

**WATER QUALITY
MONITORING REPORT FOR THE DEVELOPMENT
OF THE SHORES AT KOHANAIKI, NORTH KONA
PRELIMINARY BASELINE SURVEY
3, 5 AND 18 APRIL 2005 SURVEYS**

Prepared For:

Rutter Development Corporation
18012 Cowan, Suite 200
Irvine, California 92614-6810

By:

Richard Brock, Ph.D.
Environmental Assessment, LLC

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EXECUTIVE SUMMARY

The preliminary water quality baseline study for the Shores at Kohanaiki development has been undertaken using an agency-approved water quality monitoring plan. This program collects and analyzes water quality samples along eight marine onshore-offshore transects; five of these transects are located in the waters fronting the Kohanaiki project site, the sixth is 1.2 km to the north (near Wawaloli Beach) and the last two are to the south, being located offshore of the Kaloko-Honokohau National Historical Park. Data from the three transects located away from the project site serve as controls and are used for comparative purposes. Eight samples are collected on each transect thus 40 samples are collected offshore of the project site and 24 from the three control site transects during each sampling period for the marine portion of the monitoring program.

The Hawaii State Department of Health Administrative Rules require the collection of marine water quality samples on three separate occasions within a two-week period to establish preliminary baseline conditions. Accordingly, marine sampling was carried out on 3, 5 and 18 April 2005 and this document provides the results of this three-part survey. The marine water quality results show the usual onshore-offshore gradients of concentration in several of the parameters (nitrate nitrogen, total nitrogen, orthophosphorus, total phosphorus and silica) where concentrations are greater in the effluxing groundwater relative to the marine receiving waters. These gradients are commonplace and within the range often encountered on the West Hawaii coast. West Hawaii regional water quality standards apply to seven water quality parameters (i.e., nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorophyll-*a* and turbidity). Data from each survey are averaged over the three periods for each onshore-offshore transect and these results are used in determining compliance with the State Regional Standards. Six of the seven parameters do not meet regional standards; the only parameter in compliance at all eight transects is chlorophyll-*a*. At a minimum, one or more (up to 5) parameters are out compliance on each of the eight transects. Summarizing these data: (1) total nitrogen is out of compliance on more transects (6 of 8) than any other parameter, (2) ammonia nitrogen is out of compliance at all three of the control site transects, (3) the greatest geometric means (i.e., farther from compliance) are found at control site transects relative to transects fronting the Kohanaiki project site, and (4) if a parameter is out of compliance at some stations fronting the Kohanaiki project site, it is similarly out of compliance at some of the control stations. These data suggest that despite the fact that there is no immediate coastal development fronting any of the eight transect sites at this time, many parameters are out of compliance suggesting that the standards are too stringent and do not reflect the natural variability of the area and the geographically widespread range of noncompliance suggests coast-wide trends rather than some geographically-isolated input. These results are very similar to those found at many other South Kohala, North and South Kona project sites, whether developed or not.

Besides sampling marine waters, the Kohanaiki water quality monitoring program samples the low-salinity groundwater in anchialine pools on the project site. At present, 16 anchialine pools are sampled; these pools roughly lie in a shoreline to inland transect approximately in line with each of the five marine water quality transects that front the project site. It is expected that as the

project site is cleared of encroaching vegetation, more anchialine pools will be uncovered and added to the list of routinely sampled sites. Thus it is expected that the number of sampled sites will increase to about 35 locations. Because the Shores at Kohanaiki is environmentally sensitive, the project intends to seek and receive Silver rating for the golf course by Audubon International. Thus, Audubon International requires additional water quality sampling at seven locations on the project site. On the 5 April 2005 survey water quality samples were collected from the 16 anchialine pool sample sites as well as at the Audubon International sites. In summary, water quality in the Kohanaiki anchialine system is similar to anchialine pools elsewhere on the Kona coast. The concentrations of nutrients appear to be high relative to nearby marine sites, but these concentrations are not unusual.

Further studies have been or need to be completed to finish the final preconstruction baseline for the Shores at Kohanaiki. Data from the completed June 2005 sampling effort has not yet returned from the laboratory and samples for pesticide analyses must be collected. The pesticide sampling requires completion of the two inland water quality monitoring wells and these should be done by late September 2005. Baseline pesticide analyses will entail sample processing for about 80 products.

In summary, water quality in the Kohanaiki anchialine system as well as in the adjacent near shore marine system is typical of that seen elsewhere along the Kona coast. The concentrations of parameters measured in these coastal water surveys are well within the range measured at other developed and undeveloped sites along the West Hawaii coast and are representative of well-flushed Hawaiian coastal waters.

INTRODUCTION

The Shores at Kohanaiki development covers about 448 acres situated between the Queen Kaahumanu Highway and the shoreline in North Kona. The project site is bounded by the Kaloko-Honokohau National Historical Park to the south and the O'oma parcel (O'oma 1 and 2) to the north. The development encompasses about 1.45 km of coastline. The development is a low density residential/golf community consisting of an 18-hole championship golf course, with a maximum of 500 single family residences. Additional project components include recreational facilities for residents as well as associated infrastructure (roads and utilities, etc). The developer has committed 109 acres for the development of a public shoreline park which will have public access and other amenities (parking, restrooms, etc.). When combined with the existing public shoreline acreage, the total open space will be about 128 acres along the shoreline.

The project site is undeveloped and in the past had been used for cattle grazing. Prior to that, old Hawaiian activities on this site probably included fishing, agriculture and aquaculture in some of the anchialine pools on the project site. In recent years the parcel has been fallow and public use of the shoreline/near shore marine resources began in earnest following the development of the Queen Kaahumanu Highway and the Natural Energy Laboratory of Hawaii Authority access road in the late 1970's.

Average annual rainfall on the project site is less than 20 inches and the majority of the project site (probably ~70%) is covered by pahoehoe lava and to a lesser extent, a'a lava. Scattered along the coastal area are natural depressions in the predominant pahoehoe substratum which intersect with the underlying groundwater table. These aquatic features are known as anchialine pools. Anchialine pools are characterized as bodies of water in proximity to the ocean, not having any surface connections to the sea, yet showing measurable salinities and undergoing tidal fluctuations. The coastal region on the project site has about 140 identified anchialine pools which represents one of the single largest concentrations in Hawaii. Anchialine ponds have brackish water with a crustacean-mollusk dominated community including several species of shrimps unique to these systems. The ponds undergo a natural process of senescence over time, changing from barren lava pools to ponds with sediment bottoms and aquatic vegetation, and finally to partially filled wetlands and finally to entities with no surface water and containing grasses, shrubs and trees.

Despite having one of the single greatest concentrations of anchialine pools on Hawaii Island, many of the ponds at Kohanaiki have been biologically-degraded by the introduction and spread of alien fish which have displaced many of the native endemic crustacean species or badly overgrown by alien vegetation which speeds up senescence. A preliminary survey of the anchialine resources noted that only 83 locations contained water at the time of sampling (Brock

2003a) with the remainder of the basins either dry or filled with primarily non-native vegetation. Of the 83 sites with water, only 30 pools contained the normal complement of native endemic species while another 40 ponds were found with alien fishes. Thus much of the Kohanaiki anchialine resource is degraded but should improve under the agency-approved management program now in place (Brock 2004).

1. Purpose

The proposed 448-acre Shores at Kohanaiki development could potentially impact the quality of coastal groundwater as well as the marine receiving waters adjacent to the project site. Ultimately with declines in water quality, both anchialine pool and marine communities resident to the receiving waters could also be negatively affected. Because of the potential for impact, regulatory agencies often require the development of monitoring and mitigation plans to protect water quality and aquatic communities resident to the receiving waters for projects occurring in coastal settings.

Accordingly, in granting permits to allow the development at Kohanaiki to proceed, the Hawaii County Council change of zoning (Condition R) states:

"An anchialine pond management plan shall be submitted to and approved by the Planning Director within one year from the effective date of the ordinance or prior to conducting any land preparation activity in the affected area. The management plan shall be developed in consultation with the Army Corps of Engineers and the U.S. Fish and Wildlife Service. The objective of the management plan shall be to: (1) maintain the environmental integrity of the existing ponds, (2) protect and manage this resource to provide educational and interpretative opportunities to the public, (3) control and monitor construction activities so that impacts may be identified and mitigated to avoid any detrimental impacts to the ponds, and (4) provide for a pond manager to implement the management plan and conduct scientific monitoring programs. The management plan will detail the area of the ponds to be preserved, the dimensions of buffer zones surrounding the pond area, allowable activities within pond areas, if any, and establish a pond management program."

This condition required the development of a comprehensive water quality monitoring program to insure that degradation of the ground, anchialine pool and near shore marine waters would not occur and they are to remain in a pristine state. This document was developed, submitted and approved by the regulatory agencies (Brock 2003b) and serves as the basis for the present monitoring program.

2. Rationale/Approach

With any coastal development the potential exists for negative impacts to occur on resident

aquatic biota. Potential environmental degradation processes may be minimized if the proper information is assembled early on in any coastal development scheme. Environmental data can serve to identify areas that may be susceptible to anthropogenic impacts, or conversely, particularly resistant to such impacts. An objective of any environmental baseline assessment is to establish quantitative information to accurately depict the community structure of the extant aquatic (anchialine pool) communities as well as describe the physio-chemical environment. Aquatic community structure can be defined by the abundance, diversity and local distribution of all macrofauna and flora. The information so collected will serve to identify living aquatic resources that may be of significant commercial, cultural, recreational or scientific importance or that may represent rare or unique ecological features that could be especially susceptible to human-induced impacts. The quantitative description of the physio-chemical environment provides the baseline upon which the subsequent monitoring can be compared; significant deviation from the baseline may serve as an "early warning" of impact to the aquatic communities. Many anthropogenic impacts to aquatic communities emanating from coastal development are mediated by water. Activities on land creating potential pollutant problems are carried to the groundwater and/or near shore marine environment via water. Water is the common transport mechanism and this water may come from irrigation or from rainfall and runoff. Thus, a first means of detecting a potentially harmful impact to aquatic biota may be through changes in the quality of ground and/or receiving waters.

Marine environmental surveys and monitoring programs are usually performed to evaluate the feasibility of and ecosystem response to specific proposed activities. Appropriate survey methodologies reflect the nature of the proposed action(s). An acute potential impact (such as marine channel dredging that may be undertaken on other projects) demands a survey designed to determine the route of least harm and the projected rate and degree of ecosystem recovery. Impacts that are more chronic or progressive require different strategies for measurement. Management of chronic stress to an aquatic ecosystem demands identification of system perturbations which exceed the boundaries of natural fluctuations prior to proceeding with the project. Thus, a thorough understanding of normal ecosystem variability is required in order to separate the impact signal due to development from natural background variability. This understanding is achieved by the implementation of a quantitative monitoring program established during the preconstruction or baseline period.

The potential impacts confronting the anchialine pool and marine ecosystem on or fronting the proposed Shores at Kohanaiki development are most probably those associated with chronic progressive stresses. Human activities well inland and to the north and south of the Kohanaiki project site have been ongoing for many years providing a potential source of impact to the ground, anchialine pool and near shore marine water quality at the project site. The human use of resources along the Kohanaiki shoreline likewise could contribute to potential chronic stress in the aquatic communities.

In West Hawaii where surface runoff is rare, the major source of changes to water quality due to development in the near shore marine environment fronting the project site is via the

groundwater. Thus, the strategy proposed in the baseline work will be to sample known points where groundwater (1) occurs in open exposures prior to entering the sea (i.e., the anchialine pools), (2) in coastal monitoring wells drilled specifically for this purpose and (3) sampling in the marine environment where groundwater does enter the sea. A second part to the baseline sampling strategy will be to sample water quality during periods of relatively low rainfall ("dry" periods) and again following a periods of local heavy rainfall (if it occurs).

Potentially with sufficient rainfall, materials could be carried to the sea via surface runoff from the Kohanaiki project site but the high porosity and little change in elevation through the project site (from sealevel to about 24 m at more than a kilometer inland) suggests that the probability of this happening is very low. High rainfall, like irrigation, could carry materials from anthropogenic activities carried out on the surface through the porous lava to the seaward moving groundwater beneath and into the anchialine pools and the adjacent ocean. Thus water quality monitoring following high rainfall events could assist in identifying the extreme of the envelope of natural variability in parameter concentrations. Sampling during dry and following wet or high rainfall events should provide information on water quality at two extremes of the envelope of variability during the baseline period and is described in greater detail below.

A. Rationale for "Wet" Period Sampling Trigger

Water quality monitoring will be on a bimonthly basis at Kohanaiki with this schedule continuing through the baseline and during construction periods. However as noted above and in recognition of the fact that high rainfall events may accelerate the movement of materials from anthropogenic sources from the project site to anchialine pools and the sea, water quality sampling should be carried out following high rainfall events. What constitutes a "high rainfall event" at Kohanaiki? To objectively answer this question, rainfall as recorded at the Kailua-Kona Keahole Airport which is about 4.2 km north of the project site was examined over the last eleven years. These data span from many days and months of no rainfall to 3.0 inches in 24 hours as a maximum which occurred on two occasions over the eleven-year period. Table 1 presents a summary of the frequency of rainfall events of different magnitudes and the probability of one of these events occurring in an average year based on these data. If a 1.5-inch in 24 hours water quality sampling trigger is selected, we may expect to have to conduct a "wet" period survey 1.5 days per year. Thus, using this rainfall trigger, there would be a reasonable opportunity to have at least one "wet" period sample effort during the year-long baseline survey period. A 1.5-inch in 24 hours rainfall at Kohanaiki with the porous substratum and small change in elevation through most of the project site suggests that there would be little opportunity for surface runoff to occur into either anchialine pools or the ocean but the rainfall could serve to carry materials (via leaching) to the underlying groundwater which could appear in the anchialine pools and adjacent ocean.

The State of Hawaii Airports Division monitors daily rainfall at the Kailua-Kona Keahole Airport. These data are available on the web being updated every 12 hours making notification of when to sample for a "wet" event a simple matter.

METHODS

Sampling protocols follow those as given by the West Hawaii Coastal Monitoring Protocols (1992) and those as given in the Department of Health, Hawaii Administrative Rules, Title 11, Chapter 54 adopted in April 2000. Water quality parameters that are evaluated include those as stipulated by the Department of Health for Class AA open coastal waters as given in 11-54. These parameters include the specific criteria of ammonia nitrogen (NH_4), nitrate + nitrite nitrogen ($\text{NO}_3 + \text{NO}_2$, hereafter referred to as nitrate or NO_3), total nitrogen (TN), orthophosphorus (PO_4), total phosphorus (TP), chlorophyll-*a* (chl-*a*), turbidity, as well as the nonspecific criteria of temperature, pH and salinity. In addition, dissolved silica (Si) is measured due to its usefulness as a conservative groundwater tracer. Total organic nitrogen (TON) is calculated as the difference between total nitrogen from ammonia nitrogen plus nitrate nitrogen and total organic phosphorus (TOP) is calculated as the difference between orthophosphorus from total phosphorus. Methods and sample sites are fixed thus making all data collected through time directly comparable. Water samples are collected in the marine environment and in anchialine pools on the project site.

Water samples are collected by opening 500 ml polyethylene bottles at the desired depth. Deep samples are collected using a 2-liter Niskin bottle which is lowered to the appropriate depth and the sample collected. On the surface, the sample is transferred to the 500 ml polyethylene bottle. All bottles are acid-washed in the laboratory and triple-rinsed in the field using the sample water prior to sample collection. Subsamples for nutrient analyses are filtered through Whatman glass fiber filters (GF/F, 0.7 μm particle retention) and immediately placed in 125 ml acid-washed, triple-rinsed polyethylene bottles and stored chilled until analysis in the laboratory. Filters are retained for chlorophyll-*a* analysis. Analyses for ammonia nitrogen, orthophosphorus and nitrate are performed using a Technicon autoanalyzer following standard methods for seawater analysis (Strickland and Parsons 1972, Grasshoff 1983). Total nitrogen and total phosphorus are measured from non-filtered sample water and similarly analyzed following digestion (Standard Methods 1999). *In situ* field measurements are made for temperature using a thermometer with a readability of 0.1 $^{\circ}\text{C}$, oxygen with a meter having a readability to 0.01 mg/l and pH with a field meter with a readability of 0.01 units. All samples are handled as per the 20th Edition of Standard Methods (1999) and nutrient analyses are carried out by an EPA-certified laboratory.

Analysis of nitrate+nitrite nitrogen, orthophosphorus, ammonia nitrogen and silica are carried out on a Technicon AAl system with standard procedures modified for high precision analyses. Total nitrogen and total phosphorus are analyzed in a similar fashion following ultraviolet (UV) digestion. The limits of detection (precision) and accuracy of nutrient determinations are as follows: total nitrogen accuracy = 0.5 μM or 7.00 $\mu\text{g/l}$, limits of detection = 0.2 μM or 2.8 $\mu\text{g/l}$; total phosphorus accuracy = 0.04 μM or 1.24 $\mu\text{g/l}$, limits of detection = 0.02 μM or 0.62 $\mu\text{g/l}$; orthophosphorus accuracy = 0.02 μM or 0.62 $\mu\text{g/l}$, limits of detection = 0.01 μM or 0.31 $\mu\text{g/l}$; nitrate+nitrite nitrogen accuracy = 0.05 μM or 0.70 $\mu\text{g/l}$, limits of detection = 0.03 μM or 0.42 $\mu\text{g/l}$; ammonia nitrogen accuracy = 0.08 μM or 1.12 $\mu\text{g/l}$, limits of detection = 0.03 μM or 0.42

ug/l; and silica accuracy = 0.5 uM or 14.00 ug/l, limits of detection = 0.2 uM or 5.60 ug/l.

Turbidity is determined on 60 ml subsamples fixed with HgCl_2 to terminate biological activity using a laboratory nephelometer (limit of detection = 0.01 NTU, accuracy = 0.02 NTU). The nephelometer is calibrated as specified by the Environmental Protection Agency with standard formazin solutions prior to and after sample measurements. Prior to measurement, samples are thoroughly mixed to disperse particulate materials and measured in duplicate when all air bubbles disappear. Salinity is determined using an AGE laboratory salinometer (limit of detection = 0.0001 ‰, accuracy = 0.003 ‰). Chlorophyll-*a* is measured by filtering 200 ml of water through glass fiber filters (GF/F); pigments retained on filters are extracted and assessed fluorometrically as per Standard Methods (1999) with a limit of detection = 0.01 ug/l, and accuracy = 0.03 ug/l.

In the field oxygen is measured using a YSI Model 58 meter, pH is determined using a Hanna millivolt meter and temperature is measured using a laboratory grade thermometer. Anchialine biota is quantitatively assessed in pools by use of small 0.1 m² quadrats which are placed in pools for use in making quantitative counts of motile species. In making these counts, only native species are enumerated; no attempt is made to census alien species such as fishes.

Statistical and other data procedures are described where used in the text. In general to avoid assumptions of normality in the data, non-parametric methods are used (Siegel 1956, SAS Institute, Inc. 1985).

Water quality samples are collected in duplicate to assist in quality assurance/quality control (QA/QC) program. These "blind" samples are collected, handled, and forwarded to the laboratory where they are processed along with all others. Comparative analysis of the replicated "blind" samples affords a measure of QA/QC. This coupled with the fact that all sample processing is carried out by EPA and state approved laboratories should insure that all sample handling and processing is in conformance with accepted procedures and limits. The samples for QA/QC usually comprise about 5% of the total number collected on a given survey.

RESULTS AND DISCUSSION

The monitoring plan called for baseline water quality sampling to commence one year in advance of any construction activity on the Kohanaiki project site. The proposed monitoring plan was written and submitted in late 2003 for comment and approval from regulatory agencies. However, approvals for the monitoring plan by all regulatory (and other) parties was not completed until mid-March 2005. The initial baseline sampling representing this report commenced in April 2005. As noted above, the Shores at Kohanaiki will include a championship golf course. Because of their awareness of the environmental issues related to anchialine pools, the golf course, ground and coastal marine water pollution, the developers wanted the highest environmental standard applied to the development and operation of the golf course. To meet

this objective, Audubon International visited the project site and developed an environmental monitoring plan for the Shores at Kohanaiki (Audubon International 2005) which was received in mid-March 2005 and incorporated into the present environmental monitoring program. The ongoing monitoring program should fulfill those Audubon requirements; if other requirements are met (i.e., reduced pesticide use, appropriate handling/storage, etc), the Shores at Kohanaiki Golf Course should have a Silver rating by Audubon International.

The initial grading of access roads commenced on or about 20 July 2005 leaving a short "preconstruction" window of time for baseline sampling. The DOH Administrative Rules (Chapter 11-54) require that initial baseline marine water quality monitoring along the West Hawaii coastline be carried out on three occasions within a 14-day period. To meet this requirement, marine water quality sampling was completed on 3, 5 and 18 April 2005. During the 5 April field work, samples were also collected from anchialine pools on the project site. A condition placed on this water quality monitoring program by DOH is that field sampling is to occur bi-monthly; to meet this condition, samples from all sites (i.e., marine and anchialine pool) were again collected on 16 June 2005. The water quality monitoring program has been approved by the Planning Department, County of Hawaii as well as by the Hawaii State Department of Health.

A. Selection of Marine Sample Sites

The West Hawaii Coastal Monitoring Protocols (1992) as well as the Department of Health West Hawaii regional water quality standards [11-54-06(d)(iii)] indicate that marine water quality samples be collected along a linear transect that extends from shore to anywhere from 500m to 1 km offshore (see Hawaii State Department of Health 1997). Past experience suggests that samples be collected just under the surface (~20 cm deep) at the shoreline, 10 m, 50 m, 100 m, 200 m, and 500 m offshore, as well as at a point about one meter above the bottom at the 10 m and 50 m sample points. Sampling in this fashion will allow delineation of any groundwater inputs which are the usual source of anthropogenic materials arriving into the ocean along the West Hawaii coast and also meet the requirements of the regulatory agencies. Note that the samples collected "at depth" are not used in the determination of geometric means but provide important information about *in situ* generation of ammonia nitrogen, etc.

The objective of the ocean water quality monitoring program are (1) to quantify the concentration of measured parameters in the marine environment fronting the project site prior to any construction activities and determine the envelope of natural variability in the concentrations of these materials, (2) to quantify any input of these parameters from the project site during and following the completion of construction. To meet these objectives requires delineation of inputs from the project site separating these from inputs coming in from other areas. In the marine waters fronting the project site, sources for the measured parameters in this study come from (1) marine waters adjacent (both north and south) of the project site, (2) from groundwater entering the ocean in the intertidal/shallow subtidal along the project site, (3) from runoff emanating from the project site following heavy rainfall (a low probability on this project site), and (4) for some

parameters (i.e., ammonia nitrogen) there may be *in situ* generation by biological activity. Separation of the sources of these materials is made by sampling at sites ranging from the shore in a seaward direction both from the surface as well as at depth. In general, inputs from land will create concentration gradients because inorganic nutrients occur in low concentrations in offshore oceanic waters. Thus a number of samples taken in an onshore to offshore series will serve to identify inputs coming from land (i.e., sample through any existing gradients). Materials coming from other sources to the north and south of the project site can be identified and separated by establishing the onshore-offshore sampling points close to the north and south boundaries of the project site as well as at a location north of the project area (about 1.3 km north of the north boundary of the project site - at Wawaloli Beach), a second located to the south fronting Kaloko Fishpond (about 500 m south of the south project boundary) and a third approximately 750 m south of the Kaloko Fishpond transect offshore of Kaloko Point (both of the latter two sites are in the Kaloko-Honokohau National Park). The two Kaloko and Wawaloli Beach transects serve as three control locations where groundwater flows that are probably similar to those at Kohanaiki are known to occur. Data from these north and south locations as well as from the "boundary" samples can be compared to samples taken offshore of the middle section of the project site. To address the question of materials being generated *in situ*, the boundary and control samples can again be compared to samples collected in an onshore-offshore transect series in the central part of the project site. All comparisons and analyses are carried out using accepted statistical procedures.

As noted above, low salinity groundwater often has relatively high inorganic nutrient concentrations relative to seawater. Being lighter, low salinity groundwater will overlie denser, warmer seawater. Of course mixing by wind and waves will serve to break down this stratification with time. Thus the highest nutrient waters are often at the surface in a lower-salinity layer with is best developed close to shore. Because of this, samples are collected from just under the surface in the low salinity water layer.

Five onshore-offshore transects of water quality samples have been established fronting the Kohanaiki project site and the three transects (one north at Wawaloli Beach and two to the south at Kaloko) serve as control sites. Eight water quality samples are collected on each transect yielding a total of 40 marine samples from waters fronting the project area and 24 samples from the control sites. The locations of transects are given in Figure 1; transects established offshore of the project site are at the north boundary (Puhili Point), a second about 530 m south at a point north of the large mangrove stand, a third transect about 500 m south of the second (south of the mangrove stand) a fourth transect 450 m south of the third transect offshore of Wawahiawaa Point and a fifth transect located about 530 m to the south of the fourth transect and close to the south boundary of the project site. Along each transect samples are collected from the shoreline (lowest sample number) to a point 500 m from shore (highest sample number; see Figure 1).

The selection of marine sample sites concentrates the collection of samples in waters close to shore where inputs from land would be most noticeable. This sampling strategy allows scaling of water chemistry parameters to salinity or other conservative tracers (silica) and is applicable to a

hydrographic mixing model that has been established as an effective method of determining changes in chemical make-up of groundwater discharge (Dollar, Brock and Smith 1995). In addition, the method allows identification of chemical sources on land that are contributing to material input to the marine environment.

B. Selection of Ground and Anchialine Pool Water Quality Monitoring Sites

With approximately 140 identified anchialine pools at Kohanaiki spread along 1.45 km of coastline, the selection of sample sites in anchialine pools is important since not every water exposure can be sampled during routine monitoring. The objectives of the groundwater monitoring program are to ascertain the quality of the groundwater as it enters the project site on the mauka (inland) side and as it leaves the project site on the makai (ocean) side of the project site. Differences in measured concentrations of parameters between samples collected on the mauka side to those collected on the makai side provide information on inputs occurring on the project site. Additionally, these data also provide insight as to the quality of the groundwater entering the sea from the project site.

Along much of the makai side of the project site are the ~140 anchialine pools from which water samples can be collected. Ideally, water quality samples are collected from anchialine pools inland of each of the marine water quality transects at Kohanaiki. In many locations the anchialine pools occur roughly in a "transect" that commences near the ocean and extends inland. Thus to the extent possible, anchialine pools that occur in a mauka-makai orientation in an alignment with each of the marine water quality transects are sampled. However as noted above, many anchialine pools in the Kohanaiki project site are overgrown with vegetation often creating near-impenetrable thickets. Thus in the early preconstruction phase, sampling is carried out in anchialine pools that (1) have water present during most tidal phases, (2) are not completely overgrown with impenetrable vegetation, and (3) roughly in line with one of the five marine transect sites fronting the project site.

Anchialine pools presently sampled include nos. 14, 17 and 24 (the Puhili Point north transect alignment, ponds located from 100 to 230 m inland), transect north of the mangrove stand (pond nos. 65, 72 and 49, 70 to 165 m inland), transect south of the mangrove stand (pond nos. 92, 84, 85 and 81, 120 to 260 m inland) transect at Wawahiwa Point (pond nos. 109, 115 and 101, 105 to 240 m inland) and transect near the south boundary of the project site (pond nos. 137, 126 and 128, 45 to 75 m inland). The locations of the sampled pools is given in Figure 1. As the project site is cleared of encroaching vegetation, it is expected that additional anchialine pools will be added to the list of routine monitoring points.

The anchialine pools serve as groundwater sample points in the makai or coastal portion of the project site. However there are no anchialine pools near the mauka or inland boundary (near Queen Kaahamanu Highway). Thus, monitoring of groundwater along the mauka portion of the project site (as it enters beneath the project site) will commence as soon as two groundwater monitoring wells are drilled. These wells will be located near the inland boundary of the project

site probably close to the north and south corners of the project site (Figure 1).

C. Audubon International Sample Site Selection

As noted above, the Audubon International Natural Resource Management Plan Monitoring Program for the Shores at Kohaniki Golf Course requires the collection of water samples from specific locations in the project site. The locations of these sites as selected by Audubon scientists are given also in Figure 1 where GW-1 and 2 are the yet to be completed monitoring wells, GW-3 through 7 are five anchialine pool sample sites and SW-1 is an yet to be constructed artificial lake. The five anchialine pool sample sites also coincide with five of the routine water quality monitoring sites, where GW-3 = site 126, GW-4 = site 115, GW-5 = site 84, GW-6 = site 49 and GW-7 = site 14 (see Figure 1). Analytes sampled in water samples include pH, temperature, specific conductance, dissolved oxygen, chlorophyll-*a*, total nitrogen, nitrate-nitrite nitrogen, ammonia nitrogen, total phosphorus, orthophosphorus, total dissolved solids and turbidity. Also included are pesticide scans.

D. Water Quality Gradients

This report presents data from the initial three surveys that were carried out within a 15-day period (3, 5 and 18 April 2005). The data from these three surveys are given in Appendices 1, 2 and 3. Marine water samples were collected during the ebb tide; tide heights as follows: 3 April 2005 from 0.0 to +0.2 feet, 5 April 2005 from -0.2 to 0.0 feet, and 18 April 2005 from +0.05 to +0.3 feet.

Examination of the water quality data for marine surface samples as given in Appendices 1 - 3 show the usual gradients due to groundwater (which usually has some parameters in relatively high concentration) effluxing along the shoreline establishing gradients of concentration of these parameters due to their relatively low concentrations in more offshore ocean water. Among the constituents showing these concentration gradients are nitrate nitrogen, total nitrogen, orthophosphorus, total phosphorus and silica. These gradients are most evident on the south boundary transect (Transect F, Figure 1), the Kaloko Pond and Kaloko Point control transects (Transects G and H, Figure 1) on 3 and 5 April 2005. These gradients are less evident in the 18 April 2005 dataset. The diffuse percolation of groundwater to the sea is most evident on Transects F, G and H particularly at stations close to land where salinity is depressed and the above constituents elevated. The groundwater contributes to the geometric means of many parameters not meeting State Department of Health West Hawaii Regional standards and this has been the case at many locations along the West Hawaii coast whether the coastal areas are developed or not (Brock, data from other project sites, 1980-present).

E. Compliance with State Standards

The Hawaii State Department of Health has developed specific criteria for different classes of waters in the state (e.g., as for harbors, streams and marine waters). Up to July 2000, Kona's

coastal waters (and those fronting the Kohanaiki project site) were classed as "Class AA Open Coastal Waters" and are to remain "...in their natural pristine state with an absolute minimum of pollution or alteration of water quality from any human-caused source or action" (Hawaii Administrative Rules, Chapter 11-54-01). The most stringent standards have been set for open coastal waters. In July 2000 new regional standards were implemented for the West Hawaii coastline; these standards utilize a regression approach for marine sample sites where salinity is along the shoreline is 32 parts per thousand (ppt) or less (Hawaii State Department of Health 1997). This approach attempts to account for natural high concentration of some parameters in effluxing groundwater. This regression approach is used in determining standards for nitrate+nitrite nitrogen, total nitrogen, orthophosphorus and total phosphorus on an area-specific basis (i.e., by transect site). Standards for other parameters are based on the 95% confidence interval derived from regression calculations performed by DOH personnel using water quality data collected from "undisturbed sites" along the West Hawaii coast thus are given as single numbers.

The Department of Health prepared a rationale and procedures reference document to be used in determining whether measured parameter concentrations in a given local meet or exceed the area-specific West Hawaii Regional Water Quality Standards (Hawaii State Department of Health 1997). These procedures require (page 12) that: "Samples along the transect must be collected on at least three occasions on different days over a maximum of 14 days during dry weather conditions. Observations are averaged and the regression calculations are performed on these mean values." Field sampling was completed on 3, 5 and 18 April 2005. The sampling on three occasions in a fourteen-day period was missed by one day because of vessel availability. As noted above, the data from the three surveys are given in Appendices 1, 2 and 3. The means based on the three surveys for each parameter on each of eight transects are given in Table 2 along with the calculated geometric means for each parameter.

The West Hawaii regional water quality standards along with the old "dry" coastline open coastal water quality standards are summarized in Table 3. Besides listing the standards, Table 3 presents the results of regression analyses for transect sites where salinity adjacent to shore was below the 32.0 ppt cutoff. The salinity means from two transect sites were below 32.0 ppt adjacent to the shoreline (Table 2) prompting use of the regression approach for determining compliance with the standards; these were the transect fronting the south boundary of the project site (Transect F) as well as the control transect offshore of Kaloko Pond (Transect G). These regression results are given in Table 3. The means calculated for the other six transects did not have a significant salinity gradient present, thus the "no salinity observed" criteria as given in Table 3 are used to determine compliance with the West Hawaii Regional Standards. As noted above, Table 2 presents the geometric means which are based on the average from the three survey dates for each parameter on each of the eight transects (A through H). Underlined geometric means in Table 2 are those not in compliance for the transects sites lacking a significant salinity gradient.

Because the delineation of compliance in parameters is somewhat confusing to some readers,

Table 4 presents a summary of the seven parameters that are measured for the determination of compliance with regional water quality standards. The seven parameters with numeric standards are: nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, turbidity and chlorophyll-*a*. In Table 4, the geometric means of parameters calculated in either Tables 2 or 3 that are out of compliance are noted with a "Yes" on the five transects established offshore of the Kohanaiki project site as well as at the three transects established as control sites. Several trends are apparent from this table: (1) lack of compliance is commonplace for all parameters except chlorophyll-*a* (which is a measure of phytoplankton biomass) at all locations; (2) total nitrogen is out of compliance on more transects than any other parameter (80% fronting the Kohanaiki project site and 67% fronting the control sites); (3) for most parameters out of compliance, the greatest geometric means are found at control stations (as per Tables 2 and 3), and (4) if a parameter is out of compliance at some stations fronting the Kohanaiki project site, it is similarly out of compliance at some of the control stations also. In summary, these data on compliance/noncompliance suggest that (1) despite the fact that there is no immediate coastal development fronting any of the eight transect sites at this time, many parameters are out of compliance on a given sampling date which suggests that (a) the standards may be too stringent and (b) the lack of compliance appears to be present through much of the more than 4.3 km of coastline sampled in this study which may indicate coast-wide trends.

Although not required by the Department of Health for determining regional water quality standards, examination of compliance among the geometric means from each transect and sampling date are instructive and support the generalizations given just above. Table 5 presents the geometric means calculated for each transect and sample date (these calculations are based on the data presented in Appendices 1, 2 and 3). In the 3 April 2005 survey the 32.0 ppt salinity criteria was not met on three transects (Transect A - Wawaloli Beach control site, Transect F - south boundary transect, and Transect G - Kaloko Pond control site). On 5 April 2005, the 32.0 ppt criteria was again not met at two transect sites (Transect F - south boundary and Transect G - Kaloko Pond control site) and on 18 April all transect sites had salinities above 32.0 ppt. Table 6 presents the results of the regression analysis carried out to determine compliance with standards for the five transects requiring this approach and Table 7 provides a summary of noncompliance for all transects on each of the three sample dates. In this table parameters out of compliance on the three dates are noted with a "Yes" at transects established offshore of the Kohanaiki project site as well as at the three transects established as control sites. Again the same trends are apparent from this table: (1) lack of compliance is commonplace for all parameters except chlorophyll-*a* (which is a measure of phytoplankton biomass) at all locations and survey dates; (2) total nitrogen is out of compliance on more transects and dates than any other parameter (87% of the time fronting the Kohanaiki project site and 78% of the time fronting the control sites); (3) for most parameters out of compliance, the greatest geometric means are found at control stations, and (4) if a parameter is out of compliance on a given date at some stations fronting the Kohanaiki project site, it is similarly out of compliance at some of the control stations on that date also. In summary, these data on compliance/noncompliance suggest that (1) despite the fact that there is no immediate coastal development fronting any of the eight transect sites at this time, many parameters are out of compliance on a given sampling date which again suggests that (a) the

standards may be too stringent and (b) the lack of compliance appears to be present through much of the more than 4.3 km of coastline sampled in this study.

These results are not unusual. Applying the state coastal standards to water quality data from many parts of the Kona coast often results in the geometric means for many parameters not meeting the standards whether the old or new criteria are applied. For example, the studies by Doty (1968) found the geometric mean for nitrate nitrogen in Kealahou Bay to be 79.10 ug/l (n=17) which is 1,200 times greater than the old dry standard of 3.50 ug/l. The monitoring program carried out by Marine Research Consultants (1990a, 1990b) in Kealahou Bay noted geometric means out of compliance for nitrate, ammonia, total nitrogen, total phosphorus, and chlorophyll-*a* using either the new regional or the old dry coast standards. Brock (2005) notes that during the ten-year baseline period, total nitrogen, total phosphorus, nitrate nitrogen, orthophosphorus and turbidity were out of compliance with state standards at Kukio, in North Kona despite the fact that there was no surrounding development in the area. An ocean water quality monitoring program has been in place at the Natural Energy Laboratory of Hawaii Authority (NELHA) at Keahole Point, Hawaii since 1982. The waters offshore of Keahole Point are considered to be pristine; the presence of high quality deep ocean water adjacent to shore was an important factor in locating the NELHA facility there. The long-term mean for ammonia nitrogen and nitrate nitrogen at Keahole Point are 5.04 ug/l and 2.80 ug/l respectively, both of which exceed the Kona regional standards. Thus, despite not meeting state standards for many parameters and sample sites, the waters fronting the Kohanaiki project site are typical of well-flushed, West Hawaii coastal settings.

The water quality standards represent human-imposed criteria on a natural system. The frequent lack of compliance of near shore marine waters in areas well-removed from any coastal development indicates that the criteria may be too stringent suggesting that further revision of the standards would be appropriate. The Department of Health is well aware of these shortcomings and is working towards better, ecologically-based standards. High concentration of inorganic nutrients such as nitrate nitrogen is not unusual in groundwater at other geographical locations. Johannes (1980) reported groundwater nitrate levels between 1,610 to 5,320 ug/l from Perth, Australia and Marsh (1977) noted nitrate concentrations in Agana, Guam groundwater of 2,492 ug/l which are well above any values found in the present study.

F. Anchialine Pools

Brock (2003a) summarizes the status of the Kohanaiki anchialine resource. Previous to this most recent study, others have inventoried some of the anchialine pools present at Kohanaiki. Maciolek and Brock (1974), OI Consultants (1985, 1990) and Maciolek (1987) all mapped and described biota in some of the pools. The most recent study (Brock 2003a) noted 140 anchialine pools in the Kohanaiki parcel. However, because of time constraints, most pools were only visited once and very few were examined during higher stages of the tide. Thus many of the ponds located did not have water present at the time of sampling but many of these did have vegetation that is characteristic of Hawaiian coastal wetlands. In summary, 83 locations were

surveyed that contained water at the time of sampling, 20 basins were damp to dry at sampling but contained wetland vegetation, another 32 basins were similarly damp to dry but without wetland vegetation (many of these were at the bottom of fissures or in caves) and five large heavily vegetated basins were identified as probably containing one or more anchialine pools or pool complexes.

Of the 83 ponds/pond complexes, only 30 were identified as having their usual complement of characteristic native endemic shrimp species and 40 ponds were found to contain alien fishes thus are biologically degraded. Another 13 water exposures were found that had neither native shrimp nor alien fishes, so it is presumed that native shrimp would probably be present at higher tide states when more water was present in these pools.

Approximately 53 percent of all the basins were found to be heavily vegetated and in need of some restoration (i.e., vegetation and/or removal of sediment). Examination of many of these same pond basins 30 years ago by the author found many of them to be in much better condition (i.e., less heavily vegetated). The rapidity of the changes that have occurred in many ponds in the last 30 years suggests that without intervention (i.e., restoration), many of these pools will probably completely disappear in the next 30 years. A pond management plan has been prepared (Brock 2004) that addresses the steps to be taken in the restoration and management of the Kohanaiki anchialine pool resource with the approval of the regulatory agencies.

In conjunction with the water quality monitoring of anchialine pools, native species present in these pools are monitored. The West Hawaii Coastal Monitoring Protocol (1992) calls for the quantitative enumeration of native anchialine species that are diurnally visible; primary species include the red pigmented opae'ula (*Halocaridina rubra*), the less abundant predatory alpheid shrimp, *Metabetaeus lohena* and the relatively clear shrimp species, 'opae'oha'a (*Macrobrachium grandimanus*) and 'opae (*Palaemon debilis*). These and other native species are censused in the sampled ponds using a 0.1 m² quadrat that is placed on different substratum types within each pond and counts visually made. Any native insects (specifically damselflies) seen around anchialine pools are identified and counted. The presence/absence of damselfly nymphs in the anchialine pools are not be assessed in order to avoid any collecting in these systems. Waterfowl and wading shorebirds present in the Kohanaiki anchialine pools are identified and counted during the monitoring surveys. It is expected that as anchialine pools with high biological integrity are identified (i.e., those pools with native species and lacking the alien fishes), they will be added to the group of ponds that will be routinely monitored.

Presently, sixteen anchialine pools are sampled as part of the Kohanaiki water quality monitoring program. As soon as the two groundwater monitoring wells are drilled along the inland boundary of the project site, these will be added to the list of sites to be routinely sampled. Additionally as the thick vegetative cover is cut back and removed, additional anchialine pools will be located. Some of these recently uncovered pools will be added to the list of sample sites. Thus once these pools have been made accessible, it is expected that about 35 sites on the project site will be sampled on a regular basis.

In the preliminary baseline water quality samples were collected from 16 anchialine pools. The approximate location of these pools are given in Figure 1. The selection of pools for sampling is based on their location on the project site; the primary objective is to sample pools that lie roughly in line with the five marine water quality transects so as to obtain a more comprehensive picture of any gradients in parameters that may exist on the project site. Water quality samples were collected from the sixteen anchialine pools on 5 April 2005 and these data are given in Appendix 2. Five of these sites are the same as those required by the Audubon International sampling program; the only additional parameter required by Audubon to the routine list of sampled parameters is total dissolved solids and these results are given in Appendix 2. Nutrient parameter concentrations appear high relative to marine sites, however, the concentrations are well within the range encountered in anchialine pools elsewhere on the West Hawaii coast.

Ammonia nitrogen is the product of organism metabolism. Water samples from anchialine pools containing alien fish always have ammonia nitrogen levels considerably elevated over pools that lack such fish but contain native fauna. Thus the nine pools with native shrimp species have a mean ammonia nitrogen of 15.63 ug/l while the six pools infested with alien fishes (topminnows, family Poeciliidae, see below) have a mean ammonia nitrogen concentration of 50.75 ug/l. Undisturbed anchialine pools are those lacking alien fish and the characteristic small red caridean shrimp or opae'ula (*Halocaridina rubra*) are monitored by estimating densities of these shrimp in 0.1 m² quadrats. The estimated abundance of opae'ula in the nine pools are presented in Table 8; these estimates are similar to those seen in many other West Hawaii locations.

G. Pesticide/Heavy Metal Sampling

As part of the acquisition of baseline data, sediment and water will be sampled from a number of locations in the Shores at Kohanaiki project site. The Audubon International (2005) monitoring plan requires the sampling of water at all seven Audubon sites and collecting a sediment sample at SW-1 (Figure1). Since the Audubon pesticide sampling program requires collection of water samples from the two mauka yet to be drilled groundwater monitoring wells, these samples have not been collected.

The Shores at Kohanaiki water quality monitoring program will be collecting additional pesticide samples. These samples focus on the sediments because many pesticides are known to bind with sediments and become sequestered there. The interest in this pesticide analysis is to examine samples for products that are widely used today on golf courses as well as the most common termiticide used to protect homes from damage by ground termites (Prelude). The common products include Carbaryl 4L, Roundup, Barricade 65WG, Gallery, Chipco 26GT, Daconil WeatherStik, Prostar 70WP, and Sencor. These sediment samples will be taken from a pond inland of Puhili Point, a second pond inland of the Mangroves and a third pool near the southern boundary of the project site. Besides these anchialine pools, marine sediments will be sampled offshore of Puhili Point and the southern boundary of the project site. Control station samples (one anchialine pool and one marine sample) will be collected at Makalawena which has no nearby development. All pesticide samples will be collected in a single sampling event planned

for late September 2005 following completion of the mauka monitoring wells. The rationale for undertaking this effort is that we should establish the baseline conditions with respect to materials that may be introduced by the development of this site. There is a small database to which we have substantially contributed which demonstrates that some heavy metals occur naturally at quite high concentrations in Hawaiian sediments. There is considerable local variability in these concentrations so we should establish a baseline for the project site.

CONCLUSIONS

The preliminary water quality baseline study for the Shores at Kohanaiki development has been undertaken using an agency-approved water quality monitoring plan. This program collects and analyzes water quality samples along eight marine onshore-offshore transects; five of these transects are located in the waters fronting the Kohanaiki project site, the sixth is 1.2 km to the north (at Wawaloli) and the last two are to the south, being located offshore of the Kaloko-Honokohau National Historical Park. Data from the three transects located away from the project site serve as controls and are used for comparative purposes. Eight samples are collected on each transect thus 40 samples are collected offshore of the project site and 24 from the three control site transects during each sampling period for the marine portion of the monitoring program.

The Hawaii State Department of Health Administrative Rules require the collection of marine water quality samples on three separate occasions within a two-week period to establish preliminary baseline conditions. Accordingly, marine sampling was carried out on 3, 5 and 18 April 2005 and this document provides the results of this three-part survey. The marine water quality results show the usual onshore offshore gradients of concentration in several of the parameters (nitrate nitrogen, total nitrogen, orthophosphorus, total phosphorus and silica) where concentrations are greater in the effluxing groundwater relative to the marine receiving waters. These gradients are commonplace and within the range often encountered on the West Hawaii coast. West Hawaii regional water quality standards apply to seven water quality parameters (i.e., nitrate nitrogen, ammonia nitrogen, total nitrogen, orthophosphorus, total phosphorus, chlorophyll-*a* and turbidity). Data from each survey are averaged over the three periods for each onshore-offshore transect and these results are used in determining compliance with the State Regional Standards. Six of the seven parameters do not meet regional standards; the only parameter in compliance at all eight transects is chlorophyll-*a*. At a minimum, one or more (up to 5) parameters are out compliance on each of the eight transects. Summarizing these data: (1) total nitrogen is out of compliance on more transects (6 of 8) than any other parameter, (2) ammonia nitrogen is out of compliance at all three of the control site transects, (3) the greatest geometric means (i.e., further from compliance) are found at control site transects relative to transects fronting the Kohanaiki project site, and (4) if a parameter is out of compliance at some stations fronting the Kohanaiki project site, it is similarly out of compliance at some of the control stations. These data suggest that despite the fact that there is no immediate coastal development fronting any of the eight transect sites at this time, many parameters are out of compliance

suggesting that the standards are too stringent and do not reflect the natural variability of the area and the geographically widespread range of noncompliance suggests coast-wide trends rather than some geographically-isolated input. These results are very similar to those found at many other South Kohala, North and South Kona project sites, whether developed or not.

Besides sampling marine waters, the Kohanaiki water quality monitoring program samples the low-salinity groundwater in anchialine pools on the project site. At present, 16 anchialine pools are sampled; these pools roughly lie in a shoreline to inland transect approximately in line with each of the five marine water quality transects that front the project site. It is expected that as the project site is cleared of encroaching vegetation, more anchialine pools will be uncovered and added to the list of routinely sampled sites. Thus it is expected that the number of sampled sites will increase to about 35 locations. Because the Shores at Kohanaiki is environmentally sensitive, the project intends to seek and receive Silver rating for the golf course by Audubon International. Thus, Audubon International requires additional water quality sampling at seven locations on the project site. On the 5 April 2005 survey water quality samples were collected from the 16 anchialine pool sample sites as well as at the Audubon International sites. In summary, water quality in the Kohanaiki anchialine system is similar to anchialine pools elsewhere on the Kona coast. The concentrations of nutrients appear to be high relative to nearby marine sites, but these concentrations are not unusual.

Further studies have been or need to be completed to finish the final preconstruction baseline for the Shores at Kohanaiki. Data from the completed June 2005 sampling effort has not yet returned from the laboratory and samples for pesticide analyses must be collected. The pesticide sampling requires completion of the two inland water quality monitoring wells and these should be done by late September 2005. Baseline pesticide analyses will entail sample processing for about 80 products.

In summary, water quality in the Kohanaiki anchialine system as well as in the adjacent near shore marine system is typical of that seen elsewhere along the Kona coast. The concentrations of parameters measured in these coastal water surveys are well within the range measured at other developed and undeveloped sites along the West Hawaii coast and are representative of well-flushed Hawaiian coastal waters.

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TABLE 1. Frequency of occurrence of 24-hour rainfall events based on data collected from May 1992 through May 2003 (4045 days) as measured at the Kailua-Kona Keahole Airport about 4.2 km north of the Kohanaiki project site. These data are presented in four rainfall categories as measured in a 24-hour period: 0.05 inches or more, 0.46 inches or more, 0.95 inches or more and 1.50 inches or more. The number of events and the probability of an event of this magnitude occurring are presented in the body of the table. Data from the National Weather Service.

Category	RAINFALL CLASS (inches)			
	0.05 inches or More	0.46 inches or More	0.95 inches or More	1.50 inches or More
No. of Events	250	80	36	17
Probability of occurrence in days/year	22.6 days	7.2 days	3.3 days	1.5 days

TABLE 2. Means (in ug/l unless otherwise noted; n = 3) of parameters for all marine surface samples collected along eight transects (A through H) based on 3 sample dates (3, 5 and 18 April 2005). Three transects (A, G, H) represent control sites while five (B, C, D, E, F) front the Kohanaiki project site. Below each transect are the calculated geometric means. Underlined geometric means exceed standards for transects where salinities are greater than 32.0 ppt. Complete data are presented in Appendices 1, 2 and 3.

TRANSECT	STATION NO.	SILICA	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	TON	TOP	SALINITY [PPT]	TURBIDITY [NTU]	CHL-a	TEMP [°C]	OXY [%]	pH
A	1	1615.05	100.24	3.49	277.67	15.28	23.25	173.94	7.97	32.537	0.17	0.263	24.7	101	8.12
A	2	543.08	34.88	3.19	189.84	9.11	14.67	151.77	5.57	34.010	0.11	0.168	24.6	100	8.12
A	4	590.89	37.28	5.51	195.81	8.50	14.47	153.02	5.97	33.938	0.12	0.141	24.6	99	8.12
A	6	724.67	42.28	6.48	206.03	8.71	15.60	157.27	6.89	33.735	0.09	0.136	24.7	100	8.09
A	7	698.21	39.73	6.05	213.73	8.32	15.91	167.96	7.60	33.809	0.09	0.146	24.7	99	8.13
A	8	137.22	2.91	5.62	174.30	5.14	10.46	165.77	5.32	34.467	0.10	0.128	25.1	101	8.12
GEOMETRIC MEAN		<u>574.58</u>	<u>29.33</u>	<u>4.88</u>	<u>207.24</u>	<u>8.72</u>	<u>15.30</u>	<u>161.42</u>	<u>6.48</u>	<u>33.744</u>	<u>0.11</u>	<u>0.159</u>	<u>24.7</u>	<u>100</u>	<u>8.12</u>
B	9	200.91	6.28	2.32	151.95	5.49	10.85	143.35	5.36	34.447	0.15	0.099	24.9	101	8.11
B	10	163.28	3.75	1.37	150.17	5.30	10.44	145.06	5.13	34.477	0.11	0.159	24.7	100	8.13
B	12	290.38	3.37	2.93	130.85	5.32	10.33	124.56	5.01	34.413	0.09	0.116	24.6	100	8.09
B	14	160.27	2.09	3.64	164.82	4.87	10.08	159.09	5.20	34.439	0.09	0.105	25.1	101	8.12
B	15	162.59	1.38	1.43	166.32	4.77	10.44	163.51	5.67	34.430	0.10	0.091	24.8	99	8.13
B	16	101.34	0.73	1.34	218.91	4.46	10.02	216.85	5.57	34.513	0.08	0.100	24.9	99	8.12
GEOMETRIC MEAN		<u>171.17</u>	<u>2.34</u>	<u>2.00</u>	<u>161.76</u>	<u>5.02</u>	<u>10.36</u>	<u>156.36</u>	<u>5.32</u>	<u>34.453</u>	<u>0.10</u>	<u>0.110</u>	<u>24.8</u>	<u>100</u>	<u>8.12</u>
C	17	249.98	2.86	1.44	149.66	5.22	10.54	145.36	5.32	34.296	0.15	0.135	24.9	100	8.12
C	18	281.95	4.32	2.56	151.90	5.28	10.64	145.02	5.37	34.245	0.10	0.177	24.9	101	8.10
C	20	340.89	5.21	2.17	137.25	5.37	10.85	129.86	5.48	34.151	0.10	0.129	24.6	101	8.08
C	22	366.24	6.05	2.97	158.71	5.49	10.64	149.69	5.15	34.106	0.09	0.123	24.7	101	8.08
C	23	205.68	2.76	1.89	145.83	4.89	10.54	141.18	5.65	34.361	0.10	0.099	24.7	101	8.12
C	24	83.05	0.81	0.85	131.09	4.48	10.02	129.43	5.55	34.538	0.08	0.106	24.8	99	8.14
GEOMETRIC MEAN		<u>230.58</u>	<u>3.09</u>	<u>1.84</u>	<u>145.45</u>	<u>5.11</u>	<u>10.54</u>	<u>139.87</u>	<u>5.42</u>	<u>34.283</u>	<u>0.10</u>	<u>0.126</u>	<u>24.8</u>	<u>100</u>	<u>8.11</u>
D	25	104.99	1.77	3.01	140.56	4.51	9.20	135.77	4.69	34.528	0.11	0.115	25.2	101	8.13
D	26	121.11	1.79	2.41	154.19	4.78	10.13	149.99	5.34	34.553	0.06	0.097	25.0	101	8.12
D	28	88.40	1.10	2.02	128.94	4.42	9.40	125.83	4.99	34.539	0.08	0.110	25.0	101	8.14
D	30	84.55	0.80	1.39	148.54	4.24	9.82	146.35	5.58	34.524	0.08	0.108	24.8	100	8.14
D	31	114.02	1.52	1.40	126.98	4.40	10.23	124.06	5.83	34.486	0.08	0.108	24.9	101	8.15
D	32	127.94	1.53	1.62	133.19	4.72	9.92	130.03	5.20	34.473	0.08	0.159	25.0	100	8.15
GEOMETRIC MEAN		<u>105.60</u>	<u>1.37</u>	<u>1.89</u>	<u>138.37</u>	<u>4.51</u>	<u>9.78</u>	<u>134.99</u>	<u>5.26</u>	<u>34.517</u>	<u>0.08</u>	<u>0.115</u>	<u>25.0</u>	<u>101</u>	<u>8.14</u>
E	33	401.07	9.09	1.70	158.71	5.49	10.95	147.93	5.46	34.079	0.08	0.168	25.0	101	8.15
E	34	142.02	2.34	2.08	148.73	4.73	10.13	144.30	5.40	34.570	0.07	0.134	25.1	101	8.14
E	36	172.65	3.31	2.26	123.11	4.61	10.02	117.54	5.41	34.415	0.07	0.118	24.9	100	8.09
E	38	195.35	4.98	1.38	153.02	5.20	11.26	146.66	6.06	34.405	0.06	0.105	24.8	100	8.13
E	39	223.02	5.78	1.70	141.12	4.97	11.06	133.64	6.09	34.356	0.06	0.103	24.7	99	8.16
E	40	204.75	3.97	1.64	132.63	4.79	9.20	127.02	4.41	34.390	0.06	0.116	24.6	101	8.14
GEOMETRIC MEAN		<u>210.77</u>	<u>4.48</u>	<u>1.77</u>	<u>142.36</u>	<u>4.96</u>	<u>10.41</u>	<u>135.71</u>	<u>5.44</u>	<u>34.369</u>	<u>0.07</u>	<u>0.122</u>	<u>24.8</u>	<u>100</u>	<u>8.14</u>

TABLE 2. Continued.

STATION TRANSECT	NO.	SILICA	NITRATE	AMMONIA	TOTALN	ORTHO-P	TOTALP	TON	TOP	SALINITY [PPT]	TURBIDITY [NTU]	CHL-a	TEMP [°C]	OXY [%]	pH
F	41	6770.34	289.11	10.88	396.48	32.43	53.32	96.49	20.89	25.871	0.15	0.375	24.5	99	8.17
F	42	990.93	31.89	2.49	155.91	8.43	15.71	121.53	7.27	33.422	0.06	0.194	24.7	100	8.16
F	44	1008.94	17.26	19.52	196.28	5.01	16.02	159.50	11.01	33.957	0.06	0.138	24.8	99	8.04
F	46	478.81	14.75	1.73	144.34	6.00	12.40	127.86	6.40	34.037	0.08	0.119	24.8	101	8.14
F	47	392.33	12.01	2.71	197.40	5.68	12.71	182.68	7.03	34.160	0.08	0.111	24.6	100	8.13
F	48	757.03	21.43	4.76	160.35	6.85	13.95	134.16	7.10	33.703	0.08	0.144	24.5	100	8.11
GEOMETRIC MEAN		993.67	29.08	<u>4.77</u>	195.27	8.27	17.58	134.28	9.00	32.371	0.08	0.163	24.6	100	8.12
G	49	5668.79	197.38	11.62	344.19	28.70	48.52	135.18	19.82	27.359	0.15	0.498	24.2	99	8.16
G	50	1425.17	38.56	4.92	165.15	10.03	18.81	121.68	8.77	32.966	0.16	0.230	24.5	99	8.14
G	52	1367.58	35.84	5.94	176.31	8.94	18.29	134.53	9.35	32.968	0.12	0.270	24.8	100	8.08
G	54	852.10	22.11	2.32	166.18	7.47	15.04	141.75	7.57	33.611	0.09	0.153	24.8	100	8.08
G	55	626.18	17.19	6.31	177.61	5.66	13.95	154.11	8.29	33.907	0.08	0.127	25.0	101	8.10
G	56	721.05	19.42	2.61	174.07	6.89	13.43	152.04	6.55	33.828	0.07	0.127	25.0	100	8.10
GEOMETRIC MEAN		1272.75	35.54	<u>4.85</u>	192.88	9.53	19.00	139.44	9.35	32.351	<u>0.11</u>	0.206	24.7	100	8.11
H	57	501.32	19.56	2.53	159.18	5.76	11.88	137.09	6.12	33.743	0.09	0.180	25.2	100	8.11
H	58	275.31	10.11	2.62	152.93	5.28	11.37	140.19	6.09	34.226	0.08	0.290	25.2	99	8.15
H	60	512.13	19.69	3.40	175.56	6.31	12.61	152.47	6.30	33.936	0.09	0.138	25.2	100	8.12
H	62	636.43	22.40	2.58	166.27	6.80	13.23	141.29	6.42	33.773	0.09	0.140	25.3	100	8.09
H	63	285.33	10.45	2.25	134.40	5.47	11.37	121.71	5.90	34.255	0.07	0.112	25.2	101	8.10
H	64	371.96	11.44	2.58	157.83	5.58	11.99	143.81	6.41	34.138	0.05	0.146	25.3	101	8.05
GEOMETRIC MEAN		410.35	<u>14.78</u>	<u>2.64</u>	<u>157.17</u>	<u>5.84</u>	12.05	139.11	6.20	34.011	0.08	0.160	25.2	100	8.10

TABLE 3. Three tiers of regional water quality criteria developed by the Department of Health for the Kona or West Hawaii coast. Included are the regional criteria for three parameters under all salinity regimes, those for all sites with no significant groundwater discharge as well as the old "dry" open coastal waters standard (geometric mean not to exceed). Also given are the results of the regression analysis to determine criteria for the lower salinity waters at transects where shoreline salinities were less than 32.0 ppt based on the means of parameters from each of the three sampling dates (see Table 1).

1. All Salinity Regimes: Single Value "Not To Exceed" Criterion For:
 Ammonia Nitrogen - Criterion = 2.5 ug/l
 Chlorophyll-a - Criterion = 0.3 ug/l
 Turbidity - Criterion = 0.1 N.T.U.
2. No Salinity Gradient Observed: Single Value "Not To Exceed" Criterion For:
 Total Nitrogen - Criterion = 100.0 ug/l
 Total Phosphorus - Criterion = 12.5 ug/l
 Nitrate+Nitrite Nitrogen - Criterion = 4.5 ug/l
 Orthophosphorus - Criterion = 5.0 ug/l
3. Salinity Gradient Observed: Site Specific Regression Coefficient (Slope- 95% Confidence Limit) For:

A. Preliminary Baseline Means for Transect F (South Boundary) (Stations 41, 42, 44, 46, 47, 48):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect F Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-16.68	No
Total Phosphorus =	-2.86	-4.37	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-32.74	Yes
Orthophosphorus =	-3.22	-3.02	No

B. Preliminary Baseline Means for Transect G (Kaloko Pond Control) (Stations 49, 50, 52, 54, 55, 56):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect G Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-19.65	No
Total Phosphorus =	-2.86	-5.16	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-26.22	No
Orthophosphorus =	-3.22	-3.17	No

(Table 3 Continued on Next Page)

TABLE 3. Continued.

4. Old Dry Criterion (Geometric Mean Not To Exceed):

Nitrate+Nitrite Nitrogen	=	3.50 ug/l
Ammonia Nitrogen	=	2.50 ug/l
Total Nitrogen	=	110.00 ug/l
Total Phosphorus	=	16.00 ug/l
Chlorophyll-a	=	0.15 ug/l
Turbidity	=	0.20 N.T.U.

TABLE 4. Summary of noncompliance of parameters with the DOH West Hawaii Regional Water Quality Standards for the geometric means based on the means from three April 2005 surveys for samples collected at surface marine stations fronting the Kohanaiki development in Part A and Part B shows the noncompliance with surface marine samples collected at the three control transects ("A" offshore of Wawaloli Beach, "G" fronting Kaloko Pond and "H" offshore of Kaloko Point during the same field surveys. "Yes" indicates noncompliance and blanks in the table indicate parameters in compliance for that sample date. At the foot of the table are given the % of the time that a parameter was not in compliance at stations fronting Kohanaiki or at control stations.

PART A - FRONTING KOHANAIKI PROJECT SITE

Transect	Parameter						
	NO ₃	NH ₄	TN	PO ₄	TP	Turb	Chl- <i>a</i>
B			Yes	Yes		Yes	
C			Yes	Yes		Yes	
D			Yes				
E			Yes				
F	Yes	Yes			Yes		
% Noncompliant	20	20	80	40	20	40	

PART B - FRONTING CONTROL SITES

Sample Date & Transect	Parameter						
	NO ₃	NH ₄	TN	PO ₄	TP	Turb	Chl- <i>a</i>
A	Yes	Yes	Yes	Yes		Yes	
G		Yes			Yes	Yes	
H	Yes	Yes	Yes	Yes			
% Noncompliant	67	100	67	67	33	67	

TABLE 5. Geometric means in ug/l unless otherwise noted from surface samples on each of the eight transects on each of three sample dates. Geometric means exceeding the regional water quality standards are underlined in the body of the table. However, if the transect data do not meet the salinity criteria of greater than 32.0 ppt, compliance for nitrate, total nitrogen, orthophosphorus and total phosphorus are calculated and given in Table 6. Note that Transects A, G and H are control sites.

Date & Transect	NO ₃	NH ₄	TN	PO ₄	TP	Turb (NTU)	Chl- <i>a</i>
3 April 05							
A	46.89	<u>6.95</u>	233.24	9.62	17.57	<u>0.11</u>	0.138
B	3.36	<u>3.20</u>	<u>145.05</u>	4.90	10.42	<u>0.11</u>	0.106
C	3.94	<u>2.73</u>	<u>136.73</u>	5.06	11.04	<u>0.11</u>	0.150
D	0.49	1.55	<u>124.42</u>	4.28	9.42	0.06	0.122
E	4.27	2.00	<u>124.73</u>	4.69	10.04	0.07	0.136
F	41.24	<u>5.69</u>	228.86	9.29	20.58	0.09	0.196
G	77.58	<u>8.24</u>	240.19	13.58	27.82	<u>0.10</u>	0.261
H	<u>13.26</u>	<u>3.09</u>	<u>154.54</u>	<u>5.58</u>	11.06	0.08	0.145
5 April 05							
A	<u>26.56</u>	1.09	<u>257.51</u>	<u>10.66</u>	<u>18.22</u>	<u>0.10</u>	0.238
B	1.44	0.66	<u>183.47</u>	<u>5.16</u>	11.61	<u>0.14</u>	0.125
C	1.61	0.83	<u>192.16</u>	<u>5.35</u>	11.76	<u>0.10</u>	0.124
D	0.78	0.73	<u>170.04</u>	4.53	10.64	0.08	0.122
E	<u>6.57</u>	0.96	<u>156.51</u>	<u>5.38</u>	11.52	0.05	0.115
F	48.05	2.08	238.29	11.59	20.91	0.08	0.189
G	43.08	<u>3.03</u>	227.61	11.56	21.31	<u>0.12</u>	0.237
H	<u>18.53</u>	1.43	<u>195.01</u>	<u>7.01</u>	<u>14.53</u>	0.08	0.154
18 April 05							
A	1.29	<u>4.24</u>	<u>130.62</u>	<u>5.46</u>	9.94	<u>0.10</u>	0.099
B	0.90	1.63	<u>145.64</u>	4.96	9.15	0.06	0.091
C	2.02	1.55	<u>104.35</u>	4.89	8.78	0.08	0.101
D	2.07	<u>3.27</u>	<u>119.48</u>	4.69	9.24	0.09	0.098
E	1.71	2.18	<u>139.43</u>	4.77	9.60	0.07	0.112
F	4.08	<u>4.92</u>	<u>131.50</u>	4.71	<u>12.68</u>	0.08	0.116
G	<u>4.73</u>	<u>3.85</u>	<u>136.78</u>	<u>5.69</u>	11.89	<u>0.10</u>	0.153
H	2.92	<u>2.51</u>	<u>120.15</u>	4.65	10.58	0.07	0.147

TABLE 6. Summary of regression analysis to determine criteria for the lower salinity waters at transects where shoreline salinities were less than 32.0 ppt or greater salinity criteria. Sample dates and transect sites so affected include 3 April 2005 Transects A, F and G and 5 April 2005 Transects F and G.

Significant Salinity Gradient Observed: Site Specific Regression Coefficient (Slope- 95% Confidence Limit) For:

A. 3 April 2005 Transect A Wawaloli Beach Control (Stations 1, 2, 4, 6, 7, 8):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect A Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-40.48	Yes
Total Phosphorus =	-2.86	-4.73	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-39.62	Yes
Orthophosphorus =	-3.22	-3.08	No

B. 3 April 2005 Transect F South Boundary (Stations 41, 42, 44, 46, 47, 48):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect A Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-15.39	No
Total Phosphorus =	-2.86	-4.27	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-29.32	No
Orthophosphorus =	-3.22	-2.73	No

C. 3 April 2005 Transect G Kaloko Pond Control (Stations 49, 50, 52, 54, 55, 56):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect A Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-6.57	No
Total Phosphorus =	-2.86	-4.85	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-24.96	No
Orthophosphorus =	-3.22	-2.55	No

D. 5 April 2005 Transect F South Boundary (Stations 41, 42, 44, 46, 47, 48):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect A Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-20.12	No
Total Phosphorus =	-2.86	-4.97	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-36.06	Yes
Orthophosphorus =	-3.22	-3.43	Yes

(Table Continued on Next Page)

TABLE 6 Continued:

E. 5 April 2005 Transect G Kaloko Pond Control (Stations 49, 50, 52, 54, 55, 56):

<u>Parameter</u>	<u>DOH Not To Exceed The Absolute Value</u>	<u>Transect A Control Data</u>	<u>Exceeds Standard?</u>
Total Nitrogen =	-40.35	-18.00	No
Total Phosphorus =	-2.86	-5.03	Yes
Nitrate+Nitrite Nitrogen =	-31.92	-24.76	No
Orthophosphorus =	-3.22	-3.21	No

TABLE 7. Summary of noncompliance of parameters with the DOH West Hawaii Regional Water Quality Standards for the geometric means of all samples collected at surface marine stations fronting the Kohanaiki development by date in Part A. Part B shows the noncompliance with surface marine samples collected at the three control transects ("A" offshore of Wawaloli Beach, "G" fronting Kaloko Pond and "H" offshore of Kaloko Point during the same field surveys. "Yes" indicates noncompliance and blanks in the table indicate parameters in compliance for that sample date. At the foot of the table are given the % of the time that a parameter was not in compliance at stations fronting Kohanaiki or at control stations. Data are summarized from Tables 5 and 6.

PART A - FRONTING KOHANAIKI PROJECT SITE

Sample Date & Transect	Parameter					
	NO ₃	NH ₄	TN	PO ₄	TP	Turb Chl- <i>a</i>
3 April 05						
B		Yes	Yes			Yes
C		Yes	Yes			Yes
D			Yes			
E			Yes			
F		Yes			Yes	
5 April 05						
B			Yes	Yes		Yes
C			Yes	Yes		Yes
D			Yes			
E	Yes		Yes	Yes		
F	Yes			Yes	Yes	
18 April 05						
B			Yes			
C			Yes			
D		Yes	Yes			
E			Yes			
F		Yes	Yes		Yes	
% Noncompliant	13	33	87	27	33	27

(Continued on Next Page)

TABLE 7. Continued.

PART B - FRONTING CONTROL SITES

Sample Date & Transect	Parameter						
	NO ₃	NH ₄	TN	PO ₄	TP	Turb	Chl- <i>a</i>
3 April 05							
A	Yes	Yes	Yes		Yes	Yes	
G		Yes			Yes	Yes	
H	Yes	Yes	Yes	Yes			
5 April 05							
A	Yes		Yes	Yes	Yes	Yes	
G		Yes			Yes	Yes	
H	Yes		Yes	Yes	Yes		
18 April 05							
A		Yes	Yes	Yes		Yes	
G	Yes	Yes	Yes	Yes		Yes	
H		Yes	Yes				
% Noncompliant	56	78	78	56	56	67	

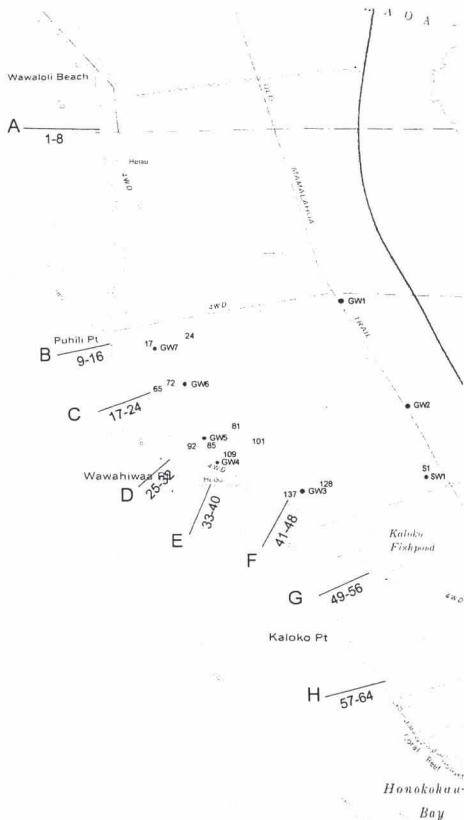
TABLE 8. Summary of quadrat counts in the body of the table of native shrimp (*Halocaridina rubra*) and presence/absence of alien fish in anchialine pools at Kohanaiki, North Kona. Pond numbering follows Brock (2003a); the “GW” number series in parentheses are the Audubon International water quality monitoring sample site designations.

Pond No.	Sample Date Apr05
17	25/0.1m ²
14 (GW-7)	Fish
24	30/0.1m ²
65	Fish
72	5/0.1m ²
49 (GW-6)	Fish
92	Fish
84 (GW-5)	Fish
85	80/0.1m ²
81	40/0.1m ²
109	80/0.1m ²
115 (GW-4)	65/0.1m ²
101	25/0.1m ²
137	No fauna
126 (GW-3)	Fish
128	60/0.1m ²

TABLE 9. List of analytes to be sampled in water samples collected at sample sites GW-1 through GW-7 as well as SW-1 on the Kohanaiki project site as required by Audubon International (2005). "MRL" indicates the minimum recorded limits and all are set at 0.1 ug/L unless otherwise given below. All units are in ug/L.

Analyte	MRL	Analyte	MRL	Analyte	MRL
Alachlor		Fluazifop-butyl		gamma-BHC (Lindane)	
Aldrin		Flurprimidol		Lambda-Cyhalothrin	
alpha-BHC		Flutolanil		4,4'-DDD	
Ametryn		Heptachlor		4,4'-DDE	
Atrazine		Heptachlor epoxide		4,4'-DDT	
Benfluralin		Hexazinone			
Butylate		Iprodione			
Chloroneb		Isofenphos			
Chlorothalonil		Metolachlor			
Chlorpyrifos		Metribuzin			
Chlorpyrifos methyl		Metsulfuron-methyl	5.0		
Cyanazine		Molinate			
Cyfluthrin	0.5	Myclobutanil			
DCPA		Napropamide			
Deltamethrin		Norflurazon			
Desethylatrazine		Oxyfluorfen			
Desisopropylatrazine		Pebulate			
Diazinon		Pendimethalin			
Dichlobenil		Pentachloronitrobenzene			
Dicofol		Profluralin			
Dieldrin		Prometon			
Diphenamid		Prometryn			
Dithiopyr		Pronamide			
EPTC		Propachlor			
Endosulfan I		Propiconazole isomer a			
Endosulfan II		Propiconazole isomer b			
Endosulfan sulfate		Terbacil			
Endrin		Thiobencarb			
Esfenvalerate		Trichlorfon	5.0		
Ethalfuralin		Trifluralin			
Ethofumesate		Trinexapac-ethyl	1.0		
Ethoprop		Vernolate			
Etridiazole		Vinclozolin			
Fenamiphos		Simazine			
Fenarimol		beta-BHC			
Fenoxaprop-ethyl		delta-BHC			

FIGURE 1. Map of the Kohanaiki project site and environs showing the approximate locations of the eight marine water quality transects along which water quality samples are collected. Five transects (from north to south B, C, D, E, F) front the project site and the remaining three (Transect A -Wawaloli Beach, Transect G - Kaloko Pond and Transect H fronting Kaloko Point) serve as control sites. Along each transect 8 samples are collected. Also shown are the present 16 anchialine pool water quality monitoring sites as well as the Audubon International required monitoring sites (GW- 1 through GW-7, plus SW-1). Note that GW-1 and 2 are the yet to be completed inland monitoring wells and SW-1 is a not yet constructed artificial lake. Due to the small scale, locations are only approximate.



APPENDIX 1. Summary of the concentrations of water quality parameters (ug/l unless otherwise noted) as measured at 64 marine sample sites fronting the Kohanaki project site on 3 April 2005. Surface samples are denoted with an "S" and deep bottom samples with a "B". ND = Non-Detectable. Geometric means for surface marine samples are given at the foot of the table, means exceeding applicable standards are underlined. Tide state: 0.0 to + 0.2 feet.

Station	Nitrate N	Ammonia N	Total N	Orp P	Total P	Silica	TON	TOP	Salinity [‰]	Turbidity [NTU]	Chlorophyll-a [ug/l]	Temp [°C]	Oxygen [% Sat]	pH
KOHANAKI Marine Samples														
10 S	5.72	2.13	169.68	4.93	10.85	183.21	160.82	5.92	34.552	0.14	0.090	24.5	100	8.03
11 S	5.22	1.43	157.22	5.24	10.54	184.41	149.87	5.30	34.447	0.14	0.101	24.2	100	8.09
11 B	1.07	1.43	155.96	4.84	9.61	68.44	153.46	4.77	34.632	0.11	0.088	24.1	99	8.10
12 S	5.18	3.54	140.56	5.35	10.54	278.53	131.84	5.19	34.348	0.09	0.109	24.1	100	8.08
13 B	0.25	1.73	151.48	4.95	8.68	43.59	149.50	3.73	34.700	0.08	0.106	24.2	101	8.04
14 S	4.62	3.27	141.68	4.56	10.85	333.78	133.80	6.29	34.284	0.09	0.114	24.3	100	8.05
15 S	3.53	3.07	144.76	5.06	10.54	313.55	139.16	5.48	34.218	0.11	0.110	24.4	96	8.06
16 S	0.96	3.45	121.10	4.36	9.30	143.38	116.69	4.94	34.463	0.08	0.117	24.4	97	8.08
17 S	0.96	4.21	145.16	4.17	11.51	250.16	137.47	5.66	34.574	0.10	0.114	24.4	100	8.07
18 S	5.08	4.21	145.88	5.27	11.16	405.89	135.59	5.88	34.674	0.13	0.211	24.6	98	8.02
19 B	1.92	10.16	160.40	3.58	11.78	206.87	178.32	8.20	34.397	0.16	0.176	24.3	101	8.03
20 S	5.52	3.24	123.76	4.99	11.16	439.86	115.00	6.17	34.005	0.10	0.162	24.1	101	7.93
21 B	0.33	1.70	218.82	4.49	10.54	78.69	216.79	6.05	34.616	0.09	0.096	24.2	102	8.05
22 S	7.54	3.12	179.48	5.50	11.78	567.26	168.82	6.28	33.809	0.11	0.144	24.2	101	7.97
23 S	5.97	4.53	121.24	5.30	11.47	466.98	110.74	6.17	33.979	0.09	0.114	24.3	99	8.07
24 S	ND	1.42	100.10	4.30	10.23	80.21	98.68	5.93	34.553	0.09	0.118	24.5	96	8.11
25 S	0.76	2.61	122.50	4.21	8.06	80.72	119.14	3.85	34.604	0.05	0.135	24.6	100	8.08
26 S	0.74	1.57	130.62	4.41	9.61	65.74	128.32	5.20	34.615	0.05	0.100	24.7	100	8.08
27 B	0.30	1.45	115.50	4.52	8.06	71.41	113.75	3.54	34.630	0.10	0.106	24.8	101	8.06
28 S	0.25	1.37	102.76	4.32	8.68	64.18	101.14	4.36	34.587	0.07	0.115	24.8	103	8.12
29 B	0.19	2.13	145.46	3.32	9.61	31.17	143.14	6.29	34.675	0.06	0.084	24.7	97	8.13
30 S	0.35	1.35	125.77	4.33	10.54	125.77	133.83	5.86	34.574	0.09	0.137	24.5	100	8.07
31 S	0.19	1.16	133.20	3.84	10.54	86.33	131.93	4.98	34.504	0.09	0.126	24.5	100	8.10
32 S	2.15	1.51	133.00	5.25	10.85	168.73	129.34	4.98	34.409	0.06	0.135	24.6	100	8.11
33 S	10.91	2.31	111.72	5.55	10.85	543.43	95.50	5.30	33.874	0.08	0.202	24.8	100	8.11
34 S	2.11	1.65	127.26	4.55	9.61	80.11	123.50	5.06	34.605	0.08	0.157	24.7	99	8.10
35 B	0.06	2.07	99.68	4.66	10.23	26.53	97.55	5.57	34.668	0.08	0.088	24.6	101	8.10
36 S	1.55	2.18	91.42	4.16	8.99	122.33	87.69	4.83	34.480	0.09	0.113	24.6	100	8.10
37 B	0.06	1.72	154.14	3.57	9.30	27.96	152.36	5.73	34.682	0.07	0.088	24.6	99	8.09
38 S	0.39	1.37	183.56	4.17	11.51	239.16	180.78	5.30	34.385	0.05	0.118	24.4	100	8.12
39 S	5.61	2.17	126.00	5.13	10.54	139.79	139.79	4.92	34.385	0.08	0.114	24.5	98	8.12
40 S	4.56	1.87	105.56	4.38	9.30	193.79	99.33	4.92	34.380	0.08	0.114	24.0	101	8.17
41 S	284.72	7.21	366.66	32.54	55.38	7987.91	74.73	19.85	25.323	0.18	0.478	24.2	99	8.11
41-Rep	294.48	6.49	384.64	32.74	52.19	7080.01	83.19	22.44	25.127	0.17	0.447	24.1	101	8.12
42 S	42.70	3.03	167.02	9.41	17.05	1239.38	121.29	7.64	33.109	0.07	0.151	24.3	100	8.13
43 B	31.32	8.29	183.40	6.81	16.12	1041.67	143.80	9.31	33.369	0.06	0.148	24.5	100	8.11
44 S	9.10	11.33	180.32	2.60	11.16	329.88	159.90	8.56	34.246	0.06	0.126	24.7	97	8.08
45 S	1.39	126.00	126.00	4.68	17.60	47.60	124.91	4.77	34.660	0.06	0.090	24.6	100	8.05
46 S	11.32	2.52	126.00	4.68	11.16	46.11	126.00	4.77	34.660	0.06	0.126	24.6	100	8.05
47 S	13.16	4.45	191.24	5.22	13.64	457.14	173.63	8.42	34.104	0.07	0.111	24.3	98	8.12
48 S	42.56	10.69	202.72	8.43	17.67	1510.76	149.47	9.24	32.804	0.08	0.212	23.8	100	8.10
Geometric Means														
	4.63	2.61	148.97	5.51	11.96	280.90	126.13	6.34	33.561	0.09	0.140	24.4	99	8.09

APPENDIX 1. Continued.

Station	Nitrate N	Ammonia N	Total N	Ortho P	Total P	Silica	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	Chlorophyll-a [ug/l]	Temp [C]	Oxygen [% Sat]	pH
CONTROL Marine Samples														
1 S	170.37	5.52	358.12	20.29	31.31	2687.37	182.22	11.02	31.087	0.14	0.279	24.3	101	8.09
2 S	40.56	5.21	211.54	9.33	14.88	543.44	165.77	5.55	34.062	0.09	0.151	24.2	99	8.08
3 B	22.96	6.29	197.54	6.51	12.40	276.89	168.29	5.89	34.408	0.13	0.114	24.1	99	8.06
4 S	69.99	9.52	243.04	11.05	18.29	1054.79	163.53	7.24	33.357	0.14	0.149	24.1	97	8.09
5 B	13.09	12.06	200.62	5.12	12.71	210.47	175.47	7.59	34.448	0.16	0.102	24.2	100	8.07
6 S	48.74	10.59	230.30	8.34	16.74	739.39	170.97	8.40	33.757	0.13	0.113	24.3	100	8.06
7 S	53.89	12.55	227.50	8.24	17.98	874.45	161.06	9.74	33.666	0.09	0.092	24.3	96	8.09
8 S	8.37	3.10	166.88	5.53	11.47	232.63	155.41	5.94	34.376	0.10	0.106	24.4	101	8.05
49 S	236.70	7.46	335.58	32.54	54.25	6864.75	91.42	21.71	25.977	0.13	0.415	23.8	101	8.13
49-Rep S	247.50	14.57	389.48	32.44	56.11	7050.18	127.41	23.67	25.681	0.11	0.398	23.8	99	8.10
50 S	42.49	5.65	166.88	9.95	18.60	1439.54	118.74	8.65	32.956	0.10	0.190	24.3	99	8.05
51 B	21.82	3.25	166.04	7.65	14.57	105.40	140.97	6.92	33.757	0.08	0.194	24.4	100	8.06
52 S	62.06	7.92	199.64	11.56	24.49	2325.37	129.66	12.93	31.746	0.12	0.359	24.3	100	7.92
53 B	10.42	5.71	166.04	6.46	13.33	378.04	149.91	6.87	34.308	0.11	0.736	24.5	100	8.08
54 S	*	*	*	*	*	*	*	*	*	0.10	*	24.3	99	8.08
55 S	34.14	15.77	221.34	5.46	18.29	1307.09	171.43	12.83	33.109	0.09	0.176	24.6	101	8.06
56 S	41.34	4.07	199.22	9.47	18.29	1481.76	153.81	8.82	32.870	0.06	0.160	24.6	100	8.05
57 S	15.00	2.78	167.16	5.67	11.47	407.58	149.39	5.80	33.983	0.08	0.143	25.0	99	8.10
58 S	8.78	2.39	161.70	5.18	10.54	251.63	150.52	5.36	34.260	0.08	0.128	25.0	96	8.08
59 B	4.12	3.60	105.42	4.48	9.92	136.75	97.70	5.44	34.531	0.07	0.122	25.0	101	8.08
60 S	9.26	3.56	166.18	4.98	9.30	273.07	153.36	4.32	34.219	0.09	0.138	25.0	100	8.08
61 B	2.53	1.89	108.92	4.49	9.61	130.05	104.51	5.12	34.545	0.09	0.134	24.9	100	8.10
62 S	9.73	2.26	149.24	4.79	9.61	279.12	137.25	4.82	34.213	0.08	0.111	25.0	99	8.10
63 S	15.38	2.71	110.46	5.80	11.16	430.69	92.37	5.36	34.033	0.07	0.148	24.9	102	8.10
64 S	29.80	5.97	183.96	7.40	15.19	922.78	148.19	7.79	33.376	0.06	0.228	24.9	101	7.97
Geometric Means	<u>36.40</u>	<u>5.61</u>	<u>205.34</u>	<u>9.00</u>	<u>17.55</u>	920.67	143.28	8.34	32.49	0.09	0.174	24.5	99	8.07

* Missing data

APPENDIX 2. Summary of the concentrations of water quality parameters ($\mu\text{g/l}$ unless otherwise noted) as measured at 64 marine sample sites fronting the Kohanaki project site on 5 April 2005 (as well as 16 sites in anchialine pools). Surface samples are denoted with an "S" and deep bottom samples with a "B". ND = non-detectable. Geometric means for surface marine samples are given at the foot of the table, means exceeding applicable standards are underlined>. Tide State: - 0.2 to 0.0 feet.

Station	Nitrate N	Ammonia N	Total N	Ortho P	Total P	Silica	TON	TOP	Salinity (‰)	Turbidity (NTU)	Chlorophyll-a ($\mu\text{g/l}$)	Temp ($^{\circ}\text{C}$)	Oxygen (% Sat)	pH
KOHANAKI Marine Samples														
9 S	12.76	0.86	154.70	6.47	12.71	391.54	140.99	6.24	34.303	0.17	0.110	24.4	99	8.16
10 S	5.62	0.80	199.22	5.61	11.78	254.74	192.80	6.17	34.490	0.14	0.296	24.1	99	8.15
11 B	0.69	0.69	219.24	5.07	11.47	141.70	217.86	6.40	34.606	0.18	0.127	24.0	97	8.10
12 S	4.54	3.91	143.78	5.60	11.47	541.37	135.33	5.87	34.406	0.14	0.124	24.0	101	8.15
13 B	1.25	1.64	203.14	5.48	11.16	149.73	200.24	5.68	34.581	0.09	0.150	24.1	98	8.15
14 S	1.26	1.00	212.80	5.05	11.78	147.18	210.55	6.73	34.564	0.16	0.110	24.0	101	8.15
15 S	0.18	0.15	228.20	4.30	11.47	97.35	227.86	7.17	34.610	0.13	0.089	24.1	100	8.17
16 S	0.12	0.19	177.24	4.29	10.54	105.31	176.94	6.25	34.600	0.12	0.087	24.2	99	8.13
17 S	1.23	1.23	178.60	5.53	12.09	391.49	172.68	6.54	34.149	0.12	0.125	24.3	100	8.10
18 S	4.57	1.53	202.40	5.32	11.78	147.18	210.55	6.73	34.564	0.16	0.110	24.0	101	8.15
19 B	2.93	1.33	179.90	5.32	12.09	273.44	175.64	6.77	34.345	0.13	0.179	24.2	98	8.11
20 S	8.42	2.95	204.40	6.27	13.02	509.47	193.93	6.75	33.970	0.13	0.150	24.2	100	8.15
21 B	1.30	0.91	171.64	5.09	10.23	129.33	169.43	5.14	34.583	0.09	0.085	24.2	99	8.13
22 S	8.43	1.29	174.72	6.04	11.47	464.83	165.00	5.43	34.030	0.06	0.146	24.2	100	8.13
23 S	0.08	0.25	213.08	4.55	11.16	92.80	212.75	6.61	34.632	0.11	0.089	24.3	101	8.15
24 S	0.14	0.29	180.74	4.43	11.16	113.84	180.31	6.73	34.588	0.09	0.093	24.3	100	8.16
25 S	1.87	0.76	168.00	4.74	10.54	142.72	165.37	5.80	34.543	0.13	0.115	24.6	100	8.14
26 S	1.87	1.10	197.68	4.73	10.85	208.22	184.71	6.12	34.595	0.03	0.091	24.4	100	8.12
27 B	0.19	0.50	153.16	4.19	10.23	77.46	152.47	6.04	34.651	0.05	0.082	24.5	99	8.12
28 S	0.19	0.97	173.60	4.18	10.54	105.32	172.44	6.36	34.595	0.11	0.112	24.2	101	8.14
29 B	0.18	0.62	161.84	4.17	11.16	85.49	161.04	6.99	34.645	0.04	0.089	24.1	100	8.15
30 S	1.35	1.05	194.18	4.48	10.85	143.08	191.78	6.37	34.546	0.12	0.118	24.1	99	8.15
31 S	2.45	0.54	147.26	4.69	10.85	177.12	144.28	6.16	34.493	0.06	0.102	24.2	100	8.16
32 S	0.34	0.34	146.58	4.36	10.23	140.62	146.14	5.87	34.548	0.12	0.232	24.2	100	8.16
33 S	13.97	1.35	168.70	6.26	13.33	595.05	153.38	7.07	33.886	0.06	0.184	24.2	100	8.15
34 S	2.47	1.00	138.46	4.89	9.92	125.10	134.99	4.94	34.613	0.07	0.093	24.4	101	8.15
35 B	0.15	0.45	160.70	4.12	11.16	70.38	161.10	7.04	34.691	0.04	0.082	24.4	99	8.12
36 S	7.96	1.91	152.60	5.49	11.16	341.78	142.74	5.67	34.271	0.05	0.127	24.0	100	8.05
37 B	0.23	0.23	131.76	4.32	9.92	99.25	137.24	5.60	34.618	0.06	0.120	24.3	99	8.13
38 S	0.87	0.87	168.20	5.46	10.54	105.32	168.20	6.83	34.595	0.06	0.093	24.4	100	8.15
39 S	0.87	0.84	168.28	5.46	10.54	305.32	158.37	6.81	34.327	0.05	0.095	24.4	100	8.12
40 S	4.69	0.58	148.82	5.03	10.40	229.78	143.55	5.51	34.427	0.04	0.112	23.8	101	8.09
41 S	563.52	12.17	672.08	58.26	89.28	11347.05	106.38	31.02	19.204	0.12	0.409	23.6	97	8.19
42 S	48.49	2.35	177.76	10.62	18.29	1468.52	121.92	7.67	32.866	0.05	0.259	23.8	99	8.13
43 B	12.93	0.77	146.02	6.26	12.40	404.28	132.33	6.14	34.253	0.10	0.119	24.1	99	8.11
44 S	39.19	1.59	190.82	9.33	17.36	1166.17	150.04	8.03	33.245	0.04	0.185	24.0	101	8.10
45 B	2.54	0.45	122.36	4.86	9.92	107.91	119.37	5.06	34.645	0.07	0.097	24.1	97	8.07
46 S	1.42	0.14	168.60	6.14	13.19	905.78	136.54	7.05	33.577	0.10	0.138	24.1	100	8.13
47 S	19.51	1.47	168.60	7.17	13.33	618.76	171.23	6.16	33.992	0.12	0.133	23.9	101	8.12
48 S	20.08	1.20	168.60	7.17	13.33	618.76	171.23	6.16	33.959	0.07	0.135	23.9	100	8.07
Geometric Means														
	3.55	0.96	186.16	6.00	12.85	314.96	164.89	6.75	33.601	0.09	0.133	24.2	100	8.13

APPENDIX 2.

Continued.

Station	Nitrate	Ammonia	Total	Ortho	Total	Silica	TON	TOP	Salinity	Turbidity	Chlorophyll-a	Temp	Oxygen	pH	TDS
	N	N	N	P	P				[gss]	[NTU]	[µg/L]	[C]	[% Sat]		[mg/L]
CONTROL Marine Samples															
1	S	129.19	2.49	353.50	19.24	27.28	2048.89	221.82	8.04	32.102	0.07	0.367	24.0	101	8.14
2	S	63.28	2.27	259.00	12.14	18.91	1006.08	193.47	6.77	33.529	0.09	0.222	24.0	100	8.14
3	B	22.61	1.33	229.32	7.47	13.31	394.67	205.38	5.86	34.380	0.21	0.149	25.0	101	8.14
4	S	114.38	2.14	353.50	19.24	27.28	2048.89	221.82	8.04	32.102	0.07	0.367	24.0	101	8.14
5	S	74.79	3.15	262.92	12.21	19.84	1229.16	184.98	7.63	33.186	0.07	0.188	23.9	99	8.12
6	S	74.79	3.15	262.92	12.21	19.84	1229.16	184.98	7.63	33.186	0.07	0.188	23.9	99	8.12
7	S	63.81	3.09	267.40	11.46	19.84	1102.50	200.50	8.38	33.356	0.10	0.260	24.0	101	8.16
8	S	0.22	0.01	186.48	4.78	11.16	115.16	186.25	6.38	34.639	0.12	0.260	24.2	101	8.17
49	S	283.64	9.26	414.82	39.74	65.41	7990.77	121.92	25.67	24.162	0.16	0.835	23.4	96	8.10
50	S	89.83	3.50	217.70	14.57	26.66	2813.94	144.37	12.09	31.638	0.23	0.253	23.5	98	8.14
51	S	114.38	2.14	353.50	19.24	27.28	2048.89	221.82	8.04	32.102	0.07	0.367	24.0	101	8.14
52	S	41.40	3.87	240.34	10.31	19.22	1579.20	192.07	8.91	33.823	0.13	0.264	24.0	100	8.17
53	B	4.78	0.92	183.96	5.20	11.16	145.00	178.26	5.96	34.622	0.09	0.119	24.1	98	8.08
54	S	40.86	3.11	205.36	10.29	19.22	1530.87	162.39	8.93	32.870	0.11	0.201	24.0	100	8.07
55	S	14.09	1.19	182.42	6.56	13.02	411.85	167.15	6.46	34.260	0.09	0.114	24.4	101	8.00
56	S	13.54	1.66	197.26	5.92	11.16	419.60	182.05	5.24	34.249	0.07	0.120	24.3	100	8.09
57	S	40.32	2.29	198.10	6.97	13.95	955.25	155.49	6.98	32.877	0.06	0.253	24.4	100	8.12
58	S	18.47	1.98	188.16	6.01	13.02	437.67	187.71	7.01	34.045	0.07	0.161	24.3	99	8.14
59	B	8.64	1.98	188.16	5.25	11.78	228.18	177.94	6.53	34.411	0.08	0.168	24.4	99	8.13
60	S	46.88	2.99	215.32	9.28	17.36	1135.64	165.45	8.08	33.198	0.10	0.157	24.3	100	8.10
61	B	14.11	1.70	179.90	5.77	10.54	199.83	164.09	4.77	34.599	0.10	0.118	24.4	98	8.09
62	S	54.53	3.11	223.72	10.96	19.22	1409.41	166.08	8.26	32.732	0.12	0.199	24.4	100	8.06
63	S	114.38	2.14	353.50	19.24	27.28	2048.89	221.82	8.04	32.102	0.07	0.367	24.0	101	8.14
64	S	1.57	0.10	170.38	4.68	10.85	76.05	188.72	6.17	34.632	0.06	0.108	24.6	100	8.04
Geometric Means															
		27.68	1.67	225.26	9.52	17.63	827.71	171.49	7.93	32.826	0.10	0.205	24.1	100	8.10

Anchialine Ponds

KOP14	186.34	88.34	689.78	29.14	95.10	13867.00	415.10	66.96	14.541	4.472	26.3	146	8.51	16600
KOP17	720.02	7.42	969.50	75.64	124.62	14884.80	242.06	48.98	14.487	0.18	0.287	25.5	88	8.07
KOP24	330.82	13.58	694.26	44.95	104.47	14881.72	349.86	59.52	12.007	0.30	3.006	24.6	89	7.96
KOP29	569.80	49.98	1001.42	58.59	122.76	15228.64	381.64	64.17	12.930	0.58	3.813	24.6	100	7.84
KOP55	621.18	23.84	940.52	67.89	117.49	14871.44	285.40	49.60	13.988	0.19	0.659	23.9	92	8.07
KOP101	894.30	19.88	1077.42	77.59	126.79	15802.92	253.36	49.29	11.733	0.26	0.317	24.1	79	7.69
KOP115-Rep	477.12	39.96	992.32	55.49	126.48	15003.96	476.14	70.99	12.567	0.39	9.146	23.6	118	8.16
KOP84	739.90	11.06	1104.74	73.47	127.72	16088.80	353.78	54.25	12.604	0.15	0.216	21.9	93	7.45
KOP85	34.16	69.58	1199.10	25.73	155.62	12467.58	1095.36	129.89	16.477	1.05	26.795	27.9	90	7.74
KOP92	871.64	2.24	1109.36	85.87	143.84	15995.28	235.48	57.97	11.398	0.30	0.064	22.5	79	7.90
KOP102	779.38	32.76	1182.30	74.76	129.88	15158.88	266.84	52.63	12.070	0.32	0.238	24.7	89	8.54
KOP115	779.38	32.76	1182.30	74.76	129.88	15158.88	266.84	52.63	12.070	0.32	0.238	24.7	89	8.54
KOP126	872.34	31.64	1235.50	74.09	131.75	15545.60	424.34	57.66	12.001	0.19	0.832	22.6	83	7.50
KOP126-Rep	853.72	7.42	1229.65	93.91	163.06	15899.72	380.74	68.75	11.524	1.97	23.012	19.5	65	7.32
KOP128	829.92	21.98	1231.02	94.86	160.27	16061.92	442.54	70.37	11.502	1.92	18.144	19.5	65	7.32
KOP137	915.14	3.36	1212.68	96.72	147.87	16058.84	379.12	54.56	11.709	0.71	2.481	20.4	81	7.70
							293.58	51.15	11.529	0.09	0.302	19.3	83	7.70

APPENDIX 3. Summary of the concentrations of water quality parameters (ug/l unless otherwise noted) as measured at 64 marine sample sites fronting the Kohanaki project site on 18 April 2005. Surface samples are denoted with an "S" and deep bottom samples with a "B". ND = non-detectable. Geometric means for surface marine samples are given at the foot of the table, means exceeding applicable standards are underlined. Tide state: + 0.05 to + 0.3 feet.

Station	Nitrate N	Ammonia N	Total N	Ortho P	Total P	Silica	TON	TOP	Salinity [‰]	Turbidity [NTU]	Chlorophyll-a [ug/l]	Temp [C]	Oxygen [% Sat]	pH
KOHANAKI Marine Samples														
9 S	1.34	1.66	131.46	5.07	8.99	47.97	128.25	3.92	34.485	0.15	0.097	25.9	103	8.15
10 S	0.39	1.17	94.08	5.06	8.99	50.69	92.52	3.93	34.493	0.04	0.080	25.6	102	8.15
11 B	0.39	1.60	123.48	5.04	8.68	50.96	121.50	3.64	34.502	0.06	0.084	25.7	100	8.15
12 S	0.38	1.33	108.22	5.03	8.99	51.24	106.51	3.96	34.464	0.03	0.150	25.7	100	8.13
13 B	0.37	1.06	102.06	4.90	8.99	49.09	110.82	4.15	34.469	0.05	0.081	26.0	102	8.13
14 S	1.10	4.60	137.34	5.15	9.30	52.34	116.43	4.15	34.469	0.05	0.081	26.0	102	8.13
14-Rep S	1.37	5.69	157.44	5.37	9.30	53.60	160.39	3.62	34.463	0.06	0.116	26.0	100	8.15
15 S	1.12	1.84	125.00	4.95	9.30	53.60	123.51	4.35	34.463	0.07	0.074	26.0	100	8.15
16 S	1.11	0.37	358.40	4.72	10.23	55.33	356.92	5.51	34.477	0.05	0.087	26.1	101	8.14
17 S	1.54	1.54	104.30	5.02	8.99	74.98	101.22	3.97	34.467	0.19	0.107	25.8	103	8.18
18 S	2.32	2.12	104.72	5.01	8.99	72.82	100.27	3.98	34.466	0.05	0.164	25.6	103	8.18
19 B	2.38	2.18	117.68	4.99	8.99	70.67	113.33	4.00	34.466	0.05	0.115	25.6	103	8.18
20 S	1.70	1.22	83.58	4.87	8.37	73.35	80.66	3.72	34.476	0.08	0.074	25.6	101	8.17
21 B	1.76	1.06	89.46	4.96	8.68	66.36	86.64	3.74	34.479	0.09	0.079	25.6	101	8.16
22 S	2.17	4.51	121.94	4.94	8.68	66.63	115.26	3.74	34.479	0.09	0.079	25.6	102	8.14
23 S	2.23	0.90	103.18	4.82	8.99	57.24	100.05	4.17	34.472	0.09	0.094	25.7	102	8.13
24 S	2.28	0.85	112.42	4.70	8.68	55.10	105.29	3.96	34.472	0.06	0.107	25.7	101	8.15
25 S	2.70	5.67	131.18	4.57	8.99	91.53	122.61	4.42	34.436	0.16	0.095	26.3	103	8.16
26 S	2.75	4.56	134.26	5.20	9.92	89.37	126.96	4.72	34.448	0.09	0.100	26.0	102	8.17
27 B	2.80	2.12	101.22	5.08	9.30	82.40	96.30	4.22	34.448	0.05	0.086	25.9	100	8.17
28 S	2.85	3.71	110.46	4.74	8.99	94.69	103.90	4.25	34.436	0.07	0.104	25.9	100	8.17
29 B	0.39	1.43	101.22	4.72	8.99	75.70	99.40	4.27	34.423	0.10	0.086	25.8	100	8.16
30 S	0.81	1.69	124.18	4.49	8.99	71.15	121.68	4.50	34.453	0.08	0.053	25.9	102	8.18
31 S	1.94	2.49	100.38	4.58	9.30	78.62	95.96	4.72	34.451	0.07	0.097	25.9	101	8.18
32 S	2.35	3.02	119.98	4.57	9.30	76.47	114.92	4.02	34.465	0.07	0.109	26.1	101	8.18
33 S	2.40	1.43	195.72	4.66	8.68	71.09	174.41	4.20	34.477	0.12	0.118	26.1	102	8.20
34 S	2.45	3.60	160.88	4.74	8.68	72.04	174.41	4.20	34.477	0.12	0.118	26.1	102	8.18
35 S	2.45	3.60	160.88	4.74	8.68	72.04	174.41	4.20	34.477	0.12	0.118	26.1	102	8.18
36 S	0.41	2.70	125.30	4.18	9.92	62.87	103.15	5.51	34.502	0.07	0.083	25.7	100	8.17
37 B	1.40	0.98	107.80	4.58	9.92	53.56	122.18	5.74	34.493	0.06	0.115	25.8	101	8.13
38 S	1.40	0.98	107.80	4.58	9.92	53.56	122.18	5.74	34.493	0.06	0.115	25.8	101	8.13
39 S	2.66	2.10	110.32	4.96	10.54	104.16	102.06	4.03	34.515	0.07	0.081	25.8	100	8.17
40 S	2.66	2.66	143.50	4.96	10.54	147.28	105.58	5.58	34.376	0.05	0.084	25.8	101	8.18
41 S	13.72	17.64	153.02	6.20	16.43	176.40	121.66	10.23	34.363	0.06	0.121	26.0	101	8.16
42 S	4.48	2.24	113.82	5.27	10.85	241.36	105.70	5.58	34.272	0.07	0.172	26.0	102	8.21
43 B	5.68	2.24	217.70	3.10	19.53	150.76	168.56	16.43	34.263	0.09	0.142	26.2	100	7.77
44 S	3.50	45.64	217.70	3.10	19.53	150.76	168.56	16.43	34.279	0.09	0.086	25.8	99	8.17
45 S	3.70	1.40	113.82	4.85	10.23	130.46	94.64	5.58	34.385	0.07	0.114	26.7	102	8.16
46 S	3.70	1.40	113.82	4.85	10.23	130.46	94.64	5.58	34.385	0.07	0.114	26.7	102	8.16
47 S	3.36	2.52	109.06	4.65	9.92	126.00	103.18	5.27	34.383	0.05	0.088	25.7	101	8.15
48 S	1.68	2.38	111.44	4.96	10.85	140.56	107.38	5.89	34.367	0.08	0.084	25.7	101	8.15
Geometric Means														
	2.08	2.54	130.24	4.89	9.93	112.31	122.80	4.68	34.371	0.07	0.106	25.8	101	8.15

APPENDIX 3.

Continued.

Station		Nitrate N	Ammonia N	Total N	Ortho P	Total P	Silica	TON	TOP	Salinity [o/oo]	Turbidity [NTU]	Chlorophyll-a [ug/l]	Temp [°C]	Oxygen [% Sat]	pH
CONTROL Marine Samples															
1	S	1.14	2.45	121.38	6.30	11.16	108.89	117.78	4.86	34.422	0.29	0.144	25.7	102	8.13
2	S	0.82	2.08	98.98	5.86	10.23	79.73	96.08	4.37	34.440	0.15	0.132	25.7	102	8.14
3	B	0.88	2.13	94.22	5.52	9.92	92.24	91.21	4.40	34.437	0.08	0.133	25.7	100	8.14
4	S	0.56	3.84	101.50	5.08	8.99	68.02	97.10	3.91	34.475	0.05	0.100	25.7	100	8.14
5	B	0.62	23.40	256.06	3.03	9.92	70.74	232.03	6.89	34.474	0.11	0.097	25.7	98	8.14
6	S	3.31	5.70	124.88	5.58	10.23	205.45	115.87	4.65	34.262	0.08	0.108	25.8	100	8.10
7	S	1.49	2.50	146.30	5.24	9.92	117.69	142.31	4.68	34.406	0.09	0.087	25.8	101	8.13
8	S	1.39	7.35	150.92	5.17	9.30	102.18	142.18	4.13	34.426	0.08	0.073	25.8	99	8.13
8-Rep	S	1.66	12.03	192.92	5.09	9.92	98.90	179.23	4.83	34.427	0.08	0.074	26.1	101	8.13
49	S	21.70	15.19	236.88	10.08	18.29	769.44	199.99	8.22	33.617	0.20	0.342	25.8	98	8.30
50	S	3.36	5.60	110.88	5.58	11.16	222.04	101.92	5.58	34.303	0.14	0.206	25.8	100	8.24
51	B	3.36	6.30	128.10	5.27	11.16	220.08	118.44	5.89	34.298	0.12	0.265	25.9	100	8.23
52	S	4.06	6.02	121.94	4.96	11.16	199.08	111.86	6.20	34.324	0.11	0.188	26.2	101	8.21
53	B	2.94	1.26	147.42	4.65	9.92	92.40	143.22	5.27	34.401	0.13	0.100	25.9	100	8.20
54	S	3.36	1.54	126.00	4.65	10.85	173.32	121.10	6.20	34.352	0.07	0.105	26.1	102	8.17
55	S	3.36	1.96	129.08	4.96	10.54	159.60	123.76	5.58	34.353	0.07	0.091	26.1	101	8.17
56	S	3.36	2.10	125.72	5.27	10.85	261.80	120.26	5.58	34.365	0.08	0.100	26.2	101	8.16
57	S	3.36	2.52	112.28	4.65	10.23	141.12	106.40	5.58	34.368	0.14	0.144	26.2	102	8.11
58	S	3.08	3.50	108.92	4.65	10.54	136.64	102.34	5.89	34.372	0.08	0.582	26.3	102	8.22
59	B	3.22	2.80	121.24	4.65	10.23	141.68	115.22	5.58	34.373	0.09	0.125	26.4	100	8.21
60	S	2.94	3.64	145.18	4.65	11.16	127.68	138.60	6.51	34.392	0.08	0.119	26.4	101	8.17
61	B	2.94	2.94	129.50	4.65	10.85	123.20	123.62	6.20	34.414	0.11	0.097	26.2	99	8.19
62	S	2.94	2.38	125.86	4.65	10.85	130.76	120.54	6.20	34.375	0.08	0.111	26.4	101	8.11
63	S	2.38	1.96	112.98	4.65	10.85	88.48	108.64	6.20	34.444	0.05	0.091	26.3	101	8.15
64	S	2.94	1.68	119.14	4.65	9.92	117.04	114.52	5.27	34.406	0.04	0.101	26.4	102	8.15
Geometric Means		2.52	<u>3.49</u>	<u>129.08</u>	<u>5.26</u>	10.73	145.14	121.88	5.41	34.343	0.09	0.129	26.0	101	8.16