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WATER QUALITY AND BIOLOGICAL STUDIES IN KAWAINUI STREAM RELATIVE TO THE KAILUA GATEWAY PROJECT DEVELOPMENT

Prepared By:

AECOS Inc.
970 Kalaheo Ave. Suite C-311
Kailua, Hawaii 96734

Prepared For:

Helber, Hastert & Fee
733 Bishop St.
Honolulu, Hawaii 96813

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INTRODUCTION

PROJECT DESCRIPTION

Kaneohe Ranch, Ltd. proposes to develop the Kailua Gateway Project near the entrance to Kailua town at the intersection of Kailua Road and Hamakua Drive. The development will be on 89 acres southeast of Kailua Road running parallel to Hamakua Drive (Figure 1). The project will comprise a retirement community of 300 individual living units, 20 personal care units, and a 60 bed skilled nursing facility. A community center and commercial area expansion at Kailua road are also proposed.

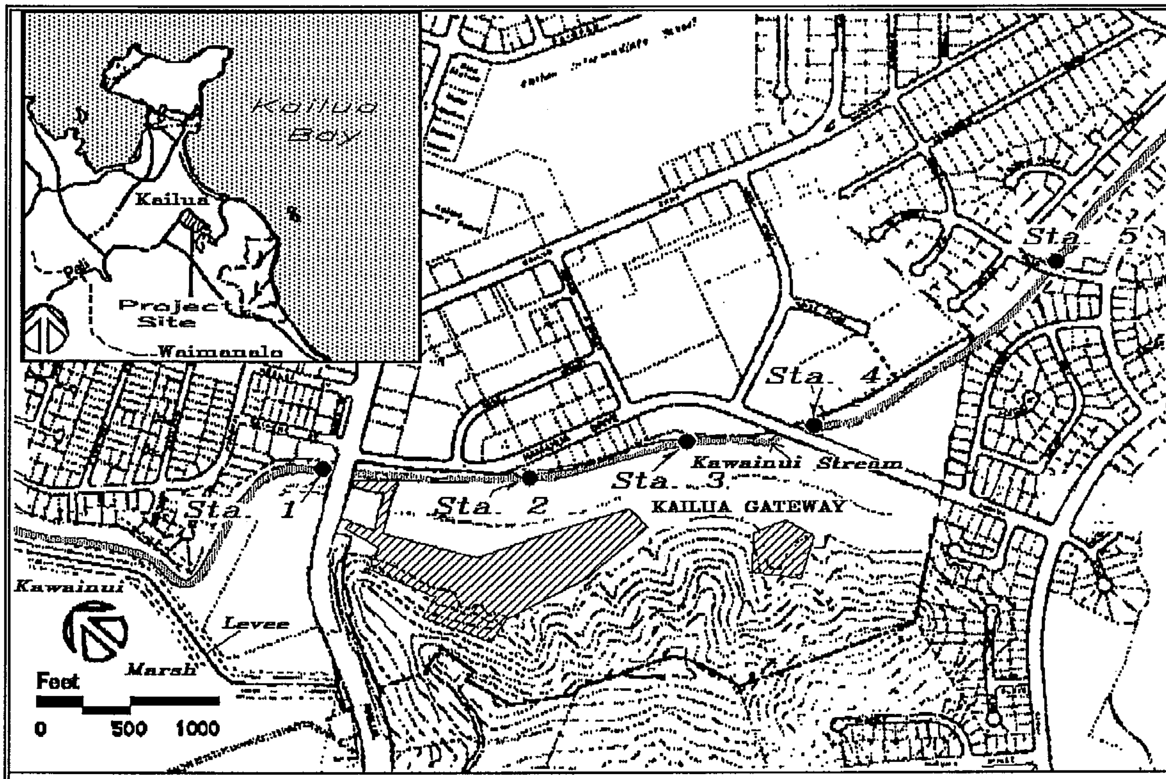

Figure 1. Project Location of Kailua Gateway and water quality sample stations.

Approximately 23 acres of the project area is designated wetlands and will not be developed, but will be transferred to a conservation group (Ducks Unlimited). The wetland is formed by drainage from Kawainui Stream, which forms the northeast border of the project. Because Kawainui Stream will be subject to impact from construction and development of the project, studies were undertaken to determine baseline conditions for the stream which could be used to assess impacts of the evaluate any long term changes in environmental conditions that might occur. This report describes the past and present aquatic environment of Kawainui Stream and evaluates the potential impacts of the development of the Kailua Gateway project on Kawainui Stream.

HISTORICAL BACKGROUND OF KAWAINUI STREAM

Kawainui Stream (now sometimes referred to as Kaelepulu Stream) consists of two main segments (Figure 2). The first is a man-made canal which runs approximately 6500 feet along the northeastern side of Kawainui Marsh, from the stream's present blind end close by the Oneawa Canal to the Kailua Road bridge. The second segment more or less follows the stream's original natural water course for about 6700 feet through a marshy area next to and beyond Hamakua Drive and joins Kaelepulu Stream, which drains Enchanted Lakes, the remaining vestige of Kaelepulu Fishpond. The upper segment of Kawainui Stream provides drainage through four canals from the Coconut Grove area, and a total of thirteen major and minor discharge points empty into the stream between its head and Kailua Road (M & E Pacific, 1989). Water from Kawainui Stream and Enchanted Lakes eventually reaches the ocean through the Kaelepulu Stream outlet at Kailua Beach Park. However, the mouth of this channel is often blocked by accumulated beach sand which limits the capacity of the system to exchange water with the ocean.

Kawainui Stream was originally the primary drainage for Kawainui Marsh, which is the largest remaining wetland in the State of Hawaii. The marsh has been shown by geological studies to have been an open lagoon embayment similar to present day Kaneohe Bay (Kraft, 1980; cited in Kelly and Nakamura, 1981 and Drigot, 1982). By the time of Hawaiian occupation 1600 to 1300 years ago an accretion barrier had formed in the present vicinity of Coconut Grove. This barrier restricted flow into the lagoon to a channel in the present location of Kawainui Stream near the present Kailua Road Bridge and possibly to an outlet north of the barrier near the present Oneawa Canal. At that time water exchanged freely between Kawainui lagoon and the ocean. The accretion of barriers along the fronts of both Kawainui and Kaelepulu lagoons continued and was possibly augmented by the Hawaiians to isolate these areas from the ocean for the purpose of confining and growing fish.

By the time of European arrivals in Hawaii both Kawainui and Kaelupulu lagoons were enclosed freshwater systems utilized by Hawaiians as the largest fishponds and taro growing areas in the Hawaiian Islands (Summers, 1964). The two ponds, totaling approximately 650 acres, were connected by a mile long watercourse in the present location of Kawainui stream which provided the principal outlet from Kawainui Fishpond and the marsh to the sea. According to Kraft (1980) there was still access to the Kawainui Fishpond by boat. Approximately 250 acres along the mauka side of Kawainui Fishpond

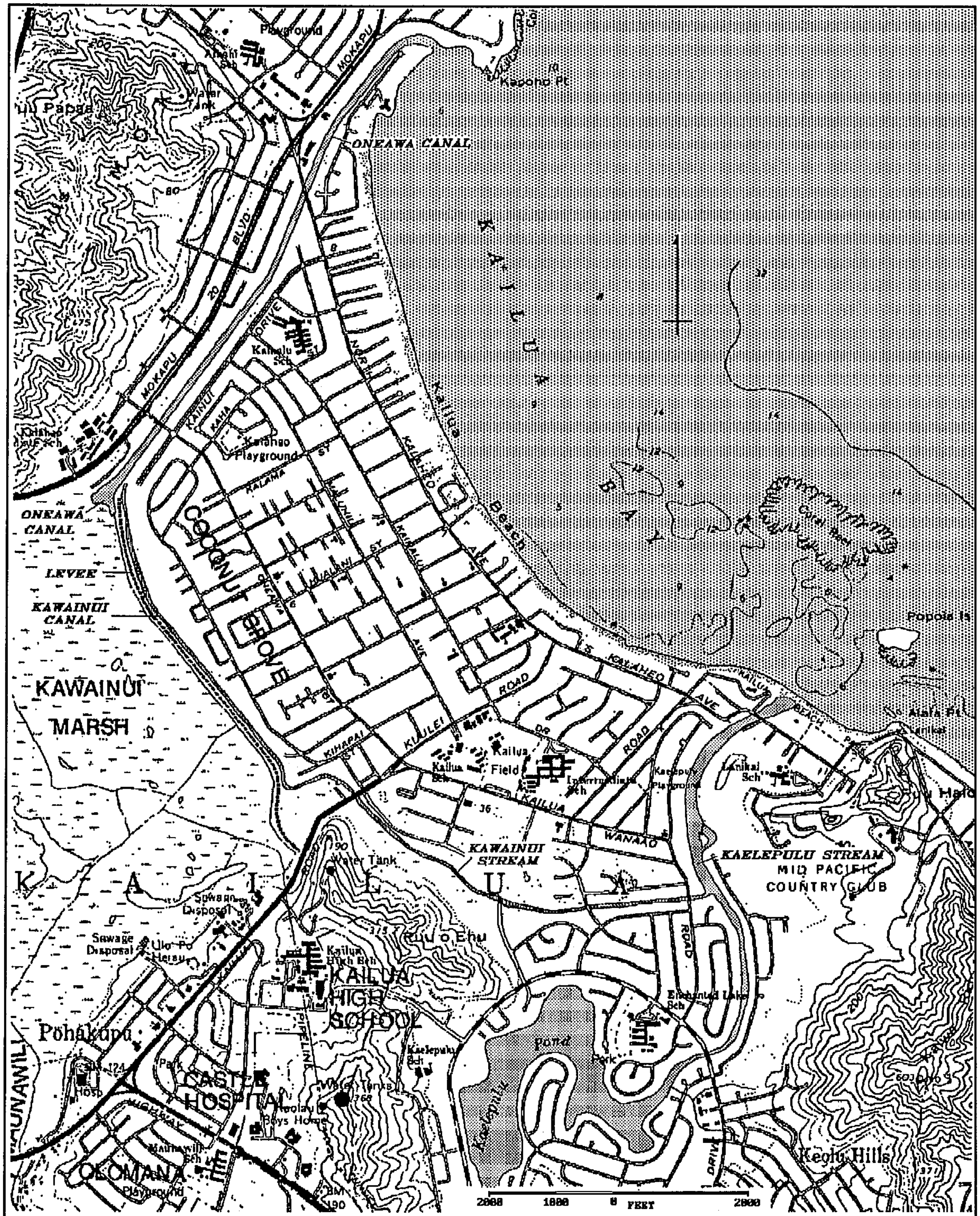

Figure 2. Map showing relationships of stream systems in Kailua, Oahu. Note that Kawainui Marsh drains to the northwest into Oneawa Canal. Kawainui Stream drains urban lands northeast of the levee (i.e., Coconut Grove), flows past the project site (north of Puu o Ehu), and enters Kaelepulu Stream.

and additional areas between the fishpond and Kawainui Stream were utilized for taro growing by controlling and damming the streams into a network of irrigation ditches. The richness and productivity of this water based agriculture/aquaculture system made Kailua a major population center and the capital of Oahu prior to European influence (Drigot, 1982).

Following European contact the Kailua Hawaiian population fell dramatically with the introduction of disease, cultural fragmentation, and migration to Honolulu when it became Hawaii's capital. By the time of the first census in 1831-32 the population of Kailua was only 760 persons, and the second census in 1835-36 showed a population of 762 (Kelly and Nakamura, 1981). The resulting lack of labor to maintain the Kawainui and Kaelepulu fishponds and clean them of unwanted plant life hastened their decline and natural evolution into marshlands. The decline in demand for taro by the Hawaiian population and increased demand for rice by Chinese and Japanese immigrants prompted a shift to rice production in the former taro pond area around Kawainui from 1850 to 1900. Likewise, rising demand for and production of sugar cane promoted further changes in the water systems affecting Kawainui Marsh and Kawainui Stream. In 1878 the Waimanalo Sugar Plantation began diverting about two million gallons of water per day to Waimanalo Valley which had formerly flowed into the marsh and out of the stream. This water diversion continues today to Waimanalo farmers even though sugar production in the area has long ceased. Further water diversion was implemented in the 1920's which effectively drained the last vestiges of Kawainui fishpond, and a vertical pump installed in 1956 and operated until 1965 dropped the water table in the marsh about four feet, increasing the grassland available for grazing (Kelly and Nakamura, 1981; Drigot, 1982).

While this transition from a predominantly freshwater to a grassland environment in the marsh was occurring, changes in land use and management of the watershed began to have an even more profound impact on the water quality in Kawainui Stream. With increasing urbanization of Honolulu, the desirability of the Kailua climate and recreational opportunities made this windward area increasingly popular as a site for weekend vacation homes. After Honolulu became more accessible with completion of the Pali tunnel and highway in 1957, the permanent population of Kailua soared from 7,740 in 1950 to 25,622 in 1960 and 33,783 in 1970. One of the earliest areas for home construction was "Coconut Grove", along the mauka part of the sand berm that had formed to isolate Kawainui Pond from the ocean. Subdivision of Coconut Grove into house lots began in 1924 on 320 acres of former sand dunes which had been planted after 1909 with over 130,000 coconut trees (*Cocos nucifera*) obtained from Samoa and Kauai.

It was soon apparent that homes and streets in this area next to the marsh were prone to flooding and the U. S. Army Corps of Engineers recommended in 1941 that the marsh drainage be altered to promote flood control in the Coconut Grove area. This need was underscored by a major flood in 1951 that extended the entire length of Coconut Grove to a little makai of Oneawa Street. The first phase of this flood control project was completed in 1952. It consisted of dredging of the pilot channel of the present Oneawa Canal from Kawainui Marsh to Kailua Bay. The final stage of this project was completed in 1966 and consisted of the present Oneawa Canal and a nine foot high levee which runs along the marsh side of Coconut Grove. This levee, which was intended to protect Coconut Grove from marsh floods, effectively isolated Kawainui Stream from marsh outflow, resulting in the present dead end configuration of the upstream section of Kawainui Stream near the Oneawa Canal.

Despite these efforts major floods continued to occur in the area in 1956, 1958, 1961, 1963, 1966, and 1969 which showed that protection of Coconut Grove from marsh overflow was not sufficient to prevent flooding among the homes. A 1971 study proposed that flooding of Coconut Grove was primarily due to a shallow water table and lack of a sufficient storm drainage system and that water from the marsh no longer contributed significantly to the flooding. Storm sewers and improved drainage into the Kawainui Stream were implemented in the early 1970's which were hoped would prevent further serious flooding. However, on New Years Eve 1987 the worst flood ever recorded occurred in the Coconut Grove area, causing damage exceeding $10 million and displacing hundreds of people from their homes (M & E Pacific, 1989). Both the levee, which was overtopped by water from Kawainui Marsh, and the Kawainui Stream drainage system were inadequate to remove water at a rate sufficient to prevent flooding.

Initial efforts to prevent a repeat of such an event consisted of raising the levee an additional foot, removal of vegetation from the mauka side of the marsh which had restricted water flow from reaching the Oneawa drainage canal, and maintaining the mouth of Kaelupulu Stream at Kailua Beach open during periods of potential high rainfall events. For a longer term solution to Coconut Grove flooding all available information was reviewed and five alternatives were evaluated (M & E Pacific, 1989). One of these alternatives was to provide the capability of overflow from Kawainui Stream at its present blind end into Oneawa Canal during periods of high water. This proposal would help reduce stagnation in Kawainui Stream from its present condition (see below). However this alternative was not approved by the U. S. Army Corps of Engineers presumably in part at least to public opposition to the idea. Rather, the plan now proposed and accepted is to raise the levee an additional eight feet and maintain areas of open water on the mauka side of Kawainui Marsh which will increase the capacity for water to flow toward the Oneawa Canal (Margo Stahl, U. S. Army Corps of Engineers, pers. comm.).

The history of Kawainui Stream in the vicinity of the Kailua Gateway project is one of significant change from a natural, free flowing water course to an artificially restricted appendix to the former Kaelepulu Fishpond, now known as Enchanted Lakes. The water quality and biological communities of Kawainui Stream were evaluated in the present study to determine the existing conditions and evaluate potential impacts of the Kailua Gateway development.

SURVEY METHODS

The water quality of Kawainui Stream was sampled at the five stations shown in Figure 1 on November 18 during dry weather, on December 13, 1991 following a heavy rain, and on September 18, 1992. Station 1 was located on the north side of the Kailua Road Bridge, Station 2 adjacent to the Creekside Tavern parking lot, Station 3 by the Kailua Kaiser Clinic parking lot, Station 4 on the east side of the Hamakua Road Bridge, and Station 5 on the east side of the Ka Awakea Street Bridge. The stations therefore extend from the upstream to below the downstream limits of the proposed Kailua Gateway development.

Water was sampled from just below the stream surface, adjacent to the stream bank. Measurements of temperature, salinity, and dissolved oxygen (DO) were made at just below the surface and just off the bottom at several stations in order to evaluate stratification in this estuarine system. On-site measurements of salinity were made using a Cambridge Instruments refractometer readable to parts per thousand (‰), temperature and dissolved oxygen with a YSI Model 54 oxygen meter and pH with Cambridge Scientific Hydac Conductivity-Temperature-pH Tester. Water samples were taken at the stations and held on ice until their return to the laboratory within 2 hours, where they were analyzed immediately or held frozen for analysis within two weeks. Analyses were made for turbidity, nonfilterable residue (NFR or suspended solids), ammonia, nitrate+nitrite, total nitrogen, orthophosphate, total phosphorus, and chlorophyll α.

Biological studies were undertaken in March and April, 1992. The entire stream course was inspected by two observers in kayaks from Station 1 to the stream mouth at Kailua Beach, and all macro-biota that could be observed from the surface in and along the stream were recorded. Benthic samples were taken on April 3 at Stations 1, 3, 5 (Figure 1) and near the stream mouth (Figure 3) using a dredge that sampled an approximate 30 by 30 cm area to a penetration depth of about 5 cm. These samples were reduced in volume on site to subsamples of about 0.5 liter by sieving through a 0.5 mm mesh size screen to remove silt and clay. The subsamples were returned to the laboratory and further sieved through 4.0, 2.0, 1.0, and 0.5 mm screens, and all organisms that could be resuspended in the washings were sorted from each size fraction, identified, and their relative abundances in the samples were estimated.

Fish and large invertebrates were sampled at Stations 1, 3 and 5 from April 9 to April 14 and at the stream mouth from April 14 to April 19 using fish traps 1 by 2 by 3 feet in dimension with a mesh size of 0.5 by 1 inch. The traps were checked at 12 and 24 hours after deployment and at 48 hour intervals thereafter for a total sampling time of five days at each station. Fishes and invertebrates caught in the traps were returned to the laboratory where they were counted, measured and weighed. Some of the specimens collected were later used to test for trace metals in aquatic animal tissues (AECOS, 1992b; also see Appendix B).

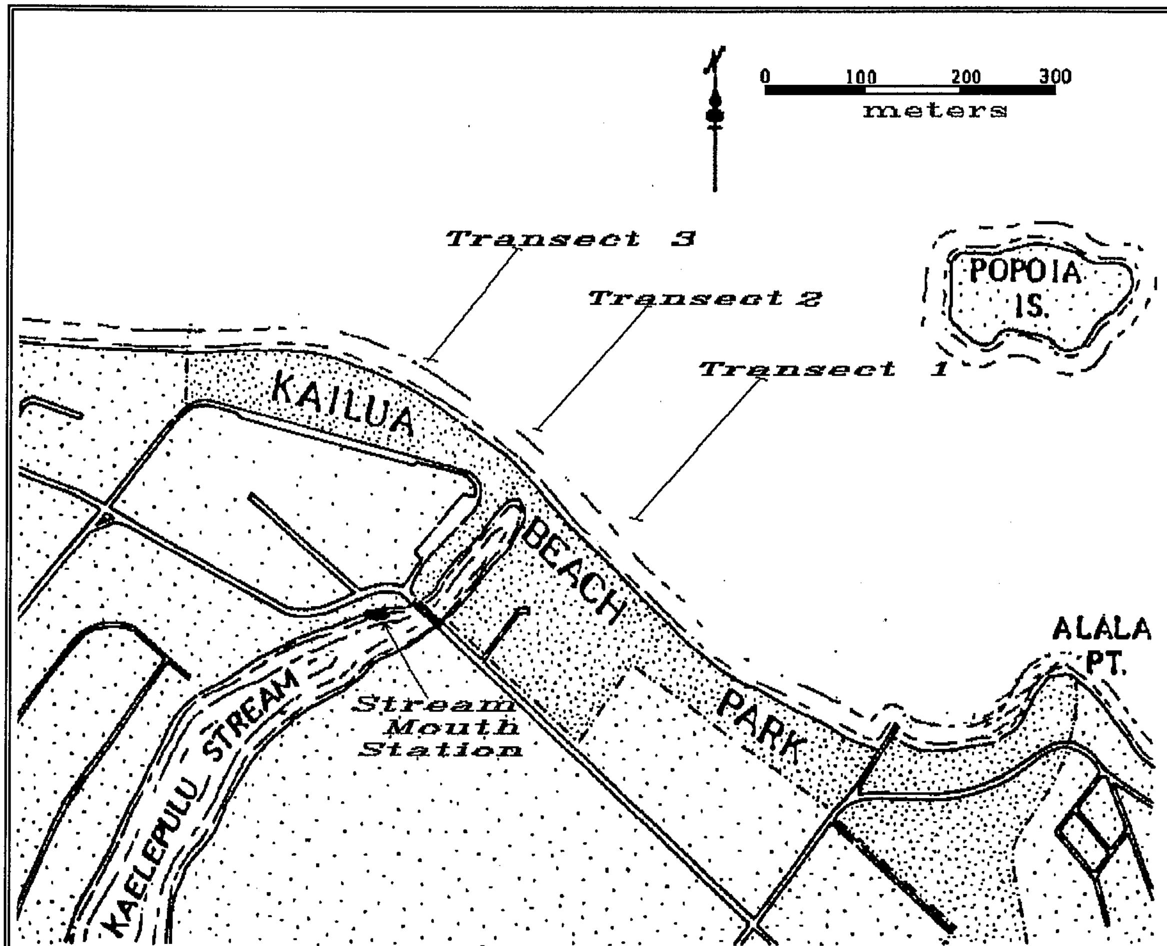

Figure 3. Kaelepulu Stream Mouth and Kailua Nearshore Area.

A survey was made offshore of Kailua beach in the vicinity of the Kawainui Stream mouth by a biologist using snorkeling gear. Three transects were inspected from the shoreline to about 250 m offshore and the relative abundances of the dominant macroalgae, invertebrates and vertebrates were recorded. The transect locations were 1) directly off shore of the lifeguard chair south of the stream mouth, 2) directly offshore of the stream mouth, and 3) offshore of the north side of the Kailua Beach Pavilion north of the stream mouth.

RESULTS AND DISCUSSION

WATER QUALITY SURVEYS

Concentrations and values of the parameters sampled at five Kawainui Stream stations established for the Kailua Gateway Project baseline are provided in Appendix A. These data are summarized in Table 1 which gives the arithmetic or geometric mean values of the parameters based on three measurements at each locatioin. Mean values for the five stations which possibly would exceed the 50% of the time criteria in the State of Hawaii water quality standards for estuaries are shown in bold type. The relationships between the results and the water quality criteria are discussed further below.

Table 1. Water quality summary for the Kailua Gateway Project baseline sampling.

STATION:	*1*	*2*	*3*	*4*	*5*
PARAMETER (unit)					
Temperature (°C)	26.5	26.8	27.0	26.9	26.9
Salinity (‰) (mg/L)	11	13	14	17	17
Dissolved oxygen	4.7	3.8	2.9	4.3	4.8
pH	7.91	7.91	7.79	7.84	7.87
Turbidity (ntu)	**2.98**	**2.90**	**2.54**	**3.40**	**2.43**
Suspended solids (mg/L)	3.6	5.4	8.5	8.5	6.1
Ammonia (mg N/L)	**0.237**	**0.127**	**0.204**	**0.171**	**0.389**
Nitrate+nitrite (mg N/L)	0.010	**0.025**	**0.022**	**0.015**	**0.060**
Total N (mg N/L)	**1.35**	**1.15**	**1.16**	**1.56**	**1.22**
Orthophosphate (mg P/L)	0.034	0.022	0.017	0.021	0.019
Total P (mg P/L)	**0.120**	**0.103**	**0.099**	**0.118**	**0.091**
Chlorophyll α (μg/L)	**9.8**	**11.2**	**16.7**	**17.0**	**9.1**

Values are geometric means except those for temperature, salinity, DO, and pH which are calculated as arithmetic means (n=3).

These data represent only three sampling events with a bias towards months late in the dry season (September) and early in the wet season (November/December). Thus, mean values for some parameters might be different, perhaps considerably different, were samples obtained from either wetter or drier periods. The question of representativeness is one always encountered in attempting to characterize a body of water from a limited number of sampling events. Estuarine environments, such as Kawainui Stream are particularly difficult in this regard because extremes are sometimes the most important charateristics. Nonetheless, the results of the sampling reported herein are instructive of some of the water quality problems that exist in Kawainui Stream. We acknowledge that it is probable that the averages reported may not be close to the true mean values for some or most parameters and that the range of values measured are probably not representative of the extremes which regularly occur on an annual cycle. The addition of a sample event in 1992 has clarified some patterns only vaguely perceived in the previous version of this report and altered other conclusions.

The data show that water quality in Kawainui Stream in the vicinity of the proposed project is generally poor. The individual values and geometric means for many parameters exceed State of Hawaii water quality standards (DOH, 1992), especially for inorganic nutrients, total nitrogen and total phosphorus, and chlorophyll α. The geometric mean not-to-be-exceeded criterion for ammonia is exceeded by the sample station geometric means by 21 to 65 times; the geometric mean criterion for nitrate + nitrite by 1 to 8 times; the geometric mean criterion for total nitrogen by 6 to 8 times; and the geometric mean criterion for total phosphorus by 4 to 5 times. The state geometric mean criterion was exceeded for chlorophyll α by a factor of 4 to 9 and turbidity by a factor of 1 to 2. All dissolved oxygen concentrations were below the state standard criterion of 75% of the saturation value for the recorded temperature and salinity, ranging to as low as 17% of saturation for the salinity and temperature measured.

Although no flow was noted on the sampling dates, the water quality data show a pronounced gradient for many of the parameters along the monitored course of the stream. Mean surface salinity increased from 11‰ at Station 1 (Kailua Road) to 17‰ at Stations 4 and 5 (Hamakua Road and Ka Awakea Road respectively). Salinity at each of the stations varied considerably from visit to visit (Appendix A), presumably reflecting differences in rainfall runoff occuring for the period of time prior to each sampling event. Even with this runoff there appears to be a pronounced influence of ocean water into the upper reaches of Kawainui Stream, even though the stations are all over 1.5 miles from the Kaelepulu Stream outlet into the ocean at Kailua Beach and the outlet is usually blocked at the shoreline by sand. Of course, evaporation will increase the salinity during dry periods and brackish ground water seepage contributes salts as well.

Ahuna (1992) measured salinity in Kawainui Stream at our Station 1 and at the upper end of the canal approximately monthly for over one year (January 1991 to March 1992). Salinities averaged 9 and 7 ‰ respectively. Roll (1992) measured salinity approximately fortnightly between September 1990 and August 1991 in Kaelepulu Stream and in Kawainui at Ka Awakea Road (our Station 5) and demonstrated that salinity in this system increases in the dry season and decreases in the wet season. Average salinity at Station 5 (his KS8) was nearly 23 ‰.

The stagnant nature of the water in this system is indicated by the low dissolved oxygen concentrations which tended to decrease upstream or towards a low value at Station 3. Average turbidity showed small changes with station location (although Station 4 had the higest mean value) while nonfilterable residue (NFR) mean values appear to peak around Stations 3 and 4. The chlorophyll α values also peak in this same area.

The patterns for the various forms of nitrogen further reflect the stagnant nature of Kawainui Stream and suggest that anoxic, reducing conditions increase in the upstream direction during periods of low rainfall (as indicated by high surface salinities). This is most clearly shown by ammonia nitrogen, which had a concentration on November 18 at the upstream Station 1 of nearly 240 times the State criterion (geometric mean) of 0.006 mg/l. On September 18, 1992 a period of relatively low surface salinity, the oxygen and ammonia gradients were the reverse of those seen on November 18, 1991. Ammonia accumulates in water from the excretion of aquatic animals and, more importantly, from decay and bacterial decomposition of plant and animal tissue under conditions of low oxygen. Where ammonia is oxidized, it converts into nitrite and then to nitrate, and the level of ammonia is often inversely proportional to the nitrate + nitrite concentration.

The concentrations of total nitrogen, which includes dissolved organic, particulate organic, and inorganic nitrogen forms, closely paralleled the pattern for ammonia, decreasing linearly from Station 1 to Station 5 in November 1991. This pattern did not hold up in later samplings. Ammonia also tended to dominate over the other forms of nitrogen, but again not consistently when all samplings are considered. When the three sampling events are averaged, the only pattern which emerges with respect to nitrogen compounds is a steady increase in nitrate + nitrite along a downstream gradient.

Orthophosphate and total phosphorus concentrations tended to decrease downstream on two of the three sampling events. At Station 1 on November 18, concentrations of orthophosphate were about ten times those of other stations. The pattern in September 1992 was similar, but the level of orthophosphate at Station 1 was closer to the levels at all other stations and the other station values were close to the average values for the stations. Orthophosphate was the only nutrient measured by Ahuna (1992) and Roll (1992) on a frequent basis covering an annual cycle in the Kaelepulu and Kawainui Stream systems. Station KC8 on Kawainui Stream (Ahuna, 1992; our Station 1) yielded a geometric mean value of 0.042 mg P/L (n=11), reasonably close to our geometric mean value of 0.034 mg P/L (n=3). Station KS8 on Kawainui Stream (Roll, 1992; our Station 5) had a geometric mean value of 0.080 mg P/L (n=29), a value which appears high relative to our results.

With the increased rainfall that preceded the December 13 sampling the concentrations of orthophosphate increased while the various forms of nitrogen appeared to decrease. It is particularly worth noting that total phosphorus increased only a little. Thus, runoff or influx of low salinity water may be a source of inorganic phosphates while diluting the other nutrient constiuents. Chlorophyll α also declined, indicating dilution and/or die-off of phytoplankton abundance. The latter could contribute to mineralization of phosphorus (an increase in the proportion of the total phosphorus that is orthophosphate). Ammonia decreased by as much as 10 times from November 18 to December 13. However, total phosphorus increased at three of the five stations, suggesting a high runoff input of phosphorus from suspended solids and other particulate sources.

Chlorophyll α concentrations were high at all stations (Table 1) indicating that nutrient inputs support a large standing crop of phytoplankton and create eutrophic conditions. Relatively low nitrate and orthophosphate levels recorded on some occasions indicate utilization of these nutrients by the phytoplankton. Chlorophyll α was highest at Station 3 and decreased downstream and upstream. Although a number of explanations for this are possible, nutrient inputs in the area may be primarily responsible. If the water is slowly flowing seaward (presumably it is), then the nutrient inputs stimulating this growth might be located somewhere upstream of Station 3. Both ammonia and phosphate tend show gradients of increasing concentrations away from Station 3.

Limited data are available to compare the present results with previous measurements in the upper reaches of Kawainui Stream or with the aquatic environment in nearby Kawainui Marsh. Temperature, salinity and dissolved oxygen were measured in July 1989 (M & E Pacific, 1989; Appendix B, Section 4) in the section of Kawainui Stream above the present study area, from 800 feet above the Kailua Road Bridge to the deadend adjacent to Oneawa Canal. Dissolved oxygen, which was measured during both morning and afternoon in the 1989 study, changed dramatically through the day, with morning measurements ranging between 2.2 to 4.8 mg/l and afternoon values from 6.3 to 7.3 mg/l. The stream water was found to be less saline than that reported here for the surface waters close to the project area, with salinity ranging only 2.4‰ to 3.5 ‰. The section of the stream above the Kailua Road bridge was also surveyed during the present study on March 1, 1992 and found to have a salinity throughout of 10 ‰. These substantially higher salinity values during the present study are probably a result of reduced precipitation and runoff during a relatively dry year.

The waters entering, within, and leaving Kawainui marsh were sampled for a full range of water quality parameters in March and April 1989 (M & E Pacific, 1989-Appendix B, Section 3). These results are summarized in Table 2 along with the geometric means of the five stations of the present study. Locations of the Kawainui stations are as a follows: Steam Input = means of values for Maunawili and Kahanaiki Streams; Southwest = means for two stations below the confluences of the tributary streams; Pond = open body of water in middle of the marsh; NE Canal 1 = upper dead end of emergency drainage canal which runs parallel to levee and Kawainui Stream on the marsh side; NE Canal 2 = emergency drainage canal midway along levee; Oneawa Canal = marsh just prior to outflow into the Oneawa Canal. The station sequence is approximately from upstream to downstream.

Table 2. Comparison of Kawainui Marsh Water Quality in March-April, 1989 with Kawainui Stream Water Quality at Station 1.

	Kawainui Marsh Location						Present Study
Parameter	Stream Input	South-west	Pond	NE Canal 1	NE Canal 2	Oneawa Canal	Sta. 1 Mean
Salinity (‰)	0.02	0.02	0.02	0.02	0.02	0.03	11.0
Dissolved. oxygen (mg/l)	7.7	6.6	....	3.6	....	3.2	4.7
pH	7.82	7.60	7.00	6.71	6.52	6.92	7.91
Turbidity (NTU)	4.63	7.50	8.60	18.00	16.60	9.30	2.98
Suspended solids (mg/L)	11.3	7.8	5.5	5.5	7.7	7.5	3.6
Ammonia (mg N/l)	0.022	0.022	0.020	0.275	0.007	0.014	0.237
Nitrate + nitrite (mg/l)	0.189	0.135	0.054	0.003	0.003	0.001	0.010
Total nitrogen (mg N/l)	0.361	0.309	0.314	0.626	0.388	0.378	1.35
Orthophosphate (mg P/l)	0.009	0.016	0.014	0.247	0.110	0.007	0.034
Total phosphorus (mg P/l)	0.037	0.048	0.051	0.339	0.166	0.123	0.120

The data contrast with the Kawainui Stream results in a number of ways. Salinity was only 0.02-0.03‰, showing little or no ocean influence on the marsh water. Dissolved oxygen ranged from near saturation in upstream areas to less than 50% saturation at the two emergency canal stations, reflecting sluggish and stagnant conditions downstream. The pH declined slightly going downstream, while turbidity generally increased, especially at the upper end of the emergency canal. Suspended solids (NFR) was maximum in the stream samples and quite similar at all the marsh stations. Both turbidity and NFR were slightly to substantially greater in the marsh water than in Kawainui Stream, suggesting a higher rate of sediment erosion and water flow or higher phytoplankton growth in the marsh.

The levels and patterns of nitrogen and phosphorus concentrations in the marsh differ most distinctly from those found in Kawainui Stream. Concentrations of ammonia nitrogen and total nitrogen approach those found in Kawainui Stream only at the upper end of the Northeast (NE) emergency canal where conditions may also be assumed to be stagnant and conducive to decomposition of accumulated organic matter. Levels of orthophosphate and total phosphorus more than ten times occurring elsewhere in the marsh were found at this station at the northeast corner of Kawainui Marsh. Ahuna (1992) sampled a station here and her data confirm the high levels of phosphates. With the exception of this station, ammonia nitrogen and nitrate + nitrite appear to decrease systematically going downstream, suggesting a nutrient stripping capability by the marsh that was described when the marsh was receiving treated sewage effluent from four sewage treatment plants (AECOS 1981).

Limited monitoring was conducted in January 1992 for proposed maintenance dredging of Kawainui and Kaelepulu Streams (AECOS, 1992a). The results of a sampling event in January 1992 are reproduced here as Table 3.

Table 3. Kawainui and Kaelepulu Stream Water Quality on January 16, 1992

PARAMETER	STATION [1] Upper end Kawainui Str.	*Sta. 1*	Kawainui Mouth	Kaelepulu at Keolu	Kaelepulu Mouth
Temperature (°C)	24.3	25.5	24.9	22.4	26.3
Salinity (‰)	14.0	14.0	15.0	17.0	21.0
Dissolved oxygen (mg/l)	7.8	6.7	12.1	5.8	8.5
pH	8.12	8.09	8.53	8.13	8.33
Turbidity (NTU)	5.04	3.71	2.15	1.98	2.98
Suspended solids (mg/l)	3.5	2.5	2.5	3.4	5.8
Ammonia (mg N/l)	0.019	0.019	0.050	0.049	0.012
Nitrate + nitrite (mg N/l)	0.001	0.001	0.013	0.015	<0.001
Total nitrogen (mg N/l)	1.25	0.938	0.710	0.565	0.408
Total phosphorus (mgP/l)	0.204	0.392	0.080	0.077	0.035
Chlorophyll α (μg/l)	8.40	4.61	5.93	10.70	6.61

1 - Stations described or numbered with respect to Kailua Gateway baseline stations.

BIOLOGICAL SURVEYS

Kawainui Stream

The Kawainui Stream channel is dominated throughout the segment from Station 1 to just above Station 5 by a dense growth of the red mangrove, *Rhizophora mangle*, which is choking off the stream by its proliferation. Other plants contributing to this occlusion of the waterway are Indian fleabane (*Pluchea indica*), Chinese banyan (*Ficus microcarpa*), sea mulberry (*Conocarpus erectus*), and Christmas berry (*Schinus terebinthifolius*). These species were most common along the area of the proposed development between Stations 1 and 4.

Few species of fish and invertebrates were observed to occur in the Kaelepulu Stream course during the kayak survey or at any time during water quality or biological sampling. Salinity in the stream at the time of this study was measured by refractometer to range from 12‰ at Station 1 to 15‰ at Station 5 and 17‰ near the blocked stream mouth at Kailua Beach. The only abundant organisms noted were tilapia (*Sarotherodon melanotheron*) observed in schools of hundreds of individuals throughout the stream course from Stations 1 to 5, and various species of topminnows (*Poecilia latipinna* and *Poecilia* spp.) and mosquito fish, (*Gambusia affinis*), which also occur in abundance throughout this area. Tubes of a polychaete worm (*Ficopomatus enigmaticus*) occur on rocks and other hard surfaces at the stream's edge, and small gastropod snails can be seen on the sediment bottom in shallow water. Water fowl observed on the kayak survey were limited to a few mallard ducks (*Anas platyrhynchos*) and blackcrowned night herons (*Nycticorax nycticorax hoactli*).

Downstream of the confluence of Kawainui Stream with Kaelepulu Stream the canal becomes substantially widened, mangroves and other vegetation are less dominant and a greater variety of organisms occur. Along with the tilapia common upstream, a swimming crab (*Thalamita crenata*), the 'alamihi or shore crab (*Metopograpsus thukuhar*), and aholehole (*Kuhlia sandvicensis*) were observed during the kayak survey. Although not observed, Hawaiian stilt (*Himantopus mexicanus knudseni*) have been reported feeding in the area near the stream mouth.

The paucity of species of aquatic organisms in Kawainui Stream suggested by the above observations were confirmed by the results of benthic sampling (Table 4) and fish trapping (Table 5) conducted in April 1992. All samples taken at Stations 1 to 5 in the vicinity of the proposed development were characterized by black, anaerobic sediments which released profuse quantities of hydrogen sulfide when brought to the surface. Also, a sheen of oil-like organic matter rose to the water surface when the bottom was sampled at Station 1. The only organism found in any abundance at this station or at Station 2 was a brackish-water, gastropod snail (*Melanoides* sp.), which had well over a thousand shells present in each sample. However, only a fraction of the shells contained the live animal. Two hundred of the *Melanoides* shells in the Station 1 sample were broken open to estimate the proportion of live to dead. Only nine, or about 4.5% of these contained live snails.

Table 4. Relative Abundances of Benthic Invertebrates Sampled from Kawainui Stream.

Species	*Sta. 1*	*Sta. 3*	*Sta. 5*	Kaelepulu Str. Mouth
ANNELIDA				
Oligochaeta	R	R	C	C
Polychaeta				
Capitellidae				
Unident.				A
Capitella capitata				P
Spionidae				
Streblospio benedicti			P	
Malacoceros sp.				P
Syllidae				
Exogone vergera				C
MOLLUSCA				
Gastropoda				
Thairidae				
Melanoides sp.	C	C		
ARTHROPODA-CRUSTACEA				
Amphipoda				
Amphipoda spp.		R	P	P
Corophium baconi			C	C
Neomicrodeutopus mekena			C	A
Total "Species" Count	2	3	5	8

Legend: R = rare; P = present; C = common, A = abundant.

The only other indications of benthic life in the upstream section of Kawainui Stream were a single oligochaete fragment at Station 1 and one oligochaete and one amphipod at Station 3. Numbers of species and individuals of oligochaetes, polychaetes and amphipods increased dramatically at Station 5 and even more so at the stream mouth, reflecting the more estuarine (saline) water, generally coarser sediment, and resumably reduced anoxic conditions that occur downstream from Station 5. The sediment sample taken furthest downstream, near the blocked outlet of Kaelepulu Stream into Kailua Bay, was free of hydrogen sulfide odor or black iron sulfides, indicating aerobic conditions. Although still limited in diversity, the benthic community at this station was relativity high in species compared to the upstream stations (Table 4), and suggest that even though the stream mouth is blocked most of the time, seepage of water though the sand is sufficient to promote aerobiosis of the sediments to support an estuarine benthic community.

Table 5. Total numbers and total. wet weights in grams of fish and macro-invertebrates sampled by traps from Kawainui Stream and Kaelepulu Stream mouth in five-day sets.

	Location			
Species	Sta. 1	Sta. 3	Sta. 5	Str. Mouth
ARTHROPODA CRUSTACEA				
Portunidae "Swimming Crabs"				
Thalamita crenata "blue clawed crab"		4 (280)	11 (505)	8 (532)
Scylla serrata "Samoan Crab"		1 (344)		
VERTEBRATA PISCES				
Cichlidae				
Sarotherodon melanotheron "tilapia"	65 (1488)	16 (389)	6 (310)	5 (179)
Eleotridae				
Eleotris sandwicencis "'o'opu 'akupa"	2 (755)	1 (36)		1 (24)
Sphyraenidae				
Sphyraena barrucuda "kaku"			2 (209)	
Tetradontidae				
Arothron hispidus "keke"				15 (1084)
Lutjanidae				
Lutjanus fulvus "to'au"				1 (20)
Total Species	2	4	3	5

The results of fish trapping further confirm the impression of limited species diversity within the upstream section of Kawainui Stream (Table 5). Of a total of seven species of fishes and large invertebrates, only two species of fishes were trapped at the upstream Stations 1 and 3: the tilapia (*Sarotherodon malanotheron*) and the 'o'opu 'akupa (*Eleotris sandwicencis*). The 'o'opu 'akupa captured at Stations 1 and 3 were infested with leeches (*Aestabdella abditovesiculata*) that were attached along the bellies, mouth, and gill areas, while a single o'opu 'akupa taken at the stream mouth was free of leeches. The only invertebrates trapped in the upstream area were swimming crabs (*Thalamita crenata*) which can often be seen along the stream's edge, and the Samoan crab (*Scylla serrata*). Tilapia were especially abundant at the furthest upstream station, where 65 individuals totaling nearly 1.5 kg were sampled in the five day period. A greater variety of fishes were trapped at the stream mouth, including many puffer fish (*Arothron hispidus*) and a snapper (*Lutjanus fulvus*). Fishermen who lay net at this spot reported that they routinely catch mullet (*Mugil cephalus*), lae (*Scomberoides sancti-petri*), moi (*Polydactylus sexfilis*), and aholehole (*Kuhlia sandvicenses*).

No previous studies have been made of the communities of macro-organisms in Kawainui or lower Kaelepulu Streams that can be compared to the present study's results. Shallenberger (1977) describes the biota in Kawainui Stream (referred to as the Hamakua Canal) to include tilapia, mosquito fish, mollies, smallmouth bass, carp, freshwater turtles, crayfish, and 'opae shrimp. However, no site-based studies are referred to in support of this description. Of these species mentioned, only tilapia, mosquito fish, and mollies were observed or sampled in the present study.

Recent comprehensive studies of bacteriological concentrations of the entire Kaelepulu Stream course and of portions of Kawainui Stream have been completed by the University of Hawaii, Water Resources Research Center (Roll, 1992; Ahuna, 1992). These studies found high levels of fecal coliforms, *Escherichia coli*, and fecal enterococci in the mid to upper stream areas. Fecal indicator bacteria increased during periods of high run-off, suggesting soil and fecal matter deposited on the watershed by wild and domestic animals as probable sources of the high counts observed. Although traditionally used as indicators of sewage contamination, the results obtained from these stream systems which lack sewage inputs suggest that nonpoint sources may be more significant. However, the risk to public health cannot be evaluated because epidemiological studies relating indicator bacteria to non-point sources and in tropical/sub-tropical aquatic environments are lacking.

Kailua Bay

The subtidal zone off Kailua Beach typifies a high energy shoreline influenced by scour and deposition of carbonate sand, the predominant bottom type. Although the area is somewhat protected by being in the lee of Popoia ("Flat") Island, the almost constant tradewinds blowing onshore create nearly continuous short period waves which are the dominant environmental factor affecting nearshore marine organisms. Fine carbonate sands are almost continuously resuspended in the water, and turbidity is usually moderate to high. These factors and the resulting sand scour prevent the development of the substantial coral and invertebrate growth that would occur under calmer conditions.

Results of the swimming survey off the stream mouth at Kailua Beach are summarized in Table 6. The observations on Transect 1, south of the Kaelepulu Stream channel, and on Transect 3, north of the channel, are typical of the conditions described above, with the substratum dominated by sand consolidated with heavy growths of macroalgae. On Transect 1 the bottom is entirely sand covered out to approximately 180 m from shore, beyond which the bottom becomes consolidated limestone interspersed with sand channels and pockets, and occasional patches of fossilized *Porites compressa* coral skeleton and other dead coral. Modest cover of live coral such as *Porites lobata*, *Pocillopora damicornis*, *Montipora verrucosa*, and *Cyphastrea ocellina* totaling less than 5% cover can be found on these patches of hard substratum on the outer zone of Transect 1.

Macroalgae are the dominant benthic organisms on the outer zone of Transect 1, and on Transect 3 high macroalgae coverage extends virtually to the shoreline. The calcareous green algae *Halimeda discoidea* and the brown algae *Padina japonica* are the most abundant species throughout the area, followed by *Sargassum echinocarpum*, *Lyngbya majuscula* and *Dictyota acutiloba*. *Acanthophora spicifera*, and *Spyridia filamentosa* are also common along Transect 3, which had the greatest number of algal species and by far the highest coverage of the three transects.

Live reef corals were sparse on Transects 1 and 3, but were relatively common on Transect 2 directly offshore of the Kaelepulu Stream mouth. Macroalgae were less abundant on Transect 2 as compared with the transects to the north and south. The most abundant coral species was *Porites compressa*, which occurred in isolated patches as close as about 120 m from shore. *Porites lobata* was also commonly found, and *Pocillopora damicornis* and *Montipora verrucosa* were occasionally seen. A single colony of *Pocillopora meandrina* was found, somewhat surprising in view of the high potential for resuspended sand, scour and turbidity in the area to restrict this sensitive species.

Along with reef corals, other benthic macro-invertebrates were rare in the area, except for the small mussel (*Brachidontes crebristriatus*) which was abundant on sand-covered limestone of the nearshore segment of Transect 3. The only other non-coral macro-invertebrate was the black sea cucumber (*Holothuria atra*) rarely seen on Transects 2 and 3. Fish were also rare on Transects 1 and 3, with only 2 to 3 species observed on the these areas where the sandy bottom offers little vertical relief. Probably due to the greater relief and the habitats provided by both live and dead coral on Transect 2, fishes were both more abundant and diverse, with a total of eight species found. Green sea turtles (*Chelonia mydas*) were observed on Transects 2 and 3, and these undoubtedly utilize the abundant macroalgae of the area for food.

Table 6. Benthic Organisms Observed off Kailua Beach. (1=rare, 2=present, 3=common, 4=abundant)			
		Location	
Species	Transect 1	Transect 2	Transect 3
CYANOPHYTA "Blue-green Algae"			
Lyngbya majuscula	2	2	3
CHLOROPHYTA "Green Algae"			
Bryopsis sp			1
Codium edule		1	
Dichtyosphaeria versluysii			1
Halimeda discoidea	4	3	4
PHAEOPHYTA "Brown Algae"			
Dictyota acutiloba	3	2	3
Padina japonica	4	4	4
Sargassum echinocarpum	3	3	3
S. obtusifolium			1
Turbinaria ornata	1		
RHODOPHYTA "Red Algae"			
Acanthophora spicifera			2
Gracilaria sp.			1
Hypnea sp.			1
Laurencia sp.			1
Porolithon gardineri	1	2	
Spyridia filamentosa			2
Trichogloea requienii			
SCLERACTINIA "Reef Corals"			
Porites lobata	2	2	
P. compressa		3	
Pocillopora meandrina		1	
P. damicornis	1	1	1
Montipora verrucosa	1		
Cyphastrea ocellina	1		
MOLLUSCA			
Brachidontes crebristriatus			3
ECHINODERMATA			
Holothuria atra		1	1
Total Species	11	12	16

Table 7. Vertebrates Observed off Kailua Beach. (1=rare, 2=present, 3=common, 4=abundant)

Species	Transect 1	Location Transect 2	Transect 3
VERTEBRATA			
PISCES			
Holocentridae			
Myripristes berndti "'u'u"		1	
Mullidae			
Parapeneus multifasciatus "moano"		2	
Chaetodontidae			
Chaetodon unimaculatus		1	
Labridae			
Stethojulis balteata "omaka"		1	
Thalassoma duperrey "hinalea lau-wili"	2	2	
Acanthuridae			
Acanthurus triostegus "manini"		1	
Ctenochaetus strigosus "kole"		1	
Ostracionidae			
Ostracion meleagris "moa"	1	1	
Tetradontidae			
Arothron hispidus "keke"			1
REPTILIA			
Chelonia mydas "Green Sea Turtle"	1		1
Total Species	3	8	2

The previous studies made in this area along Kailua Beach (Reed 1973; AECOS 1977) report similar findings to the present study, except no reef corals were previously reported. The AECOS (1977) report comments on the paucity of macro-organisms, the dominance of the area by macroalgae, and the limited fish assemblages present due to low vertical relief. Coverage by *Halimeda discoidea* ranged up to 55% of the bottom in the areas of the present Transect 3, while *Hypnea* covered up to 40% in quadrats on present Transect 1. No live coral was reported in the area by AECOS (1977) or by Reed (1973), who also commented on the dominance of the area by *Halimeda* and on the paucity of macro-invertebrates.

The absence of live coral for previous surveys may be due to the very limited distribution within the area, corals simply having been missed, or may be due to new settlement and growth since the last surveys were made. Judging from the size of the coral patches, it seems likely that at least some coral must have been present 15 to 20 years ago. What is clear is that coral growth and diverse fish assemblages are mostly confined to the channel directly seaward of the Kaelepulu Stream mouth where hard substratum is more prevalent and available for coral settlement and growth. The infrequent discharge of brackish water from Kaelepulu Stream whenever the channel has been opened has therefore not caused any negative impact on the coral reef community directly offshore, where, in fact, coral growth and fish populations are most abundant in this area off Kailua Beach.

ASSESSMENT OF PROJECT IMPACTS ON AQUATIC ENVIRONMENTS

The present survey results and comparisons with previous surveys emphasize the finding that Kawainui Stream is a stagnant, highly eutrophic estuarine system which, under its current and expected future configuration, has limited capability of removing any dissolved or suspended material which may reach it. Retention of organic detritus reaching the stream bottom, along with lack of mixing that would provide a source of oxygen, produce the anaerobic conditions that dominate the upper stream sediments. The aquatic macrobiota that survives in the area of the Kailua Gateway project is depauperate and not diverse, primarily composed of introduced exotic fishes such as tilapia, topminnows, and mosquito fish, a benthic snail, and a swimming crab. The only Hawaiian native species found anywhere in the stream was the fish 'o'opu 'akupa, which was rarely encountered and heavily parasitized by a leech at the upstream stations.

Construction Impacts

Short term impacts from the project will be primarily from runoff and sedimentation which may occur during construction. Construction of the project will require trenching, foundation excavation, grading and stabilization of the lower hillside, which will be done according to Honolulu City & County grading, soil erosion, and sediment control ordinances. Impacts to Kawainui Stream from storm runoff and sedimentation during the construction phase will be reduced by the construction of temporary sediment basins and a silt fence at the wetlands boundary (Smith, Young & Assoc., 1992a). Overflow water from the sedimentation basins will be subject to monitoring under the NPDES permit program recently implemented by the State of Hawaii, Dept. of Health (Hawaii Administrative Rules, §11-55). Sedimentation impacts from construction will be further reduced by sodding and planting exposed areas as soon as grading is completed. Impacts on Kawainui Stream from project construction will be modest and of short duration.

Increased Runoff

Long term impacts on the stream could potentially result from increased runoff into the stream coming from new paved and other impermeable surfaces on the project site after completion of construction. Presently, water reaches the stream in the vicinity of the project primarily from three sources (Smith, Young and Assoc., 1992b): 1) runoff from the Coconut Grove area upstream, 2) three storm drain outlets on the northeast side of the stream along Hamakua Drive between Kailua Road and Hekili Street which drain runoff from the makai side of Hamakua Road, and one storm outlet which drains into the wetland 300 feet south of the Hamakua Road bridge across Kawainui Stream, and 3) runoff from the project property which flows down the hillside and across the wetlands before entering the stream along the perimeter of the wetlands.

After project completion, runoff will flow from the property through two separate systems: (1) from the proposed Retirement Community area northwestward and emptying into Kawainui Stream near the Kailua Road bridge, and (2) from the Community Center area connecting to an existing 36 inch storm drain on Hamakua Drive. This runoff will reach Kaelepulu Pond below the project area (Smith, Young and Assoc., 1992b). Existing maximum or peak flow for a 10-year flood interval (Q_{10}) from the 89 acres comprising the site property has been estimated at 117 cfs. After completion of the project the Q_{10} would be 135 cfs, an increase of 18 cfs or about 15% above existing flow (Smith, Young and Assoc., 1992b). Of the 135 cfs flow rate, 97 cfs would come from the undeveloped portion of the property, pass under the access road within the developed area, and flow into the wetland, which will act as a buffer to slow this flow before it ultimately reaches Kawainui Stream or recharges the ground water. The remaining 38 cfs at peak flow (Q_{10}) will be directed mostly into the stream through the new storm drain, but a portion will flow into Kaelepulu pond through an existing 36 inch conduit.

The 18 cfs increase in peak flow attributable to proposed changes in land use (i.e., the Kailua Gateway Development) can be compared to 10-year storm peak flow (Q_{10}) in Kawainui Stream from sources upstream of the Kailua Road bridge. This has been estimated to be about 235 cfs (M & E Pacific, 1989, Table A-22). Total increased flow into Kawainui Stream and Kaelepulu Pond for a 10-year storm event due to increased runoff from the project would therefore be about 8% above the present peak flow from upstream of the project site.

The impact of this increased flow from the project site on Kawainui Stream ecology will be insignificant assuming the run-off does not contain pollutants. The increased flow will dilute substances presently found in the stream or contributed from other areas and will contribute in a small way to the infrequent flushing of the system. The primary cause of the stagnant waters, resulting in anaerobic and eutrophic conditions in Kawainui Stream, is the limitation on flow imposed by limitations on source water. Any nutrient or pollutants that reach the stream have a relatively long residence time with potential to build up. This situation could be improved if more water flowed into the stream and the stream mouth remained open. However, the small increase in total water flow from the project into Kawainui Stream resulting from the project will be insufficient in itself to produce much improvement in circulation, especially since the higher flow will be restricted to storm periods.

Runoff Water Quality

The nature of the water flowing off the developed versus the undeveloped property is expected to change. Many surfaces within the development will be impervious and composed of asphalt, concrete, and roofing material. The presence of these surfaces largely accounts for the predicted increase in peak flow runoff volume. These surfaces will collect materials characteristic of an urban setting that will be flushed into Kawainui Stream during periods of significant rainfall. Urban runoff has been studied in a wide variety of settings and locations (Sartor & Boyd, 1972) and the pollutants associated with storm runoff from urban surfaces are extremely variable both qualitatively and quantitatively. Obviously a number of substances associated with automobile use and petroleum products can be anticipated. Fecal matter from pets, fertilizers and pesticides from home garden use, organics from a variety of sources, and perhaps illicit dumping of small quantities of hazardous substances all contribute to the potential degradation of aquatic environments from urban, non-point source runoff. Table 8 summarizes results from three studies of urban storm drain water quality on Oahu. Note that even the study in Mililani Town (Yamane & Lum, 1985), which was relatively thorough, revealed significant differences in many parameters considering the runoff from two adjacent watersheds. Further, most parameters vary substantially in concentration comparing the initial flushing with runoff generated later in the same storm or comparing runoff for a storm following a long dry period with runoff from storms late in the wet season. The reasons are, of course, that pollutants tend to build up on ground surfaces over time, to be washed into the storm drainage system by the first significant rainfall. Studies have shown that much of the pollutant load in storm water runoff is associated with fine particulates, and regular street sweeping can significantly reduce pollutants entering aquatic environments in urban areas (Sartor & Boyd, 1972).

Predicting the quality of runoff from the proposed project, essentially a residential apartment complex and community center, would be fraught with uncertainty. Nonetheless, there would be nothing inherent in the project to suggest an unusual generation of pollutants beyond what normally comes off roofs, yards, and streets in urban, residential areas. The City and County has indicated that the new drainage system will be subject to NPDES storm water monitoring as a municipal drain.

Perhaps more useful for this assessment would be a summary of the expected differences in water quality between runoff from the existing pasture land and that of the proposed development. With respect to suspended solids (NFR) and turbidity, values would be less in the runoff from developed land combining impermeable surfaces and landscaped areas. The potential for soil erosion would be reduced by the project. BOD (biochemical oxygen demand) will probably be reduced, as will most nutrients, and bacteria (fecal coliforms and enterococci). The present grazing of cattle in this area contributes soluble inorganic nutrients, particulate organic matter, and fecal bacteria to run-off from the pasture areas. Increases in oil & grease, polynuclear aromatic hydrocarbons (toxic components of petroleum products), and some heavy metals are probable with a change from rural, agricultural activities to urban use. While these substances may be harmful to the stream,

Table 8. Summary of water quality characteristics for storm drain studies on O'ahu, Hawaii.

	Iwilei①	Manoa②			Mililani③	
		A	B	C	A	B
Discharge (ft^3/sec)					30	12
pH	6.5-6.7				7.2	7.0
Total solids (mg/L)	220-263				251	131
NFR (mg/L)	6 - 16	110	452	168	204	96
Turbidity (ntu)					35	20
DO (mg/L)	5.7-7.6					
Conductance (µS/cm)					79	52
Chloride (mg/L)	23-35					
Total hardness (mg/L)	64-73					
COD (mg/L)	16.5 - 82.4	120	84	43	60	34
BOD (mg/L)	3.6 - 14.1	>16	>16	6.4		
Grease (mg/L)	0.3 - 2.1					
NUTRIENTS:						
ammonia (mg N/L)		0.20	0.18	0.16		
NO_2+NO_3(mg N/L)	1.00-1.31	2.71	2.14	0.03	0.21	0.10
TKN (mg N/L)	0.08-6.97	4.01	3.28	1.92	1.2	1.4
Total N (mg/ N/L)		6.72	5.42	1.95		
ortho P (mg P/L)	0.50-1.88					
Total P (mg P/L)	1.56-2.76	0.12	0.12	0.16	0.34	0.17
METALS: (µg/L)						
arsenic		ND	ND	ND		
cadmium		ND	ND	ND		
chromium	8-17	ND	ND	ND		
copper	12-28	74	15	40		
iron	26-88					
lead	129-4560	110	ND	630	20	10
mercury		3	ND	2	0.2	0.1
nickel		79	51	68		
zinc	315-1070	371	20	203		
BACTERIA:	(MPN)				(CFU/	100ml)
Total coliform	9700-14800					
Fecal coliform	287-835					
Enterococci	5100-11800				26000	26000

① - Fujiwara (1973); range of flow weighted averages or flow proportioned composite values from three separate storm samplings in Iwilei district of Honolulu .

② - DOH (1980); results of single samples representing runoff from: A = H1-freeway, B = University Ave. commercial area, and C = Manoa mixed residential and commercial area.

③ - Yamane & Lum (1985); median values from two watersheds (A & B) in Mililani Town over four year period. Number of samples varied from 9 to 208.

the expected contribution from the project must be viewed in relative terms in the absence of any definitive quantitative estimates.

Runoff contributions to eutrophication and degradation of Kawainui Stream will be mitigated to some extent by the proposal (Engilis, 1992) to construct improved wetlands between the project area and the stream. An improved wetland would include more extensive areas of open water than presently exist to attract native wetland birds, and an increased capacity of this land to absorb nutrients and reduce turbidity in runoff water which flows through the wetland before entering the stream. Under the proposed drainage scheme, this water will be mostly that which drains undeveloped lands surrounding the project. Nonetheless, attachment of an improved and enlarged wetlands to Kawainui Stream should have a positive impact on the water quality of the latter.

Impacts on Aquatic Biota

The present biota of Kawainui Stream is limited to a few hardy species which can survive the stressful conditions found there. This particularly pertains to the stream bottom in the section above Hamakua Drive bridge which is comprised of fine, anoxic sediments that sustain only a few species tolerant of the anaerobic conditions near the bottom. There is little likelihood that the existing stream biota will be any further degraded by the runoff from the Kailua Gateway project with its reduced sedimentation and nutrient inputs to the stream. No aspects of the proposed project would physically eliminate aquatic habitat. The proposal to enhance the adjacent wetlands would alter wet pasture land to create higher quality wetland habitats.

The Kaelepulu Stream mouth is closed most of the time, even though the City and County unblocks the opening approximately monthly and more frequently during rainy periods. Wave action rebuilds the beach, closing the opening with sand within a day or two of dredging (C & C Dept. Public Works, pers. comm.). While the blockage is an indication of stream stagnation and not the cause of it, outflow from the stream has routinely reached the nearshore environment off Kailua Beach and will continue to do so whenever conditions of high runoff inputs to the stream system occur.

The comparison of the present condition offshore of Kailua Beach in the vicinity of the Kaelepulu Stream mouth with the limited information available from surveys taken in 1973 and 1977 suggests that no degradation in the offshore benthic or fish environment has occurred in the past 15 to 20 years. No reef coral and few fishes were reported from the earlier studies, compared to moderate coral growth, fish abundance and diversity in the present study. More significantly, the most diverse biota found in the present study occurred directly off the stream mouth. No negative long term impact is therefore indicated for the outflow from Kaelepulu Stream that has occurred in the past 15 to 20 years, and none would result for the modest increase in flow that may result from the Kailua Gateway project. Even when the Kaelepulu Stream channel is periodically opened, or were the flow to Kailua Bay to be permanently restored, any small increase in urban pollutants from the project runoff would be inconsequential in terms of the total flow, nutrient loading, and urban non-point source pollutants which presently reach Kawainui Stream, Kaelepulu Stream, and Enchanted Lake.

At present both the water quality and the resident biological assemblages of Kawainui Stream in the vicinity of the proposed project indicate a low quality aquatic environment which is inhabited only by a few hardy species. The moderate increase in runoff to the stream that is likely to occur during storm periods as a consequence of the project, will not have any significant impact on the stream environment. Improvement in Kawainui Stream water quality could be achieved only by enhancing the flow or circulation of water through the system. However, this approach would require locating a reliable source of input water, the absence of which is responsible for the observed stagnant conditions.

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APPENDIX A
WATER QUALITY DATA FOR KAWAINUI STREAM

STATIONS 1 THROUGH 5 OF
KAILUA GATEWAY PROJECT BASELINE MONITORING

PARAMETER:	STATION: DATE	1	2	3	4	5
Surface temperature (C°)	11/18/91	25.5	26.5	26.5	26.7	26.7
	12/13/91	24.5	24.5	24.5	24.5	25.0
	09/18/92	31.0	29.5	30.0	29.5	29.0
Bottom temperature (C°)	09/18/92	30.5	....	....	30.5	30.0
	09/20/92	31.0	....	....	30.8	29.0
Surface salinity (‰)	11/18/91	17	20	22	24	24
	12/13/91	10	10	10	10	15
	09/18/92	7	8	10	16	12
Bottom salinity (‰)	09/18/92	12	....	....	17	17
Surface dissolved oxygen (mg/L)	11/18/91	2.1	3.4	3.6	5.1	4.5
	12/13/91	4.6	5.4	3.8	4.9	5.3
	09/20/92	7.40	2.45	1.25	2.80	4.60
Bottom DO (mg/L)	09/20/92	0.30	....	....	0.15	3.75
pH (pH units)	11/18/91	7.70	7.79	7.70	7.73	7.79
	12/13/91	7.96	7.96	7.74	7.84	7.91
	09/18/92	8.06	7.98	7.93	7.94	7.90
Turbidity (ntu)	11/18/91	1.93	1.86	1.40	1.68	1.83
	12/13/91	3.47	4.02	4.37	4.40	3.42
	09/18/92	3.97	3.26	2.69	5.30	2.29
Suspended solids (NFR) (mg/L)	11/18/91	3.4	4.2	7.0	4.90	8.2
	12/13/91	3.0	4.4	8.4	5.2	5.4
	09/18/92	4.4	8.4	10.4	24.0	5.2
Ammonia nitrogen (mg N/L)	11/18/91	1.38	1.02	0.880	0.922	0.687
	12/13/91	0.108	0.023	0.102	0.038	0.102
	09/18/92	0.089	0.089	0.094	0.142	0.840
Nitrate+nitrite nitrogen (mg N/L)	11/18/91	0.037	0.062	0.045	0.048	0.084
	12/13/91	0.028	0.050	0.050	0.070	0.038
	09/18/92	0.001	0.005	0.005	0.001	0.067
Total nitrogen (mg N/L)	11/18/91	1.97	1.60	1.57	1.60	1.38
	12/13/91	0.900	0.720	0.803	0.690	0.570
	09/18/92	1.39	1.32	1.24	1.40	2.29
Orthophosphate (mg P/L)	11/18/92	0.055	0.013	0.009	0.007	0.008
	12/13/91	0.032	0.032	0.047	0.068	0.044
	09/18/92	0.023	0.024	0.012	0.019	0.018
Total phosphorus (mg P/L)	11/18/91	0.128	0.099	0.097	0.098	0.102
	12/13/91	0.130	0.120	0.142	0.138	0.098
	09/18/92	0.104	0.091	0.070	0.121	0.076
Chlorophyll α (μg/L)	11/18/91	22.0	21.1	40.0	48.0	10.6
	12/13/91	5.18	6.32	10.9	5.36	5.68
	09/18/92	8.26	10.6	10.6	19.1	12.6

APPENDIX B
TRACE METAL TISSUE BURDENS
IN SELECTED BIOTA FROM
KAWAINUI AND KAELEPULU STREAMS

	Ag	As	Cd	Cr	Cu
Kawainui Stream ①					
Crab, blue-pincher					
Thalamita crenata	<0.25	0.44	0.15	1.0	26
Fish, 'o'opu 'akupa					
Eleotris sandwicensis	<0.25	0.44	0.12	0.44	1.2
Kaelepulu Stream ②					
Crab, blue-pincher					
Thalamita crenata	<0.25	0.48	<0.12	1.5	22
Fish, 'o'opu 'akupa					
Eleotris sandwicensis	<0.25	0.27	<0.12	0.29	1.3
spike recovery	90%	98%	88%	94%	94%

	Hg	Ni	Pb	Se	Zn
Kawainui Stream ①					
Crab, blue-pincher					
Thalamita crenata	0.015	2.0	0.55	<1.0	32
Fish, 'o'opu 'akupa					
Eleotris sandwicensis	0.005	<1.2	<0.12	<1.0	30
Kaelepulu Stream ②					
Crab, blue-pincher					
Thalamita crenata	0.021	1.2	0.82	<1.0	32
Fish, 'o'opu 'akupa					
Eleotris sandwicensis	0.008	<1.2	0.31	<1.0	24
spike recovery	89%	93%	89%	121%	78%

Units for tissue concentrations of metals is mg/Kg wet tissue weight (ppm).

① - Four blue-pincher crab (176.8 gms) from Kawainui Stream Sta. 2 in AECOS (1992a), located at Sta. 1 of Kailua Gateway Baseline Survey. Two 'o'opu 'akupa (33.1 gms) from Kawainui Stream Sta. 1 in AECOS (1992a), located near upper end of canal.

② - Four blue-pincher crab (168.7 gms) and two 'o'opu 'akupa (41.7 gms) from Sta. 4 in AECOS (1992a), located on Kaelepulu Stream below Keolu Drive bridge.