of leachate, with a reported typical concentration of 18,000 mg/l, was found at a maximum median value of 38 mg/l in one of the monitoring wells, while the COD value of the surface-water sampling station counterpart was essentially the same, 39 mg/l. In the analytical results of the baseline report, no consistent correlation could be found between individual constituent concentrations of the surface-water stations or monitoring wells and groundwater levels, rainfall, or seasonal and/or annual changes (Chun and Dugan 1981).

The results of the first two years (to mid-1983) of the low-level monitoring program (Dugan and Chun 1983) revealed that the maximum median values of COD for the monitoring wells and surface-water station had increased to 57 and 46 mg/l, respectively, or were about 50% higher than the results of the baseline study. These results, however, were still quite low.

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 low-level monitoring program's analytical results for Kapaa Sanitary Landfill, covering 1981 through 1990, albeit a previous evaluation had already covered the monitoring period to mid-1983 (Dugan and Chun 1983). The decision to conduct the evaluation of the monitoring program from the time of the completion of the baseline study in 1981, rather than from 1983 (the time of the intervening reporting), was made in the interest of continuity. The results from this study of the Kapaa Sanitary Landfill will be compared with the results of the study of potential leachate generation from the nearby Kalaheo Sanitary Landfill, opened for operation in March 1986 and closed in March 1990.

PHYSICAL SETTING

The Kapaa Sanitary Landfill, located adjacent to and mauka of Kawainui Marsh, is in Maunawili Valley, and 18-mi^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 Waimānalo 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 Kapaa Sanitary Landfill 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 Sanitary Landfill area 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% (Department of Business and Economic Development 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.

BIOLOGICAL ASPECTS. 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 project's baseline study and subsequent low-level monitoring program were segregated into two components: surface water quality in the general vicinity of the Kapaa Sanitary Landfill; and groundwater quality in and around the landfill.

Surface Water Quality Baseline Study Program

Six surface-water sampling sites were established in the general vicinity of the Kapaa Sanitary Landfill to collect baseline surface-water quality data and to evaluate the potential and/or existing impact of the landfill operations on the marsh itself. The location of the surface-water sampling sites and their general position in relation to the landfill, marsh, and well sampling sites are shown in Figure 2. A description of the surface-water sampling site locations is presented in Appendix Table A.1.

Reported here is the low-level monitoring program conducted from 1981 through 1990. The baseline study (1978–1980) was conducted by the University of Hawaii at Manoa Water Resources Research Center (WRRC), and the low-level monitoring phase was the responsibility of the Division of Refuse Collection and Disposal, Department of Public Works, City and County of Honolulu. The results of the baseline study and the recommended long-range monitoring program were presented in the technical report on the baseline study (Chun and Dugan 1981).

The selection of the individual chemical and physical water quality parameters for the baseline study and subsequent low-level monitoring program 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. For comparison purposes, the quality parameters for groundwater and surface water were identical. The water quality parameters included dissolved oxygen (DO), pH, temperature, conductivity, alkalinity, COD, total dissolved solids (TDS), total suspended solids (TSS), ammonia nitrogen (NH_4-N), nitrite and nitrate nitrogen (NO_2+NO_3-N), phosphate phosphorus (PO_4-P), iron (Fe), manganese (Mn), sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), and zinc (Zn).

A proposed list of leachate constituents to be monitored for at municipal solid waste landfill units was advanced in the *Federal Register* (U.S. EPA 1988). Of the wide range of constituents suggested, the majority were monitored during the baseline study and during the subsequent annual sampling and analyses portion of the on-going low-level monitoring program. Constituents not studied were sulfate (SO_4), total organic carbon (TOC), a list of volatile organic compounds, and the metals arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), cyanide, lead (Pb), mercury (Hg), selenium (Se), and silver (Ag). It should be noted that during the low-level monitoring program following the baseline study, a sample from a silting basin was analyzed for priority pollutants, which included metals and many of the volatile organic constituents listed in the *Federal Register*. The final list of parameters to be included in the municipal leachate monitoring program of the U.S. EPA cannot be ascertained at this time, only speculated upon. However, it is anticipated that the parameters that were utilized in the baseline study, and in the annual sampling portion of the low-level monitoring program, will essentially be represented when the established list from the U.S. EPA is issued.

During the course of the baseline study, the access to Station 2 was lost (Fig. 2).

Low-Level Monitoring Surface-Water Quality Program

The surface-water quality low-level monitoring program conducted after the baseline study consisted of annual sampling and analysis of the same surface-water stations as were used in the baseline study, with the exception of Station 6, which was dropped because of its similarity to Station 5. In addition, a monthly program of sampling Station 3 and analyzing for COD, chlorides, and pH has been conducted since the conclusion of the baseline study.

Well-Water Quality Baseline Study Program

In an attempt to establish the baseline quality for groundwater entering Kawainui Marsh and to ascertain whether or not leachate produced from the Kapaa Sanitary Landfill operation was entering the underlying groundwater, six baseline study wells were situated in and around the landfill (Fig. 2). The location of the wells was based on the expected direction of groundwater movement in the vicinity of the landfill, as reported by Bowles and Mink (1977). Well A was positioned so that it would not intercept groundwater passing under either an old or existing (active) landfill site and could thus serve as a control. Wells B, C, and E were expected to intercept groundwater from beneath the existing landfill. Well D, on the other hand, was expected to be influenced by both the existing and old landfill sites, while Well F was expected to intercept groundwater passing only beneath the old landfill site.

A typical cross section of the baseline study wells is shown in Figure 3. The depths of the wells varied, depending on the distance to the water table; however, the distance beneath the water table was approximately 3 ft (1m). The 3-ft (1-m) depth was selected on the basis of the geohydrology in this area, as reported by Bowles and Mink (1977). As previously mentioned, groundwater moves as "overflow" from one dike compartment to another, rather than through the dike itself. Therefore, the presence of numerous dikes means that any leachate reaching Kawainui Marsh would remain at or near the surface.

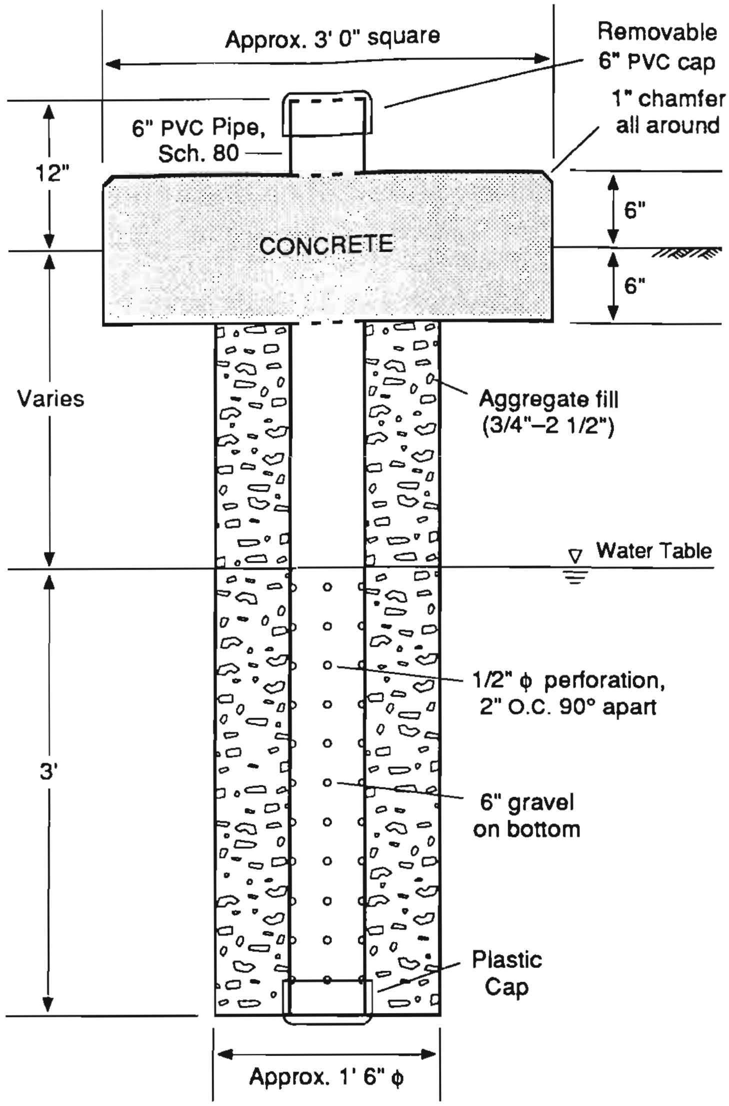
A passive baseline study monitoring program was conducted because it is well suited to landfill leachates. In this approach, the wells were located with reference to groundwater-flow directions and were sampled at regular intervals to determine changes in concentrations of quality parameters. This type of system can be used to monitor continuous, long-term contaminant input from a source, such as a landfill, with minimum disruption of the groundwater flow pattern.

The passive monitoring program was selected over an active one for several reasons. First, an active monitoring program (i.e., continuous pumping), has a measurable and continuing impact on the groundwater regime. This causes considerable alteration of the flow system in which the contaminant source is located, especially when several wells are used. Second, disposal of the pumped water can be a problem. Third, over a period of years, cumulative pumping and maintenance costs may be high. And lastly, excessive pumping may result in dilution of the contaminant concentration at the point of sampling.

A potential problem with passive wells, on the other hand, might be the introduction of foreign materials from the surface, resulting in samples that are not truly representative of the groundwater situation. However, representative samples can be obtained by pumping or bailing the well prior to sampling. Withdrawal (purging) of a minimum of one well volume of water—three to five volumes are preferable—is recommended before sampling. In a high-yielding groundwater formation where there is no stagnant water in the well above the screened section, purging prior to sampling may not be critical.

Careful construction of the wells is also necessary to obtain representative water samples. Proper grouting of the wells, sealing at the surface, and covering of the well itself will prevent foreign materials from entering.

The sampling procedure consisted of purging each well prior to securing a sample. During the baseline study, the wells initially were bailed, but this proved too time consuming and awkward. Thereafter, the wells were pumped. The same water quality parameters and



SOURCE: Austin, Tsutsumi & Associates, Inc., Honolulu, Hawaii, 20 July 1978.

NOTE: 1 in. = 25.4 mm; 1 ft = 0.3048 m.

Figure 3. Typical cross section of a baseline study well, Kapaa Sanitary Landfill, Kawainui, O'ahu, Hawai'i

preservation, storage, and analysis of samples as were used in the surface-water quality monitoring program were used in the groundwater quality baseline study program. The groundwater elevation in each well was also monitored for the baseline study.

During the course of the baseline study, Well D was abandoned because of clogging, while Wells C and E were accidentally destroyed. Wells A, B, and F were sampled and analyzed until the end of the study.

Low-Level Monitoring Well-Water Quality Program

The well-water quality low-level monitoring program following the baseline study consisted of annual sampling and analysis of Wells B, E, and F, utilizing the same analytical parameters as were used during the baseline study. Well E was accidentally destroyed by heavy equipment and replaced in approximately the same location. Because Well B was found to have a broken casing just below the concrete cap (Fig. 3), surface-water leakage into the well, starting in May 1988, was suspected. A new Well B was placed in operation in June 1990 at a more convenient and representative site, approximately 300 ft (91 m) north of the original Well B. After evaluating the results of the baseline study, it was determined that Well A was so similar to Well E as to be redundant, so it was dropped from the monitoring program. In addition, a monthly program of sampling Wells B, E, and F was conducted, with the samples being analyzed for COD, chlorides, and pH, which were the same parameters used in the monthly surface-water sampling program. The groundwater elevations in the wells were not measured after the conclusion of the baseline study.

RESULTS AND DISCUSSION

Surface-Water and Well-Water Baseline Study and Low-Level Monitoring Program

Because of the expected interrelationships between surface and groundwater, the two components were considered in combination in the baseline study program. These baseline values thus served as the datum level for the subsequent low-level monitoring program. Most of the substantive data gathering for the baseline study occurred during 1979 and 1980, with the final surface-water and groundwater sampling completed on 30 December 1980. The low-level monitoring program commenced in 1981.

Median Values for the Baseline Study Program

The median water quality baseline values for surface-water Stations 1 to 6 and Wells A to F are presented in Table 1. A complete set of analytical water quality values for the surface-water stations and wells was compiled by Chun and Dugan (1981). The median water table elevations for the baseline study are also shown in Table 1.

Based on water table elevation measurements at the individual wells (Tab. 1), the groundwater gradient fairly well follows the flow lines predicted by Bowles and Mink (1977), except for Well E, which had a median water table head of 22.7 ft (6.92 m), some 13.32 ft (4.06 m) higher than the next highest median, for Well B. Thus, Well E was probably not aligned with the groundwater gradient flow from the existing landfill, as was originally determined, and most likely any influence from the existing landfill was minor. In studying the median well water results of Table 1, Well E appears in some ways to be more representative of the control than Well A. With the exception of ammonia, iron, and manganese, the other constituents indicate that the water at Well E has a generally lower mineral content, than the water at Well A, which is undoubtedly an indication that the quality of the groundwater in Well A is being influenced to a greater extent by the marsh than is the groundwater at Well E, which is at a higher elevation. Also, it can be noted that the COD median value of Well E (3 mg/l) is even lower than the value (5 mg/l) of its lowest surface-water counterpart, Station 1, Maunawili Stream. Similarly, the general median constituent values of Wells B, C, and D appeared to be less affected by the higher mineral content from seawater intrusion than those of Well A.

Wells A and F, which had the lowest general groundwater gradients, readily showed the apparent effects of a higher intensity of seawater intrusion in their overall median constituent values. This was especially true of Well F. However, besides the generally higher mineral constituent values due to seawater intrusion, Well F—in comparison to the other wells—had the highest median COD, ammonia nitrogen, and iron values. Only Wells E and F had median ammonia values that were above the minimum detection level, while the median ammonia values for the surface-water stations were either nondetectable or below the minimum detection level.

As would be expected, the mineral content of the surface-water samples progressively increased from Station 1, at the entrance to Kawainui Marsh, to Stations 5 and 6, at the marsh's outlet; restated, seawater intrusion is more evident at the sampling sites at lower elevations. Besides Maunawili Stream, the other major surface-water input to Kawainui Marsh is Kahanaiki Stream, which apparently had quite similar constituent values, but this observation was based on only one sample collected during the baseline study period.

One definite anomaly in the surface-water baseline study program was Station 4, which had the significantly highest median constituent surface-water values for TSS, nitrite and nitrate nitrogen, phosphate phosphorus, iron, manganese, magnesium, copper, and zinc, as well as the highest—although not significantly higher—surface-water median values for pH and calcium (Tab. 1). The high median constituent values were not reflective of the effects of

TABLE 1. MEDIAN BASELINE WELL AND SURFACE WATER QUALITY, KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

Sampling Period		DO (mg/l)	pH	Temp. (°C)	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	PO_4-P	Fe	Mn	Na	K	Ca	Mg	Cu	Zn	Water Table (ft)*
						(mg/l)																
Well Water	**Wells**																					
03/79–12/80	A	0.6 (23)	6.7 (23)	25.0 (23)	2,200 (23)	400 (23)	260 (23)	9 (22)	1,746 (22)	16 (22)	ND (19)	3.70 (23)	0.08 (20)	0.75 (21)	0.22 (21)	137 (21)	5.5 (21)	143 (21)	82 (21)	0.04 (21)	0.05 (21)	5.45 (15)
03/79–12/80	B	0.7 (25)	7.2 (25)	24.0 (25)	840 (24)	50 (25)	365 (25)	32 (24)	535 (25)	17 (25)	<1.0 (14)	<0.10 (20)	0.40 (23)	1.75 (23)	1.02 (23)	53 (23)	6.2 (23)	78 (23)	39 (23)	0.03 (18)	0.06 (23)	9.38 (15)
03/79–01/80	C	2.5 (14)	7.1 (14)	24.8 (14)	1,225 (14)	150 (14)	189 (14)	14 (13)	841 (14)	3 (14)	<1.0 (3)	<0.10 (13)	0.06 (9)	0.25 (13)	0.40 (11)	54 (14)	2.4 (14)	62 (14)	39 (14)	0.04 (10)	0.05 (14)	6.50 (4)
03/79–08/80	D	1.4 (18)	7.5 (18)	25.0 (18)	1,300 (18)	230 (17)	498 (18)	16 (16)	1,076 (16)	12 (16)	<1.0 (10)	0.10 (14)	0.22 (10)	3.12 (15)	0.20 (15)	132 (17)	6.2 (17)	140 (15)	83 (16)	0.06 (14)	0.10 (17)	8.83 (10)
03/79–02/80	E	1.0 (15)	6.9 (15)	24.0 (15)	800 (15)	60 (15)	313 (15)	3 (14)	529 (15)	16 (15)	6.5 (6)	<0.10 (15)	0.06 (11)	1.33 (15)	1.25 (15)	57 (15)	1.5 (15)	67 (15)	40 (15)	0.05 (13)	0.10 (9)	22.70 (5)
03/79–12/80	F	0.5 (26)	6.5 (26)	24.5 (26)	3,500 (26)	715 (26)	577 (26)	38 (25)	2,182 (26)	77 (26)	8.4 (19)	0.14 (26)	0.12 (21)	23.3 (24)	7.3 (24)	386 (24)	9.3 (24)	118 (24)	94 (24)	0.04 (24)	0.07 (23)	4.86 (14)
Surface Water	**Stations**																					
07/78–12/80	1	7.4 (23)	7.4 (23)	24.0 (23)	186 (20)	20 (23)	65 (22)	5 (23)	143 (17)	5 (22)	ND (19)	0.13 (23)	0.09 (21)	1.10 (21)	0.10 (16)	18 (16)	1.0 (16)	19 (19)	10 (16)	<0.02 (16)	0.08 (21)	.....
06/78–01/79	2	3.4 (10)	7.1 (10)	25.2 (10)	223 (10)	23 (9)	78 (10)	14 (9)	.....	10 (9)	ND (10)	<0.10 (10)	0.06 (10)	0.36 (7)	.....	20 (7)	1.0 (7)	8 (6)	.....	<0.02 (5)	0.12 (7)	.....
06/78–12/80	3	4.3 (23)	7.5 (23)	25.5 (22)	1,100 (21)	90 (24)	320 (25)	39 (24)	576 (15)	435 (27)	ND (14)	0.13 (21)	0.19 (24)	1.41 (21)	0.80 (13)	115 (13)	8.5 (13)	55 (21)	45 (13)	0.02 (20)	0.12 (20)	.....
06/78–12/80	4	6.3 (27)	7.9 (29)	25.4 (27)	1,050 (27)	70 (29)	316 (32)	32 (30)	618 (19)	1,310 (32)	ND (28)	0.95 (31)	1.35 (30)	12.00 (25)	1.05 (15)	72 (23)	7.0 (23)	89 (24)	118 (25)	0.17 (25)	0.40 (27)	.....
07/78–12/80	5	2.4 (20)	6.9 (20)	25.0 (19)	7,500 (19)	1,265 (17)	112 (19)	16 (20)	3,132 (16)	20 (19)	<1.0 (18)	<0.10 (18)	0.09 (18)	2.77 (15)	0.25 (14)	242 (14)	19.1 (14)	73 (15)	44 (13)	0.02 (13)	0.08 (15)	.....
07/78–12/80	6	5.0 (25)	7.1 (25)	25.0 (24)	4,150 (19)	1,963 (24)	146 (24)	22 (23)	4,895 (18)	21 (23)	ND (20)	0.10 (22)	0.06 (22)	1.02 (20)	0.25 (15)	475 (15)	39 (15)	55 (22)	60 (15)	0.03 (15)	0.14 (22)	.....

NOTE: Number of samples on which median was based in parentheses.
*1 ft = 0.3048 m.

seawater intrusion, but of what would be expected from soil or other solid media contact. A one-time sampling event during the baseline study suggested that the source of the high median constituent values of Station 4 was the nearby HC & D quarry operations. Modifications of the sediment-producing aspects of HC & D quarry operations have apparently corrected this suspected pollution problem.

The possible interchange of the rich iron sediment in Kawainui Marsh with both surface water and groundwater has been previously suggested. An indication of the potential for iron interchange can be ascertained by comparison to a Kawainui Marsh sediment sample, which yielded a value of 58,100 mg/kg; thus, its corresponding potential for interchange is obvious.

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 soil media 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 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 evapotranspiration values are obviously desirable in this technique. Because of the circumstances encountered at the Kapaa Sanitary Landfill site and the expected (known to some extent from previous studies) inter-relationships between groundwater and surface water there and at Kawainui Marsh, the hydrologic technique was not deemed feasible for this study.

Over the past two decades, numerous studies on the concentration of solid waste leachate have been conducted and reported in the literature. Some of these have been laboratory and pilot plant studies, while others have been actual in-situ measurements at landfill sites. Typically reported leachate concentration values and ranges are presented in Table 2, along with the highest of the median values (Tab. 1) for the corresponding constituent from the baseline study of Wells A to F. As can be observed, most of the values are from Well F.

One outstanding characteristic of leachate, as shown in Table 2, is the high COD value (18,000 mg/l), whereas the highest median concentration of the baseline study wells (at Well F) was 38 mg/l, which is essentially the same as the highest median concentration (39 mg/l) of the surface-water stations. Even the reported typical ammonia nitrogen value of 200 mg/l is more than an order of magnitude higher than the median values of 6.5 and 8.4 mg/l for Wells E and F, respectively, whereas the other wells have median ammonia values under the detectable limit. In this situation, the respective high median sodium and chloride values of 386 and 715 mg/l for Well F are undoubtedly the result of seawater intrusion into the marsh.

The typical leachate iron value (Tab. 2) of 60 mg/l is only slightly higher than twice the median value of 23.3 mg/l for Well F, with the next highest median value being 3.12 mg/l for Well D. The correspondingly two highest median iron values for surface water-stations are

TABLE 2. COMPOSITION OF LEACHATE FROM LANDFILLS IN COMPARISON TO HIGHEST MEDIAN VALUE FROM BASELINE STUDY WELLS A–F, KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

CONSTITUENT	LANDFILL LEACHATE COMPOSITION* (mg/l)†		BASELINE STUDY	
	Range	Typical	Highest Median Value	Well
5-Day Biochemical Oxygen Demand	2,000 – 30,000	10,000	....	
Total Organic Carbon	1,500 – 20,000	6,000	....	
Chemical Oxygen Demand	3,000 – 45,000	18,000	38	F
Total Suspended Solids	200 – 1,000	500	77	F
Organic Nitrogen	10 – 600	200	....	
Ammonia Nitrogen	10 – 800	200	8.4	F
Nitrate	5 – 40	25	3.7	A
Total Phosphorus	1 – 70	30	....	
Ortho Phosphorus	1 – 50	20	0.4	B
Alkalinity (as $CaCO_3$)	1,000 – 10,000	3,000	577	F
pH	5.3 – 8.5	6	....	
Total Hardness (as $CaCO_3$)	300 – 10,000	3,500	....	
Calcium	200 – 3,000	1,000	143	A
Magnesium	50 – 1,500	250	94	F
Potassium	200 – 2,000	300	9.3	F
Sodium	200 – 2,000	500	386	F
Chloride	100 – 3,000	500	715	F
Sulfate	100 – 1,500	300	....	
Total Iron	50 – 600	60	23.3	F

*From Lovelace (1970).
†Except pH.

12.0 and 2.77 mg/l, respectively, for Stations 4 and 5. However, as previously discussed, the sediment in Kawainui Marsh and the incoming sediment have a high iron content, which undoubtedly accounts for some of the baseline study well samples having significant iron concentrations.

An attempt was made to relate levels of individual constituents of surface-water stations and baseline study wells to groundwater levels, precipitation, and seasonal and/or annual changes; however, no consistent trends were apparent. The same is true for periods of significant precipitation that preceded sampling events. Even the 7 to 11 January 1980 rainfall event that averaged 17.55 in. (445.77 mm) (based on measurements taken at the nearby Kokokahi Weather Station), which preceded the 24 January 1980 well- and surface-water sampling event, did not show consistent trends with regard to individual constituents. Although the groundwater level after this heavy storm period did increase 2.46 ft (0.75 m) in Well A, and the other wells showed increases from 0 to 1.15 ft (0.35 m), their constituent concentrations fluctuated.

During the baseline sampling study (1979–1980), if there was indeed a correlation between leachate production and the underlying groundwater quality, it was not apparent and was considered to be minor at best. However, despite the lack of conclusive evidence, based particularly on COD values, to link the landfill operations to the groundwater quality, a baseline quality level was nevertheless obtained for the groundwater and surface water in and around the landfill.

After evaluating the data generated by the baseline study program, it did not appear justified to continue routine surface-water and groundwater sampling at all the sites using the quality parameters and frequency that were used to establish the baseline water quality values. Thus, key surface-water and groundwater sampling sites, specific water quality parameters, and frequencies of sampling were chosen.

Recommendations for a Continued Monitoring Program, Resulting from Baseline Study Data

As a result of the baseline study program, it was recommended that for a continuing surface-water and groundwater monitoring program (1) COD, chlorides, and pH be monitored on a monthly basis; (2) water Well E be reestablished for a control—as long as it is still upgradient of the present active landfill operations; (3) Wells B and F continue to be sampled because they potentially intercept leachate from, respectively, active and old landfill sites; and (4) surface-water quality be represented by Station 3. In addition, it was recommended that the entire baseline water quality parameters for remaining monitoring Wells A, B, E, and F, and for surface-water Stations 1, 3, 4, and 6 should be determined on an annual basis. It was also decided that surface-water sampling Station 5 was not necessary if sampling Station 6 was used, and vice versa.

Surface-Water and Well-Water Low-Level Monitoring Program

Following the recommendations of the baseline study program, the present monitoring program was established in 1981, essentially using the recommended sampling stations, frequency of sampling, and water quality parameters. Well E was reestablished in March 1982 in approximately the same location as the original Well E, for the purpose of serving as the control in place of Well A; thus, the sampling of Well A was discontinued. Also, the option of using surface-water sampling Station 5 over Station 6 was exercised.

Eleven complete sets of baseline water quality parameter were compiled annually at the selected baseline well-water and surface-water sampling stations from 1981 to 1990 during the low-level monitoring program. This total includes two baseline sets compiled in 1981. In addition, monthly sampling and analysis of Wells B, E, and F, and surface-water Station 3 for COD, chlorides, and pH were conducted from 1981 through 1990 and are reported here. The analytical results of the baseline and monthly low-level sampling program, along with a few other selected sampling locations, are tabulated in Appendix Table A.2. The designations of the sampling site locations in Appendix Table A.2 are spelled out in Appendix Table A.1, and the primary well- and surface-water locations are shown in Figure 2.

The median low-level monitoring values of the monthly samples from Wells B, E, and F, surface-water Station 3, and the leachate manhole are shown in Table 3. The leachate manhole, located just mauka (west) of the entrance road to Kapaa Sanitary Landfill, about 300 ft (91 m) in front of the Scale House, is the receptacle of a branched 650-ft (198.1-m) long, 8-in. (16.9-mm) diameter subsurface underdrain pipe system that was designed to collect leachate generated from the overlying sanitary landfill. The leachate manhole was reported to have about 300 to 400 gal (1.14–1.51 m^3) of leachate pumped out at approximately three-day intervals, with the contents being transported to the Kailua WWTP for disposal.*

As can be observed in Table 3, the annual median COD values for sample Wells B, E, and F and surface-water Station 3 were all higher than those obtained during the baseline study; however, these values are only a fraction of the reported typical leachate value of 18,000 mg/l (Tab. 2).

The COD values for the leachate manhole contents were relatively low from 1981 to 1984, with the 1984 value exceeding the baseline value. However, the 1988 value of 3,200 mg/l was especially high in comparison to the earlier values; the 1989 value was reported to be 475 mg/l. The number and frequency of samplings of the manhole leachate are too low for meaningful speculation, but it must be noted that the subsurface drainage lines are positioned just below the active landfill site, with the objective of intercepting leachate. Interestingly, the chloride value of the 1988 sample was also quite high, 2,270 mg/l, in comparison to previous values. High chloride values are known to interfere with the COD test, but generally chloride values of less than 2,000 mg/l are not considered to appreciably alter the COD results (APHA, AWWA, and WPCF 1985).

The most notable increase in the annual median COD value was at surface-water Station 3, especially from 1984 to 1988 (Tab. 3), with the 1988 value being more than twice as high as the next highest annual median value; however, the COD values for 1989 and 1990 were

*S. Carson (Kapaa and Kalaheo sanitary landfill operations) March 1989: personal communication.

TABLE 3. MEDIAN ANNUAL LOW-LEVEL MONITORING VALUES OF MONTHLY SAMPLES FROM WATER WELLS AND SURFACE-WATER STATIONS, KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

YEAR	MEDIAN ANNUAL RAINFALL* (in.)	WATER WELLS (mg/l) B COD	B Cl	E COD	E Cl	F COD	F Cl	SURFACE-WATER Station 3 (mg/l) COD	Cl	LEACHATE MANHOLE (mg/l) COD	Cl
1981	56.47	68 (4)	98 (4)	.....	.....	71 (4)	841 (4)	44 (4)	75 (4)	22 (2)	213 (2)
1982	95.33	46 (10)	65 (10)	10 (9)	51 (9)	69 (11)	860 (11)	36 (11)	80 (11)	12 (1)	44 (1)
1983	29.36	66 (12)	53 (12)	18 (12)	50 (12)	57 (11)	745 (11)	65 (12)	135 (12)	41 (1)	1,030 (1)
1984	39.92	79 (11)	50 (11)	20 (12)	50 (12)	64 (12)	823 (12)	59 (11)	103 (11)	73 (1)	350 (1)
1985	53.17	84 (11)	100 (11)	37 (11)	55 (11)	95 (10)	862 (10)	97 (10)	205 (10)	.....	.....
1986	54.67	85 (12)	75 (12)	38 (10)	65 (10)	60 (5)	1,500 (5)	155 (12)	310 (12)	.....	.....
1987	60.28	60 (10)	273 (10)	75 (10)	130 (11)	80 (10)	1,600 (10)	100 (9)	619 (9)	.....	.....
1988	66.13	60 (4)	58 (4)	60 (10)	68 (10)	80 (11)	280 (11)	325 (12)	555 (12)	3,200 (1)	2,270 (1)
1989	74.49	.....	.....	.....	.....	100 (8)	318 (8)	320 (11)	520 (11)	475 (1)	830 (1)
1990	≥ 59.10**	70 (5)	100 (5)	.....	.....	80 (9)	180 (9)	290 (9)	615 (9)	.....	.....
Baseline, 1979/1980	64.84/ 67.31	32 (24)	50 (25)	3 (14)	60 (15)	38 (25)	715 (26)	39 (24)	90 (24)	53 (5)	200 (5)

NOTE: Number of samples on which median was based in parentheses.
NOTE: Refer to Figure 2 for locations of sampling sites.
*Based on U.S. Weather Bureau station (Kokokahi, No. 781.6), for which the 22-yr (1965–1983) minimum, mean, median, and maximum records are 28.8, 58.7, 57.5, and 95.3 in., respectively (years of complete records).
**Missing data for 19 November–4 December 1989.

slightly lower than the 1988 value. Of note is that the annual median chloride value for Station 3 also increased. A graphic representation of the annual median COD values for sample Wells B, E, and F and Station 3 (Fig. 4) clearly demonstrates the higher rising annual median COD values for Station 3 from 1987 to 1990, with the monitoring wells remaining at a relatively low concentration level.

In order to ascertain any statistical correlation between the COD and chloride values in Appendix Table A.2 and those of any of the monthly monitoring stations, a linear regression analysis was performed on various combinations. The number of COD and chloride values available for comparison ranged from 72 to 101. The program used was Macintosh Cricket Graph. For purposes of evaluation, it was assumed that very little correlation exists when the coefficient is below 0.5. Based on this assumption, there were no meaningful relationships between any of the individual analytical parameters and sampling wells and surface-water stations. However, when the annual median COD values were plotted against chloride concentration values for Station 3, a correlation coefficient of 0.637 was obtained, as shown in Figure 5. Although this is not a strong correlation, it does show that the two parameters are somewhat related.

It is assumed that the chloride concentration of Station 3 was influenced mainly by seawater intrusion into Kawainui Marsh. The typical chloride concentration of leachate is 500 mg/l, while its typical corresponding COD value is 18,000 mg/l (Tab. 2), or stated differently, the typical chloride concentration of leachate is expected to be approximately 1/36 (or 0.028) of the COD concentration. As can be observed in Table 3 and Figure 5, the annual median chloride values are around two times higher than the annual median COD values; thus, it is assumed that the chloride contribution from leachate would be considered minor at best, and/or highly diluted by the Kawainui Marsh water. Although several theories for this apparent relationship could be postulated, presently it is not clear why the COD/chloride relationship exists for Station 3. Nevertheless, it does appear that a rise in the concentration of chloride at Station 3 tends to elevate the concentration of COD. Undoubtedly, the hydraulic circulation pattern in the marsh contributes to the alternating chloride values and is determined in part by the marsh's vegetative growth and dredging operations.

The overall median values for selected constituents (App. Tab. A.2) of the monitoring study (1981–1990) are compared to those of the baseline study (1979–1980) (Tab. 1) and tabulated in Table 4. A presentation of this type does not correlate concentration to time, as was done in Table 3, so changes for particular periods are not apparent. However, the scope of Table 4 also includes surface-water Stations 1, 4, and 5, in addition to Station 3, Wells B, E, and F, and the leachate mandhole, which were included in Table 3. Thus, the overall relationships among the various sampling stations can be compared.

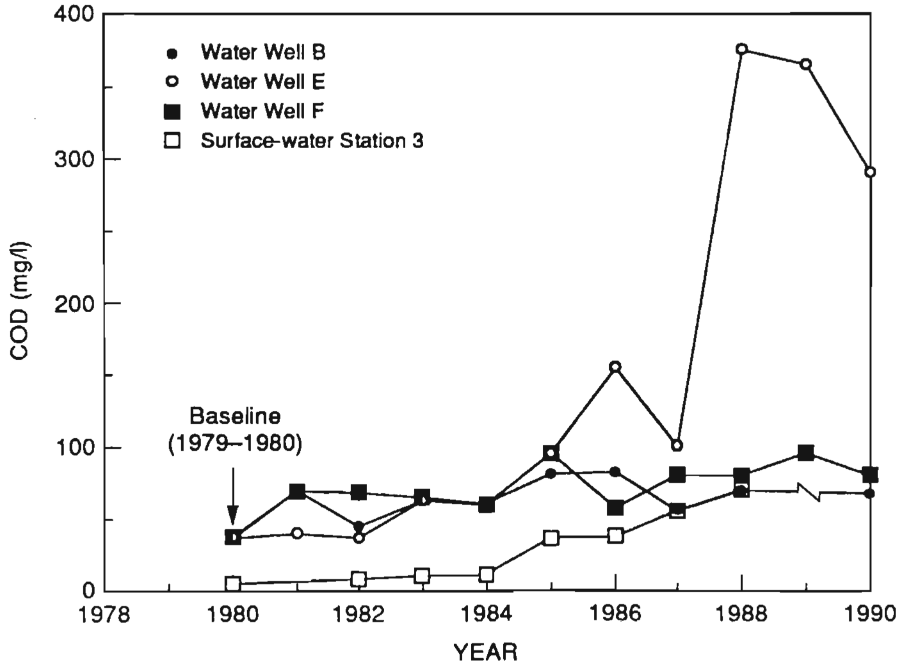


Figure 4. Annual median chemical oxygen demand values for sampling stations, Kapaa Sanitary Landfill, Kawainui, O'ahu, Hawai'i

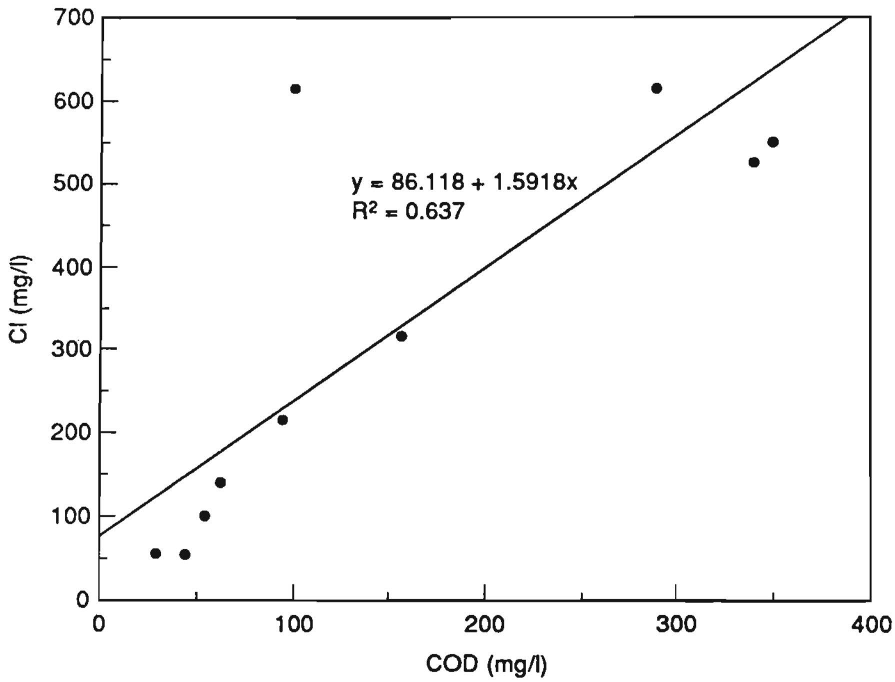


Figure 5. Annual median chemical oxygen demand vs. chloride values for surface-water Station 3, 1981–1990, Kapaa Sanitary Landfill, Kawainui, O'ahu, Hawai'i

TABLE 4. BASELINE STUDY MEDIAN VALUES (1981–1990) VS. MONITORING PROGRAM VALUES (1979–1980), KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

CONSTITUENTS (mg/l)*	STUDY	WATER WELL STATIONS			SURFACE-WATER STATIONS				LEACHATE MANHOLE
		B	E	F	1	3	4	5	
COD	B	32 (24)	3 (14)	38 (25)	5 (23)	39 (24)	32 (30)	16 (20)	53 (5)
	M	63 (79)	30 (72)	73 (75)	<5 (7)	81 (84)	23 (8)	39 (10)	41 (7)
Cl	B	50 (25)	60 (15)	715 (26)	20 (23)	90 (24)	70 (29)	1,265 (17)	200 (5)
	M	80 (74)	60 (72)	839 (75)	25 (7)	175 (83)	85 (8)	6,925 (10)	350 (7)
pH	B	7.2 (25)	6.9 (15)	6.5 (26)	7.4 (23)	7.5 (23)	7.9 (29)	6.9 (20)	7.3 (5)
	M	7.37 (77)	6.98 (73)	6.90 (73)	7.41 (7)	7.75 (82)	7.75 (7)	7.84 (8)	7.33 (5)
NH_4-N	B	<1.0 (14)	6.5 (6)	8.4 (19)	ND (19)	ND (14)	ND (28)	<1 (17)	<1 (2)
	M	1.3 (8)	0.2 (7)	12.6 (10)	0.01 (7)	2.3 (10)	0.15 (8)	0.11 (10)	0.28 (6)
NO_2+NO_3-N	B	<0.10 (20)	<0.1 (15)	0.14 (26)	0.13 (23)	0.13 (21)	0.95 (31)	<0.1 (18)	<0.1 (5)
	M	<0.1 (8)	<0.1 (7)	<0.1 (10)	0.1 (7)	0.26 (10)	0.19 (8)	0.1 (10)	0.15 (6)
Fe	B	1.75 (23)	1.33 (15)	23.3 (24)	1.10 (21)	1.41 (21)	12.00 (25)	2.77 (15)	2.83 (1)
	M	7.2 (9)	3.1 (7)	30 (11)	1.05 (8)	2.6 (11)	0.97 (9)	1.0 (11)	1.7 (5)

NOTE: Number of samples on which median was based in parentheses.
NOTE: B = baseline study phase value; M = monitoring study phase value.
*Except pH.

As can be noted in Table 4, the monitoring program median COD concentrations of Wells B and F and surface-water Stations 3 and 5 approximately doubled over baseline values, while Stations 1 and 4 decreased slightly. The median COD concentration of Well E (relocated in 1982) increased tenfold over that of the original Well E, although this was only to 30 mg/l. After the baseline study, modifications were made to the sediment-controlling facilities for HC & D quarry operations, which apparently contributed to the decrease in the median COD value. As in the baseline study, Well F and Station 3 had the highest median COD values, 73 and 81 mg/l, respectively; however, these values appear minor in comparison to the typically reported value of 18,000 mg/l (Tab. 2) for landfill leachate.

The chloride values for all the sampling stations (Tab. 4) increased during the monitoring phase, with the exception of that of Well E, which remained unchanged. A slight increase can also be observed in the pH of all stations—except that of Station 4, which decreased slightly—but all increases were within a relatively narrow, neutral range of 6.90 to 7.84. As was the case during the baseline study, Well F had the highest ammonia nitrogen median value of all the stations during the monitoring phase. In comparison to the baseline values, the ammonia nitrogen for Station 5 remained about the same, the value for the repositioned Well E was notably lower than the value for the original Well E (used during the baseline study), and the values of the remaining stations increased somewhat, especially those of Wells B and F.

The median value for nitrite and nitrate nitrogen remained approximately the same during the monitoring phase, as was true during the baseline study, except at Station 4, where it decreased significantly, and Station 3, where it was double the baseline value. The iron concentration of all the wells and Station 3 increased during the monitoring phase, while that of Station 1 decreased slightly. The concentration of Station 4 decreased sharply from 12.00 to 0.97 mg/l, under baseline and monitoring phase conditions, respectively, while that of Station 5 decreased from 2.77 to 0.70 mg/l. The concentration values of the leachate manhole samples were relatively the same during the baseline study and monitoring phase, considering the small number of samples that were analyzed.

As was discussed in the section on the baseline study results, iron-rich soils in the Kawainui drainage basin are believed to be the cause of the high iron concentration in the sediments of the marsh, wells, and surface-water stations. The modification of the sediment-control facilities for HC & D quarry operations was assumed to be the main reason that the COD, pH, nitrite and nitrate nitrogen, and iron values decreased during the monitoring phase (Tab. 4).

The median concentration values of two other metals tabulated in Appendix Table A.2, copper and zinc, were only <0.02 and 0.03 mg/l, respectively, for the 72 samples from all the stations, while high values were only 0.13 and 0.24 mg/l, respectively. Although not directly applicable, the secondary drinking water regulations recommend upper limits for these two metals of 1.0 and 5.0 mg/l, respectively (U.S. EPA 1979). The U.S. EPA issued 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.

A one-time sampling of the liquid in the silting basin, located approximately 300 ft south of the Scale House and above (west) the entrance road to Kapaa Sanitary Landfill, was done on 25 April 1988. The results of the sample, analyzed for priority pollutants—which include an array of constituents such as metals, purgeables, base/neutrals, and acids—are shown in Appendix Table A.3. It should be noted that all the concentrations, except those for the metals arsenic, nickel, and zinc, are below the lowest level of detection. As a comparison of the magnitude of the concentrations involved, the 0.02 mg/l value for arsenic in Appendix Table A.3 is less than the 0.05-mg/l limit specified in the State of Hawaii's primary drinking water regulations (Department of Health 1981); and the 0.12 mg/l concentration for zinc compares to a limit of 5 mg/l recommended in the federal secondary drinking water regulations (U.S. EPA 1979). The metal nickel, found in a low concentration of 0.06 mg/l, is not covered by either the primary or secondary drinking water regulations. As previously mentioned, drinking water regulation concentration limits do not directly apply to this situation. These values are thus presented only for the sake of comparison.

As previously discussed, leachate production is a function of the magnitude of precipitation being greater than that of evapotranspiration and water storage in the soil media. In order for reasonable estimates to be made of the potential generation of leachate, it is obviously desirable to have daily precipitation and evapotranspiration values, or at least shallow pan evaporation measurements with correction to evapotranspiration coefficients.

The nearest U.S. Weather Bureau Station is at Kokokahi (Sta. No. 781.6), located approximately 1.0 mi (1.6 km) northwest of Kapaa Sanitary Landfill, which has been keeping daily rainfall records since 1965. The rainfall at Kokokahi Weather Bureau Station is considered to be comparable to the rainfall expected at Kapaa Sanitary Landfill, inasmuch as the rainfall isohyets are positioned in the same general northwest-southeast direction (Fig. 1). The annual rainfall during the baseline period (1979–1980) and low-level monitoring study (1981–1990) is tabulated in Table 3, which also shows the minimum, mean, median, and maximum values recorded at the Kokokahi Station: 28.8, 58.7, 57.5, and 95.3 in., respectively.

It should be noted that the highest annual rainfall on record occurred in 1982, followed by 1983, which was only 0.56 in. above the lowest on record (Tab. 3). Sixteen days of rainfall data were not collected in November and December 1990; thus, the annual rainfall for 1990 was eliminated for statistical comparative purposes. However, the value of 59.1 in. that was recorded is slightly higher than the station's mean and median values. Of the remaining 11 yr (1979–1989) of annual rainfall records listed in Table 3 during the overall project period, the values for 6 were above and 5 below the station's mean and median values. The mean and median values for the 11 yr of record are 60.1 and 60.3 in., respectively (Tab. 3); thus, the 11 yr yield values slightly higher than do the station's full 22 yr of records. The station's daily rainfall records for the period January 1981 through December 1990 are tabulated in Appendix Table B.1.

No daily evapotranspiration data were collected near the Kapaa Sanitary Landfill site, so evaporation data would have to be imported from another area or assumed. The hydrologic techniques developed during the 1970s to estimate the production of leachate (U.S. EPA 1975; Mather and Rodriguez 1978) were considered; however, due to the lack of applicable evapotranspiration data and because of the previously discussed interrelationships between groundwater and surface water at Kapaa Sanitary Landfill and Kawainui Marsh, the hydrologic technique was not considered feasible for the baseline and low-level monitoring study programs. As previously discussed, groundwater moves to Kawainui Marsh as overflow from one dike compartment to another, rather than through the dike itself; thus, leachate should remain at or near the surface of the groundwater table, while the surface level of Kawainui Marsh represents the area's groundwater level (Bowles and Mink 1977).

It was determined during the baseline study period (1979–1980) that there was no apparent correlation between leachate production and the quality of the underlying groundwater. There could be numerous reasons for this apparent lack of correlation, not the least of which is the high potential for dilution by Kawainui drainage basin's groundwater, which terminates at the marsh before flowing into the ocean. However, with an additional nine complete years of rainfall and water quality data, a renewed effort can be made to compare leachate production and groundwater quality.

The magnitude of individual storm events (lasting up to several days), the interval between the rainfall events, precedent soil moisture conditions, as well as climatic conditions (wind, temperature, and humidity) all contribute to the potential for leachate production. Of these factors, ambient temperatures and rainfall amount, duration, and time between events are the most convenient to study without an extensive and expensive research effort, which if conducted, would also undoubtedly involve field determinations of groundwater occurrence, elevation, and movement. Based on the above rationale, the daily rainfall for events ≥ 0.25 in. were plotted in bar-graph form for comparison with corresponding COD values for monthly monitoring Wells B, E, and F and surface-water Station 3 (App. Tab. A.2).

Study of the plots for August 1981 through 1990 did not yield any consistent pattern between rainfall events, duration, and magnitude and the corresponding COD values of the sampling stations. A complicating factor, besides leachate dilution in the groundwater, is the time required for the net percolating rainfall (rainfall less evaporation and changes in soil water storage) to reach the individual sampling sites—a factor that would be expected to vary for each sampling station. The lack of consistent correlation, as previously mentioned, was also observed during the 1979 to 1980 baseline study. Another potential complicating factor is that the COD values for the sampling stations were only collected once a month; thus, it is possible that potential leachate production, as measured by the groundwater and surface-water quality at the sampling stations, could be in any stage of movement, if in fact a quantity or "slug" of leachate does percolate to and flow along the groundwater table to the sampling stations. However, this question arises in any monitoring program that is not an expensive, weighted-composite procedure. In addition, it is possible that significant slug loads do not occur and/or that the leachate production is small and thus diluted to a large extent by the underlying groundwater.

The intensity (in.) of 24-hr rainfall for recurrence intervals of 2-, 10-, 50-, and 100-yr events at the landfill is shown in Table 5. In this situation, the quantity of rainfall recorded at the Kokokahi Weather Station is an accumulation of the amount of rainfall that has occurred up to a specific time during the day. Consequently, a 24-hr storm could stretch over a two-day period. Thus, it is not possible to ascertain the quantity of 24-hr rainfall unless no rainfall was recorded on the preceding and succeeding days. Considering the foregoing and the recurrence intervals for 24-hr storms (Tab. 5), an attempt was made to ascertain if major storms did influence the water quality at the monitoring sampling stations, which was not apparent in the plotting of COD against rainfall events producing ≥ 0.25 in./day (not included here). To this end, rainfall events lasting one (or less) to several days that produced ≥ 2.0 in. of rainfall were compared to the concentration of COD for the preceding and succeeding sampling event (Tab. 6). The duration and quantity of rainfall for a specific event was based on the accumulated amount of rainfall for consecutive days on which the rainfall was ≥0.25 in. The values in parentheses in Table 6 represent the number of days between the monthly sampling dates and the start or conclusion of the rainfall event. In some situations in which significant rainfall events occurred over a limited period, the COD concentration values for a succeeding storm event were the same as those for the preceding storm event of the next storm event, while in other situations, two storm events might have occurred between COD sampling dates. Thus, two separate storm events might have the same COD preceding and succeeding concentration values.

TABLE 5. RAINFALL FREQUENCY FOR 24-HR STORMS AT KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

Recurrence Interval (yr)	Rainfall Intensity (in.)
2	5.4
10	9.1
50	13.0
100	13.5

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

Based on a comparison of the rainfall events listed in Table 6, the daily rainfall values in Appendix Table B.1, and the rainfall frequency and intensity for 24-hr storms (Tab. 5), it can be determined that at least three 2-yr and one 10-yr recurrence interval storms occurred between 1981 and December 1990. In addition, seven near 2-yr recurrence interval storms (> 4.5 in.) also occurred during this period. Potentially, two other storm events could be 2-yr recurrence interval storms if rainfall recorded over a consecutive two-day period actually occurred within a 24-hr period. If the two consecutive-day rainfall amounts for the 1988 New Year's storm—which flooded out and did extensive damage to many areas on O'ahu, including the Coconut Grove subdivision, just makai of Kawainui Marsh—were considered as the product of one 24-hr storm, the potential recurrence interval would approximate a 50-yr event rather than the presently considered 10-yr one.

The foregoing discussion illustrates that major storms did occur over the 10-yr period of the monitoring study, and at a frequency, at least at the 2-yr recurrence interval, greater than what normally would be expected statistically. In view of this, and in line with what was ascertained for the plotting of COD against rainfall events ≥ 0.25 in., a consistent rainfall vs. COD concentration was not apparent. Again, a major drawback to this type of determination is the length of time between monthly sampling dates; however, at this time this is only a supposition.

CONCLUSIONS

Considerable concern has been expressed 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 (3.035×10^6 m^2) Kawainui Marsh.

TABLE 6. RAINFALL EVENTS (1981–1990) WITH ≥ 2.0 IN. RAINFALL VS. CHEMICAL OXYGEN DEMAND VALUES, KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

RAINFALL EVENTS (mo/day/yr)	RAINFALL AMOUNT (in.)	COD (mg/l) Well B P	Well B S	Well E P	Well E S	Well F P	Well F S	Surface-Water Station 3 P	Surface-Water Station 3 S
04/13/81–04/14/81	3.05	....	....	....	....	....	....	....	....
05/07/81–05/08/81	6.24	....	....	....	....	....	....	....	....
08/04/81–08/05/81	2.17	63 (0)	63 (0)	....	....	54 (0)	54 (0)	23 (0)	23 (0)
12/19/81–12/23/81	12.38	73 (10)	80 (29)	....	....	77 (10)	89 (29)	46 (10)	114 (29)
01/06/82	3.36	73 (27)	80 (15)	....	....	77 (29)	89 (15)	46 (29)	114 (15)
01/20/82–01/22/82	10.90	80 (0)	80 (0)	....	....	89 (0)	89 (0)	114 (0)	114 (0)
03/12/82–03/13/82	4.27	189 (16)	46 (4)	....	<5 (4)	92 (16)	56 (4)	62 (16)	10 (4)
06/10/82–06/11/82	3.49	23 (56)	45 (5)	<5 (56)	8 (5)	41 (56)	49 (5)	23 (56)	22 (5)
06/16/82–06/18/82	3.62	45 (0)	45 (0)	8 (0)	8 (0)	49 (0)	49 (0)	22 (0)	22 (0)
07/23/82–07/24/82	5.87	36 (8)	46 (18)	10 (8)	25 (18)	30 (8)	70 (18)	10 (8)	28 (18)
08/17/82	2.63	46 (6)	46 (34)	25 (6)	10 (34)	70 (6)	72 (34)	28 (6)	98 (34)
10/27/82–10/30/82	8.86	64 (14)	62 (18)	6 (14)	10 (18)	69 (14)	13 (18)	64 (14)	36 (18)
12/22/82–12/24/82	2.49	44 (6)	55 (19)	512 (6)	60 (19)	119 (6)	56 (19)	451 (6)	58 (19)
04/20/84	4.52	58 (1)	79 (34)	13 (1)	6 (34)	79 (1)	47 (34)	59 (1)	71 (34)
10/29/84–10/30/84	3.10	117 (5)	138 (14)	50 (5)	21 (14)	98 (5)	73 (14)	65 (5)	44 (14)
11/26/84–11/28/84	5.92	138 (12)	89 (35)	21 (12)	37 (35)	73 (12)	54 (35)	44 (12)	73 (35)
12/24/84–12/26/84	5.07	138 (40)	89 (7)	21 (40)	37 (7)	73 (40)	54 (7)	44 (40)	73 (7)
02/12/85–02/15/85	9.82	100 (14)	49 (5)	53 (14)	14 (5)	154 (14)	86 (5)	40 (14)	43 (5)
10/20/85–10/21/85	4.87	90 (24)	270 (10)	20 (24)	270 (10)	....	270 (10)	120 (14)	....
11/10/85–11/13/85	3.20	270 (10)	....	270 (10)	112 (35)	270 (10)	....	....	....
09/28/86	5.40	80 (4)	60 (25)	45 (4)	....	110 (4)	185 (25)	280 (4)	580 (25)
11/11/86–11/12/86	11.42	60 (19)	620 (9)	....	....	185 (19)	60 (9)	580 (19)	135 (9)
02/13/87–02/16/87	4.00	50 (22)	270 (2)	30 (22)	190 (2)	90 (22)	310 (2)	70 (22)	290 (2)
12/12/87–12/15/87	9.12	60 (23)	50 (1)	20 (23)	50 (1)	40 (23)	60 (1)	20 (23)	50 (1)
12/17/87–12/20/87	6.87	50 (1)	80 (24)	50 (1)	70 (24)	60 (1)	130 (24)	50 (1)	80 (24)
12/31/87–01/03/88	13.53	50 (15)	80 (10)	50 (15)	70 (10)	60 (15)	130 (10)	50 (15)	80 (10)
01/28/88–01/30/88	3.40	80 (15)	50 (11)	70 (15)	260 (11)	130 (15)	80 (11)	80 (15)	60 (11)
09/10/88–09/13/88	2.13	....	....	70 (3)	90 (36)	490 (3)	400 (36)	960 (3)	65 (36)
09/27/88–09/29/88	2.52	....	....	70 (16)	90 (20)	490 (16)	400 (20)	960 (16)	65 (20)
11/04/88–11/06/88	3.40	....	....	90 (16)	55 (3)	400 (16)	190 (3)	65 (16)	190 (3)
12/06/88–12/07/88	5.08	....	....	55 (27)	530 (7)	190 (27)	....	190 (27)	350 (7)
12/16/88–12/18/88	2.78	....	....	....	....	530 (2)	475 (31)	350 (2)	350 (31)
01/10/89–01/13/89	3.25	....	....	....	....	530 (27)	475 (5)	350 (27)	350 (5)
02/02/89–02/03/89	3.14	....	....	....	....	120 (15)	140 (12)	670 (15)	160 (12)
02/10/89–02/12/89	3.30	....	....	....	....	120 (23)	140 (3)	670 (23)	160 (3)
03/01/89–03/03/89	4.94	....	....	....	....	140 (13)	170 (12)	160 (13)	340 (12)
04/04/89–04/05/89	4.18	....	....	....	....	170 (20)	70 (14)	340 (20)	320 (14)
04/07/89–04/09/89	9.03	....	....	....	....	170 (23)	70 (10)	340 (23)	320 (10)
04/12/89–04/13/89	2.12	....	....	....	....	170 (28)	70 (6)	340 (28)	320 (6)
06/01/89–06/02/89	2.74	....	....	....	....	70 (43)	90 (19)	320 (43)	330 (19)
07/21/89–07/23/89	3.30	....	....	....	....	90 (30)	110 (58)	392 (2)	40 (5)
10/03/89–10/04/89	4.62	....	....	....	....	110 (13)	44 (17)	570 (13)	110 (17)
12/20/89	2.28	....	....	....	....	50 (0)	50 (0)	70 (0)	70 (0)
01/15/90–01/17/90	3.72	....	....	....	....	50 (26)	94 (28)	70 (26)	470 (28)
01/19/90–01/20/90	3.91	....	....	....	....	50 (29)	94 (25)	70 (29)	470 (25)
02/25/90–02/26/90	4.16	....	....	....	....	94 (11)	55 (30)	470 (11)	140 (30)
03/01/90–03/02/90	3.69	....	....	....	....	94 (15)	55 (26)	470 (15)	140 (26)
11/12/90–11/14/90	5.32	60 (19)	....	....	....	88 (19)	....	156 (15)	....
11/17/90–11/18/90	5.02*	60 (24)	....	....	....	188 (24)	....	156 (15)	....
12/05/90	2.25*	60 (42)	....	....	....	188 (42)	....	156 (15)	....
12/18/90–12/21/90	3.39	60 (55)	....	....	....	188 (55)	....	156 (15)	....
12/23/90–12/26/90	3.19	60 (60)	....	....	....	188 (6)	....	156 (15)	....

NOTE: Rainfall data from Kokokahi Weather Sta. No. 781.6.
NOTE: Based on accumulated amount of rainfall for consecutive days in which rainfall is ≥0.25 in. Values in parentheses represents number of days preceding (P) or succeeding (s) storm events; (0) represents sample collection during storm events.
*Rainfall data were not collected from 19 November – 4 December 1990.

Although previous limited field studies of leachate production at Kapaa Sanitary Landfill all concluded that the sanitary landfill operation does not adversely affect the quality of marsh water by way of leachate production or migration, the City and County of Honolulu elected to take a cautious approach and established a 2-yr baseline study program (1979–1980) and, commencing in 1988, an ongoing low-level monitoring study.

Kawainui Marsh has several functions. It is the buffer zone—between land and Kailua Bay—for sediment, nutrients, and contaminants in general from the 18-m^2 (46.6-km^2) Maunawili Valley drainage basin; a flood-control facility for most of the Kailua area; and a desirable area for housing and commercial ventures, active recreation, and the protection of wildlife.

The project's baseline water quality program consisted of two major components: (1) analyzing an array of water quality parameters for samples collected from six surface-water sampling stations near the Kapaa Sanitary Landfill and in Kawainui Marsh; and (2) analyzing six groundwater sampling wells within and near the landfill. The low-level monitoring program consisted of analyzing samples collected from the baseline sampling stations once a year, and monthly analysis for COD, chlorides, and pH at water Wells B, E, and F and surface-water Station 3.

The one outstanding characteristic of leachate from landfill operations is a high COD concentration, or organic content, of approximately 18,000 mg/l. The highest median concentration for the period (1979–1980) of the six baseline monitoring wells was 38 mg/l, which was essentially the same as the highest median concentration, 39 mg/l, for the six baseline surface-water stations. During the low-level monitoring study (1981–1990), the annual median COD values were all higher than the baseline values; however, the highest annual median COD values over the 10-yr low-level monitoring study were only 85, 75, 95, and 325 mg/l, respectively, for water Wells B, E, and F and surface-water Station 3. Even though the median COD concentrations were higher during the subsequent monitoring phase than during the baseline study, the highest annual median COD concentrations for the sampling stations were still only a fraction of the concentration of 18,000 mg/l typically reported for landfill leachate.

The annual median COD concentration for surface-water Station 3 appears to be correlated with the station's annual median chloride level (correlation coefficient of 0.64), as can be observed in Figures 4 and 5. The increased chloride concentration during the monitoring phase is presumed to result from changes in the hydraulic flow patterns within Kawainui Marsh caused by vegetative growth and dredging operations.

No consistent correlation could be found between levels of individual constituents of the surface water-stations and monitoring wells and groundwater levels, rainfall, or seasonal and/or annual changes during the baseline study (1978–1980) or the subsequent ongoing monitoring period (commencing in 1981 and continuing through 1990). During the baseline study, there seemed to be a correlation between groundwater depth and quality and the surface-water quality of Kawainui Marsh, suggesting an interchange between groundwater quality and surface-water quality in and around the Kapaa Landfill. Although the water depth was not measured during the low-level monitoring study, the correlation between the quality of the lower-elevation wells and the quality of Kawainui Marsh was obvious, especially in terms of chloride concentrations. If there is indeed a correlation between leachate production and the quality of the underlying groundwater, it was not readily apparent during the baseline study and during the monitoring study phase in general. Thus, it is concluded that any correlation would have to be considered minor at best.

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APPENDIX CONTENTS

Appendix Tables

APPENDIX TABLE A.1. SAMPLING STATION DESIGNATIONS, KAPAA SANITARY LANDFILL, KAWAINUI, O'AHU, HAWAI'I

Sampling Station	Description
ROUTINE*	
Well B	
Well D	
Well E	
Well F	
Surface-Water Station 1	Maunawili Stream, about 100 yd upstream of Kalanianaole Highway (61)
Surface-Water Station 2	Pond in Kawainui Marsh that received stream flows; access lost to this station
Surface-Water Station 3	Marsh side of Quarry Access Road below Kapaa Landfill office, just beyond drainage pipe that discharges into marsh
Surface-Water Station 4	Small intermittent stream on quarry side of Quarry Access Road that flows through HC & D quarry operation site
Surface-Water Station 5	Off the levee, on marsh side
Surface-Water Station 6	Kawainui Canal, near Mokapu Boulevard
Leachate Manhole	Just mauka (west) of entrance to sanitary landfill, about 300 ft before Scale House
SPECIAL	
BCY	Standing storm water, behind corporation yard
QAR	Standing storm water, near quarry across road
CB	Concrete box by Gate and Scale House; surface-water runoff
SB	Silting basin, approximately 300 ft south of Scale House and below (east) of entrance road, Kapaa Sanitary Landfill
DD	Drainage ditch to conrete box by Gate and Scale House
IB	Intake box; location not specified
M	Sample collected in Kawainui Marsh approximately 200 yd offshore of surface-water Station 3

*Refer to Figure 2.

APPENDIX TABLE A.2. LOW-LEVEL MONITORING PROGRAM, KAPAA SANITARY LANDFILL, O'AHU, HAWAI'I

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
08/05/81	LM		1,140	203	391	29	524	9	0.45	0.06	0.04	1.7	200	6.9	190	32	<0.02	0.06	.....
	B		1,400	98	745	63	948	26	2.20	0.15	0.34	4.7	135	12	250	68	<0.02	0.11	.....
	F		2,650	890	701	54	2,100	78	13.80	0.06	0.12	31	670	11	300	112	<0.02	0.07	.....
	2		685	72	279	33	476	68	0.12	0.12	0.22	11	100	6.9	68	30	0.02	0.08	.....
	3		540	42	180	23	369	44	0.78	1.2	0.21	12	45	53	73	27	0.03	0.07	.....
	4		7,300	6,950	138	18	.....	32	0.08	0.02	0.04	0.7	3,200	125	310	425	<0.02	0.03	.....
	5		8,000	5,870	145	19	10,600	36	0.02	0.02	0.04	0.7	2,800	108	280	350	<0.02	0.04	.....
	6		155	23	.....	<5	.....	32	0.01	0.07	0.06	1.5	14	1.9	16	6	<0.02	0.04	.....
09/23/81	LM		1,150	223	381	15	884	17	0.10	0.03	0.08	3.0	200	8.1	120	.....	<0.02	0.07	1.5
	B		1,400	151	783	21	1,060	19	3.0	0.02	0.34	6.2	190	13	160	.....	<0.02	0.09	2.3
	F		2,600	860	728	57	2,190	80	15	0.03	0.09	59	480	13	240	.....	0.02	0.07	3.0
	2		630	62	273	55	442	69	0.06	0.02	0.17	7.4	100	7.0	33	.....	0.03	0.05	1.1
	3		1,100	99	481	41	744	23	3.8	0.32	0.05	2.4	140	18	80	.....	0.03	0.03	0.40
	5		9,000	9,810	144	35	17,100	13	0.12	0.03	0.03	1.0	5,100	188	230	.....	0.07	0.07	0.16
	6		280	24	57	7	128	4	0.09	0.16	0.08	0.86	21	2.7	12	.....	<0.02	0.01	0.09
11/03/81	B	7.04	.....	97	.....	105	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.56	.....	760	.....	84	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.41	.....	60	.....	105	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/09/81	B	7.12	.....	69	.....	73	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.68	.....	822	.....	77	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.28	.....	89	.....	46	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/21/82	B	7.40	.....	67	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.18	.....	860	.....	89	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.61	.....	71	.....	114	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/24/82	B	7.22	.....	48	.....	189	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.55	.....	907	.....	92	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.63	.....	83	.....	62	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (µmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
03/17/82	LM	8.03	430	44	165	12	340	2	<0.1	0.2	0.06	0.79	30	2.6	22	11	0.03	0.40	.....
	B	7.46	1,320	63	736	46	920	15	1.7	<0.1	0.32	4.3	95	10	117	64	<0.02	<0.01	.....
	D	7.97	810	57	314	21	588	15	0.1	0.1	0.18	2.5	109	6.8	51	35	0.02	0.04	.....
	E	6.95	630	51	256	<5	488	96	0.2	<0.1	0.44	19	58	2.1	58	36	0.04	0.06	.....
	F	6.76	3,600	855	777	56	2,396	41	13.5	<0.1	0.15	42	487	14	194	108	0.02	0.05	.....
	2	7.82	1,010	88	475	46	724	5	0.7	<0.1	0.04	1.4	115	9.3	62	57	0.02	<0.01	.....
	3	7.86	560	42	209	10	476	46	0.3	0.8	0.18	9.8	49	3.8	39	28	0.03	<0.01	.....
	5	6.74	780	205	75	14	596	5	<0.1	<0.1	0.18	4.5	94	6.8	16	20	<0.02	<0.01	.....
	6	7.60	190	22	64	<5	160	3	<0.1	0.1	0.02	0.85	14	1.2	10	7	<0.02	<0.01	.....
04/15/82	B	7.69	.....	109	.....	23	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.89	.....	74	.....	<5	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.67	.....	839	.....	41	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.59	.....	38	.....	23	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/16/82	B	7.37	.....	41	.....	45	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.68	.....	60	.....	8	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.51	.....	940	.....	49	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.71	.....	80	.....	22	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
07/15/82	B	7.42	.....	102	.....	36	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.97	.....	55	.....	10	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.97	.....	850	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.74	.....	89	.....	10	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
08/11/82	B	7.38	.....	51	.....	46	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.85	.....	50	.....	25	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.55	.....	890	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.66	.....	86	.....	28	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/20/82	B	7.81	.....	99	.....	46	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.78	.....	48	.....	10	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.59	.....	870	.....	72	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.18	.....	45	.....	98	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (µmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
10/13/82	B	7.19	.....	55	.....	64	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.83	.....	39	.....	6	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.55	.....	880	.....	69	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.66	.....	125	.....	64	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11/17/82	B	7.67	.....	75	.....	62	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.79	.....	58	.....	10	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.75	.....	105	.....	13	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.68	.....	195	.....	36	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/16/82	B	7.68	.....	.....	.....	44	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.92	.....	.....	.....	512	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.70	.....	8	.....	119	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.25	.....	.....	.....	451	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/12/83	B	7.17	.....	51	.....	55	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.22	.....	63	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.22	.....	47	.....	56	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.54	.....	146	.....	58	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/09/83	B	7.05	.....	49	.....	40	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.8	.....	53	.....	13	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.6	.....	958	.....	73	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.6	.....	184	.....	81	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/16/83	B	7.19	.....	54	.....	128	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.55	.....	45	.....	87	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.72	.....	915	.....	138	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.01	.....	200	.....	159	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/13/83	B	7.70	.....	135	.....	76	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.0	.....	54	.....	15	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.65	.....	745	.....	57	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.75	.....	130	.....	74	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
05/18/83	B	7.32	.....	47	.....	75	.....	...	....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.15	.....	50	.....	20	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.0	.....	49	.....	8	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.0	.....	193	.....	97	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/15/83	B	6.98	.....	50	.....	127	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.80	.....	44	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.58	.....	162	.....	110	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
07/13/83	B	7.90	.....	164	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.60	.....	310	.....	28	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	8.00	.....	300	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.30	.....	50	.....	58	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
08/17/83	B	7.36	1,400	60	790	103	992	23	0.3	<0.1	0.25	5.5	112	12	91	70	<0.02	<0.02	.....
	E	6.94	640	50	240	13	420	5	<0.1	<0.1	0.11	3.1	64	2.0	30	30	<0.02	0.06	.....
	F	6.81	3,400	1,000	750	52	2,250	70	17.2	<0.1	0.02	38	538	13	219	114	<0.02	0.07	.....
	LM	7.33	1,700	1,030	660	41	1,060	16	<0.1	<0.1	0.20	1.7	231	9.4	172	42	<0.02	<0.02	.....
	1	7.41	200	16	62	<5	180	4	<0.1	0.1	0.08	1.0	15	0.9	5.0	9.0	<0.02	0.03	.....
	3	7.97	1,000	140	410	66	656	38	<0.1	0.11	0.28	4.0	145	14	24	42	<0.02	<0.02	.....
	4	7.53	1,000	87	470	23	640	17	<0.1	0.44	0.13	0.82	104	15	46	46	<0.02	0.03	.....
	5	7.76	13,000	8,600	190	43	12,500	57	<0.1	<0.1	0.08	0.48	3,710	179	238	491	<0.02	<0.02	.....
09/21/83	B	7.10	.....	42	.....	62	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.75	.....	40	.....	<5	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.70	.....	800	.....	63	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.10	.....	116	.....	64	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/19/83	B	6.95	.....	44	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.75	.....	40	.....	<5	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.75	.....	670	.....	56	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.60	.....	107	.....	54	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
11/16/83	B	7.94	.....	97	.....	46	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.90	.....	45	.....	14	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.97	.....	68	.....	141	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.74	.....	43	.....	35	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/19/83	B	7.90	.....	67	.....	39	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.30	.....	703	.....	79	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.49	.....	770	.....	109	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.74	.....	73	.....	47	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/19/84	B	7.25	.....	82	.....	32	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.65	.....	48	.....	22	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.80	.....	710	.....	44	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.42	.....	83	.....	27	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/15/84	B	7.20	.....	35	.....	53	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.70	.....	65	.....	8	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.85	.....	770	.....	59	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.65	.....	80	.....	32	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/22/84	B	7.30	.....	50	.....	53	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.88	.....	50	.....	6	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.92	.....	768	.....	59	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.72	.....	91	.....	29	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/19/84	B	7.57	.....	47	.....	58	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.15	.....	51	.....	13	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.32	.....	638	.....	79	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.13	.....	103	.....	59	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
05/24/84	B	8.10	.....	40	.....	79	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.75	.....	50	.....	6	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.90	.....	1,888	.....	47	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.0	.....	126	.....	71	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
06/21/84	B	7.44	.....	45	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.86	.....	45	.....	19	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.23	.....	640	.....	56	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.74	.....	125	.....	76	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
07/25/84	B	7.20	1,080	45	700	90	980	905	2.6	<0.1	1.54	54	128	13	119	88	0.13	0.12	.....
	E	6.80	610	50	260	10	480	11	0.40	<0.1	0.12	3.2	68	1.9	53	39	<0.02	<0.01	.....
	F	6.75	3,300	1,100	730	69	2,580	48	15.7	<0.1	0.07	15	650	10	153	126	<0.02	<0.01	.....
	LM	7.12	1,530	350	440	73	1,250	22	1.6	0.33	0.19	2.3	240	11	134	45	<0.02	<0.01	.....
	1	7.15	170	20	65	<5	155	4	<0.1	0.35	0.13	0.71	15	0.9	10	9.1	<0.02	<0.01	.....
	3	8.05	790	110	360	66	590	31	<0.1	0.11	0.19	0.84	144	13	20	45	<0.02	<0.01	.....
	4	7.50	840	75	470	32	640	24	2.0	0.26	0.14	1.1	104	9.9	70	48	<0.02	<0.01	.....
	5	7.70	12,000	14,300	160	190	25,300	17	<0.1	<0.1	0.07	0.46	8,000	326	297	990	0.03	<0.01	.....
08/23/84	B	7.18	.....	55	.....	567	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.00	.....	48	.....	39	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.90	.....	1,000	.....	116	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.80	.....	107	.....	87	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/20/84	B	7.29	.....	45	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.93	.....	65	.....	62	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.72	.....	945	.....	114	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.55	.....	95	.....	52	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/24/84	B	7.35	.....	85	.....	117	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.00	.....	52	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.70	.....	875	.....	98	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.75	.....	100	.....	65	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11/14/84	B	7.17	.....	95	.....	138	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.94	.....	65	.....	21	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.74	.....	975	.....	73	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.13	.....	175	.....	44	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (µmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
01/02/85	B	7.61	.....	230	.....	89	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.78	.....	50	.....	37	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.85	.....	210	.....	54	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.90	.....	240	.....	73	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/29/85	B	6.96	.....	105	.....	100	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.84	.....	55	.....	53	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.78	.....	1,030	.....	154	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.87	.....	145	.....	40	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/20/85	B	7.15	.....	60	.....	49	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.95	.....	50	.....	14	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.72	.....	876	.....	86	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.55	.....	140	.....	43	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/21/85	B	7.57	.....	170	.....	35	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.09	.....	55	.....	14	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.64	.....	790	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.17	.....	65	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/23/85	B	7.30	.....	85	.....	84	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.28	.....	50	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.68	.....	850	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.06	.....	230	.....	100	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
05/21/85	B	6.87	.....	90	.....	1,280	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.56	.....	930	.....	90	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.66	.....	180	.....	180	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/20/85	B	7.18	.....	100	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.91	.....	50	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.73	.....	920	.....	100	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.45	.....	260	.....	120	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
07/10/85	B	7.50	1,400	100	732	20	580	2,290	<0.1	<0.1	3.15	9.2	100	11	122	68	0.06	0.09	.....
	E	7.61	910	90	264	30	920	680	<0.1	0.6	0.16	2.4	32	1.9	51	36	<0.02	0.02	.....
	F	6.89	5,000	880	732	100	2,300	2,580	11.7	1.10	0.27	30	467	12	174	116	<0.02	0.05	.....
	1	7.40	210	25	62	6	180	2	<0.1	0.1	0.08	0.86	17	0.88	10	12	<0.02	<0.02	.....
	3	8.11	1,600	290	420	120	1,100	42	<0.1	<0.1	0.27	2.6	226	28	30	54	<0.02	0.03	.....
	4	7.75	920	83	355	30	600	22	<0.1	0.4	0.11	0.90	82	5.7	61	48	<0.02	<0.02	.....
	5	7.45	900,000	7,600	158	210	14,000	33	<0.1	0.1	0.04	0.14	3,560	163	153	463	<0.02	<0.02	.....
08/22/85	B	7.66	.....	70	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.43	.....	60	.....	210	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	8.10	.....	80	.....	7	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.36	.....	80	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/26/85	B	7.44	.....	100	.....	90	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.88	.....	50	.....	20	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.65	.....	300	.....	120	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/31/85	B	9.02	.....	510	.....	270	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	8.98	.....	510	.....	270	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	9.07	.....	510	.....	270	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/18/85	E	7.15	.....	70	.....	112	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	BCY	6.90	.....	43	.....	8	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	QAR	6.90	.....	50	.....	8	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/30/86	B	7.55	.....	620	.....	1,140	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.04	.....	55	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.04	.....	690	.....	390	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/19/86	B	9.15	.....	380	.....	180	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.84	.....	80	.....	14	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	6.75	.....	60	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/20/86	B	7.10	.....	80	.....	105	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.80	.....	60	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.90	.....	310	.....	170	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (µmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
04/23/86	B	6.90	.....	80	.....	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.71	.....	60	.....	30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.65	.....	410	.....	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
05/21/86	B	7.15	.....	80	.....	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.75	.....	60	.....	50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	QAR	6.70	.....	200	.....	830	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.95	.....	530	.....	290	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/20/86	B	7.36	.....	60	.....	30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.83	.....	70	.....	490	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.23	.....	100	.....	40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
07/23/86	B	7.08	1,340	90	490	70	1,040	160	<0.1	50.3	0.51	7.2	151	16.0	83.1	59.4	0.06	<0.02	.....
	C	7.12	1,340	160	300	380	1,040	6	<0.1	2.6	0.14	1.4	98	4.7	45.8	46.7	<0.02	<0.02	.....
	E	7.45	1,050	80	230	6	815	20	<0.1	0.6	0.12	2.0	86	4.7	59.3	32.9	0.04	<0.02	.....
	F	8.34	7,000	1,690	860	60	3,600	380	4.2	<0.1	0.29	12.2	1,150	63.2	81.2	134	0.06	<0.02	.....
	1	7.41	200	30	62	4	185	8	<0.1	0.1	0.09	3.2	16	1.9	5.5	8.4	0.09	0.05	.....
	3	7.46	1,650	300	470	140	1,120	35	5.90	<0.1	0.34	2.9	258	79.1	30.6	49.9	<0.02	0.24	.....
	4	7.55	950	90	385	20	660	18	<0.1	<0.1	0.11	0.97	82	8.5	35.3	37.9	<0.02	<0.02	.....
	5	7.35	.....	14,100	142	50	24,000	103	<0.1	<0.1	0.14	1.4	7,900	336	206	595	<0.02	<0.02	.....
08/20/86	B	7.05	.....	75	.....	70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	C	6.98	.....	240	.....	740	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.86	.....	70	.....	30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.72	.....	1,500	.....	50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.69	.....	300	.....	110	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/24/86	B	8.36	.....	65	.....	80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	C	7.97	.....	195	.....	430	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	8.48	.....	55	.....	45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.83	.....	1,560	.....	110	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.57	.....	310	.....	280	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/23/86	B	7.27	.....	1,540	.....	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.38	.....	1,580	.....	185	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.23	.....	660	.....	580	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	...

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
11/21/86	B	7.28	.....	110	.....	620	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.04	.....	1,090	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.85	.....	280	.....	135	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/19/86	B	7.80	.....	255	.....	105	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.30	.....	330	.....	740	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.70	.....	320	.....	10	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.80	.....	430	.....	190	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/22/87	B	7.17	.....	315	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.87	.....	300	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.01	.....	1,500	.....	90	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.76	.....	780	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/18/87	B	7.31	.....	220	.....	270	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.09	.....	85	.....	190	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.19	.....	650	.....	310	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.84	.....	380	.....	290	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/16/87	B	7.20	.....	1,070	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.95	.....	70	.....	....	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.72	.....	1,070	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.04	.....	619	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
05/28/87	B	8.60	.....	895	.....	180	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.82	.....	205	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.78	.....	2,110	.....	120	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.43	.....	1,610	.....	100	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/22/87	B	8.15	.....	1,400	.....	500	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.90	.....	390	.....	190	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	8.00	.....	845	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.15	.....	1,050	.....	430	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
07/16/87	B	.....	.....	....	.....	.....	.....	....	.....	....	.....	14.1	89	7.8	88	55	<0.02	<0.02	.....
	E	7.32	650	50	216	170	492	796	0.22	<0.1	0.17	52.8	47	2.0	38	36	0.10	0.10	.....
	F	7.43	4,000	1,700	1,160	70	3,576	21	11.6	<0.1	0.96	15.5	1,020	32	71	132	<0.02	<0.02	.....
	1	7.75	190	20	63	10	128	11	0.02	0.1	0.22	5.5	14	0.96	8.9	8.2	<0.02	<0.02	.....
	3	8.44	2,800	615	576	275	1,788	40	28.70	0.2	0.26	2.6	410	62	45	56	<0.02	0.03	.....
	4	8.08	760	65	266	23	484	21	0.59	<0.1	0.25	5.1	64	3.0	46	35	0.06	0.15	.....
	5	7.92	3,600	1,110	140	21	2,136	5	0.12	<0.1	0.11	3.3	720	22	41	84	<0.02	<0.02	.....
08/19/87	B	7.51	.....	275	.....	110	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.02	.....	140	.....	150	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.06	.....	1,790	.....	110	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	8.64	.....	1,270	.....	640	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/10/87	B	7.58	.....	270	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.98	.....	135	.....	40	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.98	.....	1,740	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	7.09	.....	1,220	.....	460	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/15/87	B	7.38	.....	215	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.04	.....	125	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	7.08	.....	1,870	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.44	.....	900	.....	420	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11/19/87	B	7.33	.....	190	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	6.95	.....	130	.....	20	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.12	.....	2,400	.....	40	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.20	.....	230	.....	20	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/16/87	B	7.53	.....	10	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.43	.....	130	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.37	.....	440	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.28	.....	10	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/13/88	B	7.32	.....	65	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.19	.....	55	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	8.13	.....	230	.....	130	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.08	.....	95	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (µmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
02/10/88	B	6.85	.....	50	.....	50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.75	.....	480	.....	260	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.00	.....	170	.....	80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.20	.....	90	.....	60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/16/88	B	7.80	.....	50	.....	40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.02	.....	70	.....	30	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.02	.....	280	.....	80	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.70	.....	180	.....	90	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/13/88	B	7.80	.....	80	.....	70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	E	7.60	.....	55	.....	150	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.31	.....	270	.....	150	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.05	.....	830	.....	210	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
05/11/88	E	7.32	.....	75	.....	110	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.20	.....	320	.....	55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.83	.....	800	.....	330	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/14/88	E	7.92	690	65	253	170	645	158	0.2	<0.1	0.28	1.7	61	1.7	47	37	<0.02	0.04	.....
	F	7.36	1,850	30	628	60	1,415	13	0.1	0.5	0.06	0.19	347	15	62	65	<0.02	0.06	.....
	LM	6.97	.....	2,270	3,776	3,200	30,000	9,720	42.3	0.8	.....	.....	.....	.....	.....	.....	.....	.....	.....
	1	7.79	180	25	64	<1	185	13	0.1	0.1	0.09	1.1	18	1.3	9.6	8.6	<0.02	0.03	.....
	3	8.56	2,600	710	582	410	2,170	56	4.3	0.5	0.73	1.4	518	88	42	73	<0.02	0.06	.....
	4	7.99	780	75	327	20	615	35	0.2	0.2	0.15	2.4	83	3.3	52	43	<0.02	0.06	.....
	5	8.27	8,900	3,520	294	50	2,010	31	0.4	<0.1	0.16	0.39	1,980	104	113	274	<0.02	0.06	.....
07/20/88	F	7.24	.....	330	.....	65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.58	.....	820	.....	320	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
07/28/88	CB	7.54	.....	960	.....	450	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	SB	8.01	.....	900	.....	425	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	DD	6.82	.....	670	.....	250	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
08/16/88	E	6.79	.....	65	.....	30	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.95	.....	380	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.32	.....	780	.....	390	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/07/88	E	7.16	.....	70	.....	40	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.05	.....	490	.....	90	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.21	.....	960	.....	380	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	IB	7.0	.....	820	.....	4,850	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	CB	7.22	.....	760	.....	230	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/19/88	E	6.97	.....	90	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.87	.....	400	.....	160	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	4	7.88	.....	65	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11/09/88	E	6.99	.....	55	.....	23	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.73	.....	190	.....	296	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.42	.....	190	.....	576	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/14/88	F	7.55	.....	530	.....	82	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	6.56	.....	350	.....	560	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
01/18/89	F	6.75	.....	475	.....	120	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.46	.....	350	.....	670	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/15/89	F	6.73	.....	460	.....	140													
	3	7.50	.....	420	.....	160	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/15/89	F	6.65	.....	440	.....	170	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.80	.....	520	.....	340	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/19/89	F	6.83	.....	295	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.98	.....	620	.....	320	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/21/89	F	7.17	.....	785	.....	90	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.18	.....	675	.....	330	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
07/19/89	3	8.45	.....	700	.....	390	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	LM	7.55	.....	830	.....	475	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (µmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2+ NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
07/28/89	3	6.76	.....	275	.....	40	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	M	8.08	.....	450	.....	178	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
08/22/89	F	.....	.....	.....	.....	.....	.....	...	.....	.....	.....	3.1	450	15	52	59	<0.02	0.05	.....
	1	.....	.....	.....	.....	.....	.....	...	.....	.....	.....	0.86	15	1.4	12	11	<0.02	0.07	.....
	3	.....	.....	.....	.....	.....	.....	...	.....	.....	.....	0.86	92	39	37	41	<0.02	0.10	.....
	4	.....	.....	.....	.....	.....	.....	...	.....	.....	.....	0.74	88	10	60	54	<0.02	0.14	.....
	5	.....	.....	.....	.....	.....	.....	...	.....	.....	.....	1.7	940	52	60	152	<0.02	0.11	.....
09/20/89	F	6.73	.....	340	.....	110	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.20	.....	610	.....	570	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/18/89	3	8.08	.....	280	.....	110	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11/21/89	F	7.08	.....	215	.....	44	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.89	.....	700	.....	280	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12/20/89	F	7.27	.....	225	.....	50	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.38	.....	210	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
02/14/90	F	6.80	.....	233	.....	94	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.04	.....	700	.....	470	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
03/28/90	F	7.23	.....	205	.....	55	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.77	.....	115	.....	140	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
04/18/90	F	7.04	.....	140	.....	72	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.10	.....	820	.....	414	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
05/23/90	F	7.39	.....	145	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.09	.....	220	.....	250	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
06/20/90	B	7.77	.....	145	.....	92	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	7.19	.....	180	.....	56	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.33	.....	630	.....	350	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

APPENDIX TABLE A.2.—*Continued*

Date	Sample Site	pH	Cond. (μmhos/cm)	Cl	Alk. as $CaCO_3$	COD	TDS	TSS	NH_4-N	NO_2 + NO_3-N	Total P	Fe	Na	K	Ca	Mg	Cu	Zn	Mn
				(mg/l)															
07/24/90	B	8.81	840	40	392	130	785	2,600	0.8	0.05	1.57	6,400	120	21	700	320	2.1	2.6	.....
	F	7.53	2,950	52	711	165	1,970	760	7.8	0.08	0.67	540	500	12	75	70	0.14	0.38	.....
	1	7.85	220	25	70	7	130	8	0.6	0.07	0.05	9.2	15	0.55	9.6	9.5	<0.02	<0.02	.....
	3	8.22	2,800	630	594	290	1,760	52	24.8	1.23	0.51	18	490	67	45	71	<0.02	0.04	.....
	4	7.92	1,450	125	451	46	495	32	8.0	0.17	0.12	21	110	16	62	53	<0.02	0.02	.....
	5	7.94	9,800	6,250	150	17	10,100	79	0.6	0.07	0.05	19	2,700	110	130	380	<0.02	0.02	.....
08/22/90	B	8.39	.....	105	.....	70	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	6.62	.....	290	.....	80	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	9.06	.....	615	.....	510	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
09/26/90	B	8.19	.....	100	.....	20	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	8.04	.....	330	.....	78	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	7.02	.....	400	.....	55	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10/24/90	B	7.64	.....	35	.....	60	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	F	8.38	.....	110	.....	188	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	3	8.11	.....	450	.....	156	.....	...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

NOTE: Refer to Appendix Table A.1 for designation and Figure 2 for locations of routine sampling stations.

APPENDIX TABLE A.3. PRIORITY POLLUTANT ANALYSES, KAPAA SANITARY LANDFILL SILTING BASIN, KAWAINUI, O'AHU, HAWAI'I, 25 APRIL 1988

Pollutant	Concentration
Metals	(mg/l)
Antimony	<1.0
Arsenic	0.02
Beryllium	<0.03
Cadmium	<0.005
Chromium	<0.05
Copper	<0.02
Lead	<0.1
Mercury	<0.001
Nickel	0.06
Selenium	<0.01
Silver	<0.02
Thallium	<0.5
Zinc	0.12
Purgeables	(µg/l)
Acrolein	<50
Acrylonitrile	<50
Benzene	<10
Bromomethane	<50
Bromodichloromethane	<10
Bromoform	<10
Carbon Tetrachloride	<10
Chlorobenzene	<10
Chloroethane	<50
2–Chloroethylvinyl Ether	<10
Chloroform	<10
Chloromethane	<50
Dibromochloromethane	<10
1,1–Dichloroethane	<10
1,2–Dichloroethane	<10
1,1–Dichloroethene	<10
Trans–1,2–Dichloroethene	<10
1,2–Dichloropropane	<10
Cis–1,3–Dichloropropene	<10
Trans–1,3–Dichloropropene	<10
Ethylbenzene	<10
Methylene Chloride	<10
1,1,2,2–Tetrachloroethane	<10
Tetrachloroethene	<10
1,1,1–Trichloroethane	<10
1,1,2–Trichloroethane	<10
Trichloroethene	<10
Toluene	<10
Vinyl Chloride	<10
Base/Neutrals	(µg/l)
Acenaphthene	<10
Acenaphthylene	<10
Anthracene	<10
Benzo(a)anthracene	<10
Benzo(b)fluoranthene	<10
Benzo(k)fluoranthene	<10
Base/Neutrals (continued)	(µg/l)
Benzo(a)pyrene	<10
Benzo(g,h,i)perylene	<20
Benzidine	<50
Bis(2–chloroethyl)ether	<10
Bis(2–chloroethoxy)methane	<10
Bis(2–ethylhexyl)phthalate	<10
Bis(2–chloroisopropyl)ether	<10
4–Bromophenyl Phenyl Ether	<10
Butyl Benzyl Phthalate	<10
2–Chloronaphthalene	<10
4–Chlorophenyl Phenyl Ether	<10
Chrysene	<10
Dibenzo(a,h)anthracene	<20
Di–n–Butyl Phthalate	<10
1,3–Dichlorobenzene	<10
1,4–Dichlorobenzene	<10
1,2–Dichlorobenzene	<10
3,3–Dichlorobenzidine	<50
Diethyl Phthalate	<10
Dimethyl Phthalate	<10
2,4–Dinitrotoluene	<10
2,6–Dinitrotoluene	<10
Dioctyl Phthalate	<10
1,2–diphenylhydrazine	<20
Fluoranthene	<10
Fluorene	<10
Hexachlorobenzene	<10
Hexachlorobutadiene	<10
Hexachloroethane	<10
Hexachlorocyclopentadiene	<10
Indeno(1,2,3–cd)pyrene	<20
Isophorone	<10
Naphthalene	<10
Nitrobenzene	<10
N–Nitrosodimethylamine	<50
N–Nitrosodi–n–propylamine	<20
N–Nitrosodiphenylamine	<20
Phenanthrene	<10
Pyrene	<10
1,2,4–Trichlorobenzene	<10
Acids	(µg/l)
4–Chloro–3–methylphenol	<10
2–Chlorophenol	<10
2,4–Dichlorophenol	<10
2,4–Dimethylphenol	<50
2–Methyl–4,6–dinitrophenol	<20
2–Nitrophenol	<20
4–Nitrophenol	<50
Pentachlorophenol	<50
Phenol	<50
2,4,6–Trichlorophenol	<10

SOURCE: R. Goo, Sanitary Chemist IV, City and County of Honolulu, 16 May 1988.
NOTE: Results are from duplicate and blank analyses.
NOTE: Analytical methods used were: for metals, EPA-600/4-79-020 (rev. March 1983), Methods for Chemical Analysis of Water and Wastes, Sec. 200 Metals; for organics, 40 CFR Part 136, method 624; for base/neutrals, 40 CFR Part 136, method 625; and for acids, 40 CFR Part 136, method 625.

APPENDIX TABLE B.1. ANNUAL RAINFALL AT U.S. WEATHER BUREAU STATION KOKOKAHI (STA. NO. 781.6), KAWAINUI, O'AHU, HAWAI'I, 1981–1990

Date	1981											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	.....	0.01	TR	0.06	2.07	0.04	0.05	0.01	.....	0.22	0.68	0.27
2	.....	.....	0.09	0.29	0.01	.....	0.20	0.01	0.05	0.03	0.42	0.01
3	0.15	.....	0.06	0.06	0.09	.....	0.01	0.15	0.18	0.06	0.17	0.02
4	0.43	.....	0.01	.....	.....	.....	0.01	0.45	0.01	0.02	0.02	0.01
5	0.02	0.63	0.10	0.08	0.03	0.21	.....	1.72	0.08	TR	0.08	.....
6	.....	0.03	0.07	0.01	0.03	0.27	.....	0.12	0.18	.....	0.01	0.01
7	.....	.....	0.73	0.18	3.82	TR	.....	0.02	.....	TR	0.11	0.08
8	0.31	0.39	0.03	TR	2.42	0.04	0.14	.....	.....	.....	0.02	0.05
9	0.25	0.05	0.01	0.24	0.11	0.02	0.02	0.02	0.08	.....	0.01	.....
10	0.01	.....	0.20	.....	0.02	TR	0.13	0.01	.....	.....	.....	0.02
11	.....	0.32	0.02	.....	.....	0.12	0.01	0.20	.....	.....	0.10	.....
12	0.05	0.12	0.01	.....	TR	0.06	0.01	0.22	0.05	0.10	0.12	TR
13	0.23	TR	.....	0.49	0.01	0.02	0.01	0.15	0.32	0.15	.....	0.01
14	.....	.....	.....	2.56	.....	0.02	0.35	0.10	0.01	0.03	0.02	0.07
15	.....	.....	.....	0.01	0.01	TR	0.58	0.02	.....	0.01	0.23	0.04
16	.....	.....	.....	0.03	0.02	0.01	0.13	0.01	0.10	0.01	0.25	TR
17	0.18	TR	.....	.....	0.03	0.05	0.10	.....	.....	0.02	1.70	.....
18	.....	.....	0.02	0.01	0.05	0.14	0.33	0.15	.....	.....	TR	.....
19	.....	.....	0.05	.....	0.09	.....	0.08	0.14	0.12	0.14	0.09	1.30
20	TR	0.04	.....	TR	0.18	0.03	0.02	0.11	0.25	.....	0.13	5.20
21	.....	0.16	.....	0.01	.....	0.01	0.43	0.01	0.03	.....	0.02	3.57
22	.....	0.06	.....	.....	0.04	0.04	TR	0.01	.....	0.02	.....	2.01
23	0.06	0.02	.....	TR	.....	.....	0.03	0.15	0.17	0.10	0.10	0.30
24	0.04	0.03	0.40	0.06	0.05	0.01	0.01	0.01	.....	0.13	0.17	0.20
25	0.01	0.01	0.13	.....	.....	0.05	0.35	.....	.....	TR	0.01	0.25
26	.....	TR	TR	0.03	0.01	.....	0.01	.....	.....	0.15	0.02	2.79
27	0.31	0.01	.....	.....	.....	0.17	.....	.....	.....	0.21	0.09	0.06
28	0.39	TR	0.07	0.47	0.03	0.12	0.07	0.06	0.05	0.78	0.06	0.05
29	0.05	.....	0.05	0.07	.....	.....	0.09	0.04	.....	0.91	0.02	0.02
30	0.12	.....	0.07	0.21	.....	TR	0.01	0.34	.....	0.16	0.40	0.01
31	.....	.....	0.17	.....	.....	.....	0.01	.....	.....	0.52	.....	.....
Total (monthly)	2.61	1.88	2.29	4.87	9.12	1.43	3.19	4.23	1.68	3.77	5.05	16.35
Total (yearly)	56.47											

APPENDIX TABLE B.1.—*Continued*

Date	1982											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.01	.....	0.40	0.58	TR	0.01	0.12	0.05	0.03	0.06	0.04	0.01
2	0.13	0.07	0.27	0.13	0	0.09	0.18	0.25	1.15	0.05	0.30	.....
3	0.99	0.03	0.03	1.63	0.02	0.01	0.10	0.01	0.01	.....	0.27	0.15
4	0.01	.....	0.11	0.10	.....	0.31	0.05	.....	TR	0.06	0.66	1.25
5	.....	0.08	TR	0.01	0.01	0.18	0.21	0.01	0.03	0.09	0.10	0.12
6	0.05	0.20	.....	.....	0.01	1.25	0.31	0.05	0.07	0.21	0.06	0.10
7	3.36	0.01	0.01	0.56	0.13	0.12	0.19	0.03	0.47	TR	0.28	0.47
8	0.01	0.04	0.02	0.26	0.16	TR	0.02	0.05	TR	0.03	.....	0.01
9	0.01	0.08	TR	0.99	TR	0.11	0.39	0.06	0.12	.....	TR	0.01
10	0.74	.....	0.28	TR	.....	2.37	0.02	0.03	0.21	.....	0.06	0.10
11	0.02	0.55	0.12	.....	0.03	1.12	.....	0.05	0.03	0.19	.....	0.01
12	0.03	1.42	1.02	0.01	0.06	.....	0.12	0.24	0.10	0.19	0.12	0.31
13	.....	TR	3.25	0.02	.....	0.04	0.02	0.02	.....	0.18	0.26	0.42
14	.....	0.01	0.01	0.20	.....	0.05	0.10	0.06	0.05	0.01	TR	0.11
15	0.01	.....	1.83	0.13	TR	.....	0.02	0.15	TR	.....	TR	TR
16	0.17	TR	0.01	0.10	.....	0.57	0.09	0.24	.....	0.04	0.03	0.09
17	0.30	.....	TR	0.01	.....	0.94	0.35	2.63	.....	0.02	0.03	0.04
18	0.12	0.01	1.06	0.02	0.72	2.11	0.12	0.13	0.08	0.08	TR	0.24
19	0.01	TR	0.01	0.03	0.01	0.05	0.01	0.03	.....	0.01	0.01	0.01
20	3.60	0.19	0.06	0.06	.....	0.09	0.02	0.02	0.01	.....	0.18	TR
21	3.84	0.32	0.03	0.16	0.04	0.05	0.03	0.17	.....	.....	0.01	0.11
22	3.46	0.02	TR	0.42	0.05	.....	0.07	0.08	.....	0.05	0.03	0.42
23	0.01	.....	0.52	0.05	0.01	0.06	1.12	0.27	0.05	0.02	0.03	0.51
24	0.18	1.33	0.05	0.13	.....	.....	4.75	0.15	0.01	.....	1.24	1.56
25	0.79	0.07	.....	0.02	0.20	0.11	0.02	0.04	TR	.....	0.02	0.23
26	0.19	0.38	.....	0.07	0.07	0.29	0.03	1.05	0.44	0.01	0.01	0.74
27	0.05	0.22	0.21	TR	0.01	0.02	0.07	0.04	0.01	2.31	0.05	0.89
28	0.01	0.32	0.24	0.20	0.02	0.23	0.24	TR	0.01	2.70	0.01	0.20
29	0.12	.....	0.03	0.02	.....	0.11	0.07	.....	.....	2.31	0.06	1.56
30	0.10	.....	0.36	0.05	0.16	0.14	0.17	.....	0.02	1.54	0.05	0.35
31	.....	.....	1.35	.....	0.06	.....	TR	0.01	.....	0.22	.....	0.07
Total (monthly)	18.32	5.35	11.28	5.96	1.77	10.43	9.01	5.93	2.90	10.38	3.91	10.09
Total (yearly)	95.33											

APPENDIX TABLE B.1.—*Continued*

Date	1983											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.15	0.01	TR	.....	.....	0.17	.....	.....	.....	0.24	0.16	0.05
2	0.01	.....	0.01	.....	0.09	0.12	.....	0.01	0.01	TR	0.04	TR
3	0.02	0.07	.....	TR	.....	0.07	0.03	0.89	0.20	0.02	0.10	TR
4	0.08	TR	.....	1.47	0.03	.....	0.09	0.26	0.18	0.16	0.06	.....
5	0.01	0.05	.....	0.01	0.27	.....	0.09	0.08	0.08	0.56	0.09	TR
6	0.02	0.03	.....	1.21	0.19	0.05	0.16	0.05	0.15	0.15	0.07	.....
7	0.01	.....	.....	TR	0.03	.....	0.20	0.06	0.36	.....	.....	0.01
8	.....	.....	0.07	TR	0.08	0.02	0.16	0.01	0.44	0.03	0.02	0.10
9	.....	.....	TR	.....	.....	0.07	0.05	.....	0.16	.....	TR	0.15
10	TR	.....	.....	0.02	.....	0.07	0.01	.....	.....	.....	0.03	0.44
11	0.81	.....	0.05	.....	0.14	.....	0.22	0.05	0.10	.....	0.02	0.02
12	1.07	.....	0.02	0.01	0.04	0.01	0.02	0.01	0.01	0.25	0.28	0.05
13	0.03	0.01	0.17	TR	0.17	.....	0.15	.....	TR	0.08	0.11	0.36
14	0.05	.....	.....	0.01	TR	TR	0.23	.....	.....	0.04	TR	0.25
15	0.03	.....	0.18	.....	TR	0.05	0.08	0.24	0.02	0.02	.....	0.11
16	TR	.....	TR	.....	.....	0.15	0.07	0.04	.....	0.02	0.07	0.01
17	TR	0.09	.....	0.21	.....	0.03	0.05	0.10	0.27	0.16	0.03	.....
18	.....	TR	0.03	0.04	0.15	0.12	0.29	0.05	0.02	0.08	.....	.....
19	.....	0.01	.....	0.10	0.12	0.01	0.30	.....	0.42	0.28	TR	.....
20	0.04	.....	.....	0.02	.....	0.20	0.03	.....	.....	0.48	0.28	.....
21	.....	.....	.....	0.09	1.02	0.08	.....	TR	0.03	0.08	0.14	.....
22	.....	0.15	.....	0.02	0.06	0.09	0.02	0.28	0.20	0.01	0.01	.....
23	0.24	0.09	0.12	0.11	.....	0.05	0.22	0.10	TR	0.03	0.02	.....
24	0.15	0.01	TR	0.03	0.15	0.11	0.22	0.02	0.04	0.01	0.02	.....
25	0.10	TR	0.02	0.02	.....	0.07	0.18	0.07	0.04	0.10	0.01	0.50
26	.....	0.10	.....	0.12	0.02	0.30	0.02	.....	0.15	0.06	0.09	0.67
27	.....	.....	.....	0.07	0.11	0.01	.....	0.01	0.01	0.10	0.01	.....
28	0.01	0.06	.....	0.01	0.17	0.01	TR	0.04	0.06	0.04	.....	0.01
29	.....	.....	TR	TR	0.05	TR	0.11	.....	0.55	0.04	0.09	0.26
30	0.12	.....	.....	.....	0.03	.....	.....	0.05	0.04	0.27	0.03	.....
31	0.08	.....	.....	.....	TR	.....	0.04	0.02	.....	0.03	.....	.....
Total (monthly)	3.03	0.68	0.67	3.57	2.92	1.86	3.04	2.44	3.54	3.34	1.78	2.99
Total (yearly)	29.36											

APPENDIX TABLE B.1.—*Continued*

Date	1984											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	.....	0.49	0.12	0.23	0.01	0.10	.....	0.14	0.08	0.03	0.05	0.08
2	TR	0.83	0.93	0.14	0.01	TR	0.01	0.01	0.11	0.08	0.01	0.01
3	.....	0.01	0.03	0.07	0.02	TR	0.12	0.01	.....	0.04	0.03	0.10
4	TR	TR	0.15	TR	0.03	.....	0.17	0.04	0.17	.....	0.13	0.12
5	0.47	.....	0.05	0.02	0.04	.....	.....	0.06	0.11	TR	0.10	0.01
6	0.46	0.01	.....	0.06	0.04	.....	.....	.....	TR	TR	0.18	0.04
7	TR	0.09	.....	0.03	.....	0.13	.....	.....	.....	0.01	0.07	0.55
8	0.10	0.34	.....	0.07	0.07	0.01	.....	.....	0.09	0.30	0.07	0.33
9	0.02	0.05	.....	0.10	.....	0.05	0.01	.....	TR	.....	0.09	0.08
10	.....	0.04	.....	0.08	.....	0.32	0.06	TR	0.09	.....	TR	0.01
11	0.02	0.04	0.01	0.19	.....	0.04	.....	0.05	TR	0.16	0.07	.....
12	0.01	0.01	.....	.....	0.22	0.04	.....	.....	.....	0.01	0.06	0.02
13	0.28	TR	TR	0.11	.....	TR	0.04	0.04	.....	0.01	0.04	.....
14	1.25	0.34	.....	0.08	TR	.....	TR	.....	0.14	TR	TR	.....
15	0.02	0.21	TR	0.02	.....	0.02	.....	.....	0.25	.....	0.09	.....
16	0.06	0.10	.....	0.01	0.06	0.18	TR	.....	0.06	0.03	.....	.....
17	0.17	0.02	.....	0.03	0.06	0.07	0.11	0.02	0.11	.....	.....	0.14
18	0.01	0.05	.....	0.02	0.11	0.02	.....	0.05	0.08	.....	0.07	0.01
19	0.06	0.22	TR	0.02	0.01	.....	0.04	0.01	0.05	.....	.....	0.01
20	0.31	0.06	.....	4.52	0.05	.....	0.02	.....	TR	.....	.....	.....
21	TR	0.06	0.01	0.10	0.04	.....	0.30	.....	.....	.....	0.01	.....
22	.....	.....	.....	TR	0.17	0.01	.....	.....	.....	.....	.....	TR
23	0.04	TR	TR	TR	0.10	0.01	.....	0.13	.....	0.12	.....	0.07
24	0.20	0.02	.....	.....	0.01	0.03	.....	0.01	.....	.....	.....	0.65
25	.....	.....	.....	0.09	0.01	.....	.....	.....	.....	.....	0.14	3.93
26	0.09	0.14	.....	0.58	0.01	0.03	.....	.....	0.03	0.01	2.19	0.49
27	0.03	0.01	0.13	0.09	.....	.....	.....	.....	0.04	0.30	3.33	0.09
28	0.02	0.01	0.43	TR	0.02	.....	.....	.....	0.17	.....	0.40	0.06
29	TR	0.02	0.01	.....	0.05	0.08	0.01	.....	0.01	2.06	0.01	TR
30	.....	.....	0.12	TR	0.10	TR	.....	.....	.....	1.04	0.02	0.03
31	0.06	.....	0.02	.....	0.03	.....	.....	.....	.....	0.15	.....	0
Total (monthly)	3.68	3.17	2.01	6.66	1.27	1.14	0.89	0.57	1.59	4.35	7.16	6.83
Total (yearly)	39.32											

APPENDIX TABLE B.1.—*Continued*

Date	1985											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	.....	0.02	.....	0.02	0.10	.....	TR	0.19	.....	0.59	0.35	0.06
2	.....	.....	.....	0.10	0.19	0.07	.....	0.17	.....	0.07	.....	TR
3	0.16	.....	0.01	0.01	TR	TR	.....	.....	0.14	0.06	0.01	TR
4	0.78	1.26	0.20	.....	0.02	0.02	.....	0.20	0.13	0.01	TR	.....
5	0.01	0.85	0.09	0.03	.....	0.04	0.01	0.05	.....	.....	0.48	.....
6	.....	0.02	0.21	TR	0.81	.....	.....	0.01	0.05	0.62	0.02	.....
7	.....	0.02	0.03	TR	0.45	.....	0.02	0.01	TR	TR	.....	.....
8	TR	0.19	0.01	0.05	0.02	.....	0.02	0.02	0.09	TR	0.07	TR
9	.....	0.01	0.07	.....	0.08	.....	.....	0.05	TR	.....	0.05	TR
10	.....	0.07	0.08	.....	0.01	TR	.....	.....	0.07	TR	0.68	0.01
11	0.75	0.02	0.16	0.23	0.03	TR	TR	0.03	0.44	0.12	0.26	0.15
12	0.09	0.47	TR	TR	.....	.....	.....	0.01	0.23	0.21	0.68	TR
13	.....	1.14	0.01	.....	0.18	.....	0.02	0.14	0.05	0.12	1.58	.....
14	1.05	6.02	0.10	.....	0.05	TR	.....	.....	0.02	.....	TR	.....
15	0.05	2.19	TR	0.04	0.12	.....	.....	0.23	.....	0.04	0.23	.....
16	0.01	0.02	0.13	TR	0.35	0.02	0.22	0.47	0.01	0.22	0.17	0.20
17	.....	0.02	0.04	0.83	0.12	TR	0.16	0.02	.....	0.82	.....	.....
18	.....	0.02	.....	TR	0.42	0.01	0.24	0.07	0.02	0.17	0.03	.....
19	.....	0.07	.....	0.04	0.01	.....	.....	TR	0.04	.....	1.06	TR
20	.....	.....	0.07	0.10	0.06	0.03	.....	0.10	0.05	4.60	.....	TR
21	.....	0.05	TR	0.02	0.02	0.13	TR	TR	0.43	0.27	.....	.....
22	0.26	......	0.05	0.38	0.18	.....	0.02	0.02	0.21	TR	.....	.....
23	0.25	0.20	0.38	0.23	0.25	0.04	0.03	0.01	0.25	0.07	0.15	0.12
24	0.13	0.02	.....	0.02	0.12	0.04	0.29	.....	0.51	0.07	0.60	0.31
25	0.06	0.11	0.01	0.01	0.11	0.08	0.38	0.01	0.05	0.12	0.03	.....
26	0.44	0.97	TR	.....	TR	......	.....	0.06	0.03	.....	0.20	.....
27	0.01	0.32	.....	.....	0.02	0.01	0.03	0.04	0.99	TR	0.51	0.01
28	.....	0.09	0.04	0.06	.....	0.05	0.04	0.03	0.27	TR	1.22	......
29	0.01	.....	0.05	.....	.....	TR	.....	0.07	0.05	0.05	TR	TR
30	0.88	.....	0.03	.....	.....	0.03	0.02	0.10	0.04	TR	0.07	TR
31	0.03	.....	.....	.....	TR	.....	0.48	.....	.....	.....	.....	.....
Total (monthly)	4.97	14.17	1.77	2.17	3.72	0.57	1.98	2.11	4.17	8.23	8.45	0.86
Total (yearly)	53.17											

APPENDIX TABLE B.1.—*Continued*

Date	1986											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	0.02	0.56	TR	TR	0.17	TR	0.03	0.04	TR	0.44	.....	0.08
2	0.03	TR	0.10	0.04	.....	0.01	0.02	.....	0.01	0.54	0.05	.....
3	0.06	0.02	0.01	0.11	0.03	0.06	TR	0.29	0.01	0.02	0.02	.....
4	.....	0.12	0.03	0.80	0.12	TR	0.30	0.37	0.12	.....	0.03	.....
5	.....	0.50	.....	0.65	0.07	.....	TR	0.09	0.09	TR	0.02	.....
6	0.01	TR	.....	0.11	0.04	TR	0.17	.....	0.03	0.04	.....	0.94
7	0.02	0.11	.....	0.04	0.05	0.25	0.20	0.03	0.33	.....	0.18	0.09
8	.....	0.03	TR	0.19	0.02	TR	0.04	.....	TR	0.06	0.79	.....
9	0.03	TR	.....	0.22	TR	.....	0.04	0.06	.....	.....	0.33	.....
10	.....	0.14	.....	0.12	0.23	0.15	0.04	0.30	.....	.....	0.15	TR
11	.....	0.02	TR	0.12	TR	0.51	0.45	0.03	0.05	.....	7.98	TR
12	0.03	0.10	.....	0.01	.....	0.01	0.05	0.04	0.16	0.15	3.44	0.41
13	.....	.....	0.03	TR	TR	.....	0.10	0.09	0.03	0.63	0.15	0.02
14	.....	.....	0.10	TR	.....	0.06	0.53	0.24	0.18	0.05	0.04	0.01
15	.....	1.11	0.13	.....	TR	TR	0.04	0.23	.....	0.02	0.02	0.03
16	.....	TR	0.19	0.14	.....	0.03	TR	0.04	.....	0.10	0.04	0.04
17	0.07	.....	0.20	.....	.....	0.15	0.37	0.13	.....	0.12	0.13	0.01
18	0.10	.....	0.01	.....	0.13	0.09	0.32	0.23	0.04	0.04	0.01	0.01
19	0.24	.....	0.13	.....	.....	0.01	0.04	0.18	.....	0.07	0.09	TR
20	0.04	.....	1.19	0.07	.....	0.02	0.01	0.01	0.07	0.45	0.04	0.02
21	.....	0.08	0.39	.....	0.17	0.22	TR	0.35	0.21	TR	0.02	0.44
22	0.06	0.14	0.07	0.06	.....	0.03	TR	0.06	1.24	.....	0.03	0.32
23	TR	0.26	0.08	0.08	.....	0.15	TR	0.04	0.07	.....	TR	TR
24	.....	.....	0.58	.....	.....	0.07	0.02	0.16	0.06	TR	0.48	.....
25	0.23	.....	0.53	0.03	0.59	0.12	1.53	TR	0.05	0.59	0.18	.....
26	0.30	.....	0.02	.....	0.07	0.01	0.24	.....	TR	0.13	TR	TR
27	TR	.....	0.06	.....	0.13	TR	0.08	.....	.....	0.10	0.08	.....
28	.....	.....	TR	0.01	0.12	TR	.....	.....	5.40	0.13	0.26	0.11
29	.....	.....	0.01	0.01	0.05	0.01	0.08	0.64	0.02	0.04	.....	0.81
30	0.01	.....	0.07	0.12	0.20	0.22	.....	0.03	0.25	.....	0.05	0.01
31	.....	.....	TR	.....	.....	.....	0.02	0.15	.....	.....	.....	0.35
Total (monthly)	1.25	3.19	3.93	2.93	2.19	2.18	4.72	3.83	8.42	3.72	14.61	3.70
Total (yearly)	54.67											

APPENDIX TABLE B.1.—*Continued*

Date	1987											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	TR	0.01	.....	0.22	0.04	......	TR	0.02	.....	0.48	0.12	.....
2	0.08	.....	.....	.....	0.01	1.42	0.01	0.20	0.03	0.08	0.32	.....
3	0.02	.....	0.04	0.01	0.16	0.01	0.30	0.03	0.67	0.04	0.92	.....
4	.....	.....	.....	0.01	0.16	0.29	0.28	0.03	TR	0.12	0.09	0.03
5	0.03	.....	.....	0.07	0.23	0.18	0.03	0.06	0.04	TR	0.02	0.10
6	0.02	.....	.....	.....	0.16	0.09	0.39	0.04	.....	0.04	0.12	0.06
7	.....	.....	TR	.....	0.42	0.04	0.14	.....	.....	0.07	1.26	.....
8	.....	.....	TR	0.38	TR	TR	0.01	0.02	.....	0.02	0.18	0.22
9	.....	.....	.....	0.04	.....	0.08	0.16	0.07	.....	.....	TR	0.34
10	0.23	.....	0.03	.....	0.02	.....	0.10	0.04	0.05	0.03	0.03	0.03
11	.....	.....	.....	0.05	0.03	0.02	0.17	TR	0.24	0.06	0.01	TR
12	.....	0.18	.....	0.89	TR	0.30	0.14	0.02	0.29	0.59	0.08	4.68
13	0.02	1.07	.....	0.05	0.62	0.06	0.16	.....	0.02	TR	.....	2.99
14	0.20	0.73	.....	0.06	0.04	0.14	0.14	.....	TR	.....	.....	0.73
15	0.05	1.33	0.02	0.14	0.01	0.16	0.15	0.01	.....	TR	0.95	0.72
16	0.05	0.87	.....	0.01	0.01	0.08	TR	0.20	0.02	0.03	0.01	0.08
17	0.30	0.02	0.05	0.06	0.07	0.14	0.01	0.18	.....	0.02	0.57	0.30
18	0.15	0.02	0.02	0.23	0.16	0.03	0.01	0.07	TR	.....	0.33	1.66
19	0.04	.....	0.11	0.12	0.02	.....	0.01	.....	TR	0.06	0.10	1.10
20	.....	0.11	.....	0.93	.....	0.05	TR	.....	0.01	.....	0.02	3.81
21	0.01	0.05	0.01	0.14	TR	0.48	0.23	0.07	.....	.....	0.56	0.08
22	0.01	0.03	.....	0.63	0.93	0.03	0.15	0.04	0.57	0.05	0.22	0.02
23	0.03	.....	.....	0.12	0.05	0.08	0.22	.....	0.79	0.07	0.03	TR
24	0.01	0.01	0.03	0.27	0.30	0.04	.....	.....	0.36	.....	0.09	0.35
25	0.42	0.88	0.26	TR	.....	TR	0.01	.....	0.37	0.05	.....	0.01
26	0.24	TR	0.01	1.04	0.13	0.01	0.26	0.13	0.01	0.05	0.09	0.07
27	0.01	.....	0.69	0.57	0.15	0.09	.....	0.11	0.28	TR	0.02	0.16
28	0.02	TR	TR	0.05	0.07	TR	0.01	0.03	TR	.....	.....	TR
29	.....	.....	.....	0.02	.....	0.02	0.04	0.03	0.01	0.04	0.04	.....
30	.....	.....	0.01	0.03	0.07	0.26	0.01	0.03	0.72	0.02	0.33	0.05
31	0.22	.....	0.02	.....	0.03	.....	0.01	0.03	.....	TR	.....	2.27
Total (monthly)	2.16	5.31	1.30	6.14	3.89	4.10	3.15	1.46	4.48	1.92	6.51	19.86
Total (yearly)	60.28											

APPENDIX TABLE B.1.—*Continued*

Date	1988											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1	9.83	0.40	.....	0.18	TR	0.17	TR	TR	.....	.....	0.01	0.12
2	1.13	.....	TR	0.03	0.05	TR	.....	0.01	0.01	.....	0.04	0.23
3	0.30	.....	0.03	0.20	0.07	0.08	0.03	1.08	.....	.....	.....	TR
4	0.10	0.96	0.02	0.62	0.27	0.01	TR	0.01	.....	.....	1.27	.....
5	TR	.....	0.01	0.17	0.87	.....	TR	0.02	0.03	.....	1.05	.....
6	0.14	0.12	0.06	.....	0.01	0.07	.....	0.01	0.08	0.01	1.08	4.51
7	TR	0.05	0.03	0.02	0.81	0.01	0.06	0.11	.....	0.17	0.04	0.57
8	.....	0.01	.....	0.01	0.04	TR	0.20	0.13	.....	0.09	.....	0.02
9	.....	.....	TR	0.01	TR	0.06	0.27	.....	0.05	.....	0.02	.....
10	0.73	TR	.....	0.01	0.39	.....	0.21	.....	0.72	.....	0.01	.....
11	0.13	TR	.....	0.02	0.11	.....	0.04	0.35	0.67	TR	0.03	TR
12	TR	0.02	TR	0.01	0.26	0.07	0.17	0.29	0.37	0.01	.....	0.51
13	0.01	0.02	.....	0.01	0.13	.....	0.03	0.01	0.37	0.40	0.40	TR
14	.....	TR	0.44	0.04	0.40	0.01	0.18	0.16	.....	0.17	0.11	0.01
15	TR	TR	0.37	TR	0.50	TR	.....	0.04	0.05	TR	.....	0.01
16	0.16	0.03	0.80	0.03	0.11	.....	.....	0.02	.....	0.01	0.01	0.60
17	0.39	TR	1.28	0.04	.....	.....	.....	0.03	.....	0.92	0.20	1.86
18	1.49	.....	0.29	.....	.....	.....	0.18	0.36	0.02	TR	0.04	0.32
19	0.03	.....	0.30	0.02	.....	.....	.....	0.07	0.03	.....	0.11	0.01
20	TR	.....	0.02	0.01	0.02	TR	TR	0.06	.....	.....	0.02	0.01
21	.....	.....	TR	TR	TR	0.02	0.02	0.02	.....	1.06	0.19	TR
22	0.13	0.09	0.02	0.03	0.05	0.02	.....	0.06	0.30	0.26	TR	.....
23	TR	0.15	0.04	.....	TR	0.03	0.02	TR	0.40	0.29	0.10	0.22
24	0.05	0.53	0.07	.....	TR	0.24	TR	0.08	0.07	0.50	0.27	0.04
25	0.05	0.39	1.13	0.56	0.06	TR	0.14	0.07	0.01	0.21	0.18	TR
26	0.59	0.03	0.02	0.23	0.01	.....	0.18	TR	0.06	TR	1.11	0.06
27	0.22	TR	.....	TR	.....	0.24	0.03	0.12	0.93	0.10	0.05	0.02
28	1.18	.....	.....	0.35	.....	0.01	.....	.....	1.29	TR	.....	.....
29	1.74	.....	.....	0.03	0.02	.....	.....	TR	0.30	0.02	0.04	0.29
30	0.48	.....	0.08	0.01	0.13	TR	0.06	0.09	.....	0.06	0.03	0.13
31	TR	.....	0.30	.....	0.07	.....	0.02	.....	.....	0.03	.....	0.02
Total (monthly)	18.88	2.80	5.31	2.64	4.38	1.04	1.84	3.20	5.76	4.31	6.41	9.56
Total (yearly)	66.13											

APPENDIX TABLE B.1.—*Continued*

Date	1989											
	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
Total (monthly)	5.13	9.74	7.55	17.75	1.84	3.80	5.60	3.81	1.72	10.48	2.27	4.80
Total (yearly)						74.49						

APPENDIX TABLE B.1.—*Continued*

Date	1990											
	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	.....	.....
2	0.30	0.10	0.91	0.02	0.10	0.02	0.04	0.06	0.01	0.04	0.32	.....
3	0.02	0.32	0.02	0.09	0.35	.....	0.01	.....	.....	0.01	0.01	.....
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	.....	0.71
21	0.10	0.01	0.07	0.01	0.10	0.04	TR	0.04	0.31	.....	.....	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	.....	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	.....	0.02
30	0.01	.....	0.05	.....	0.03	0.04	0.02	0.01	0.24	0.44	.....	.....
31	0.02	.....	0.02	.....	.....	.....	0.02	.....	.....	0.14	.....	.....
Total (monthly)	9.35	6.58	6.72	1.32	3.02	1.33	2.56	1.69	3.79	2.58	(10.78)	(9.38)
Total (yearly)	$\geq$ 59.10*											

NOTE: Records maintained at the Division of Water Resource Management, Department of Land and Natural Resources, Honolulu, HI 96813.

*Missing data for November and December.