'O'oma
BEACHSIDE VILLAGE

Preliminary Final Environmental Impact Statement

North Kona, Hawai'i

Volume 2 of 2
Appendices

Prepared for:
Accepting Authority,
State of Hawai'i Land Use Commission
Docket No. A07-774
&
Petitioner,
'O'oma Beachside Village, LLC

Prepared by:
PBR HAWAII
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LIST OF APPENDICES

Appendix A

Ground Water Quality Assessment

Assessment of the Potential Impact on Water Resources of the Proposed O'oma Beachside Village in North Kona, Hawaii

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Table of Contents

List of Figures

List of Tables

Introduction

This report presents an assessment of the potential impact on water resources of the proposed O'oma Beachside Village to be located on TMKs 7-3-09:4 and 22 in North Kona, Hawaii (its location is shown on Figure 1. The project site is approximately 303 acres. The inland 228 acres of the site would be developed for 950 to 1200 single and multi-family residential units and related uses. The remaining 75 acres along the shoreline would be a coastal preserve (57 acres) and a shoreline park (18 acres).

Specifics of the Proposed Development

Exhibits 1 through 8 in the Appendix to this report provide specific details of the land use plan, development areas, water supply requirements, wastewater generation and treatment, and stormwater collection and disposal as prepared by the project's planning and civil engineering consultants. Approximate water use and wastewater generation amounts by development area are tallied below and are briefly described in the paragraphs following.

Projected Average Water Use and Wastewater Generation by the O'oma Beachside Village*

Development Area	Potable Supply (MGD)	Irrigation Supply (MGD)	Wastewater Generation (MGD)
A	0.212	0.123	0.132
B	0.280	0.078	0.219
C	0.201	0.168	0.128
Other	--	0.036	--
Cumulative Total	0.693	0.405	0.479

* Refer to Exhibits 4, 5, and 6 in the Appendix for details on these projected quantities.

<u>Potable and Irrigation Water Supply</u>. Two quite different alternatives for potable and irrigation supply have been considered. One of these is to develop, individually or as a joint venture, a well or wells which would tap high level groundwater above Mamalahoa Highway. For this alternative, the well (or wells) would be connected to the Department of Water Supply's (DWS') North Kona System. Costs, timing, and other considerations for this alternative have directed the project to the second alternative. This second and preferred alternative would consist of the desalinization of saltwater to produce the necessary potable and irrigation supply. The two possible sources of feedwater supply being considered for the desalinization are seawater from NELHA and deepwells which would tap saline groundwater at depth beneath the brackish lens. For the deep saline wells alternative, several different locations are being considered: (1) at DWS' existing 0.5 MG Keahole Tank directly inland of the Keahole Airport; (2) near to the future 1.0 MG Palamanui Tank to the north of DWS' Keahole Tank; (3) on land directly inland of the O'oma project site; and (4) at another inland site mutually agreeable to DWS and O'oma Beachside Village, LLC.

For the purposes of the analyses of the impact on water resources herein, it has been assumed that reverse osmosis (RO) desalting would be the source of potable and irrigation supply. It is anticipated that the product recovery rate would be on the order of 40 to 45 percent if saline groundwater is the feedwater supply. The recovery rate would be slightly greater if saltwater from NELHA is used. In any event, the remaining 55 to 60 percent would be a brine "concentrate" that would be disposed of in deep wells.

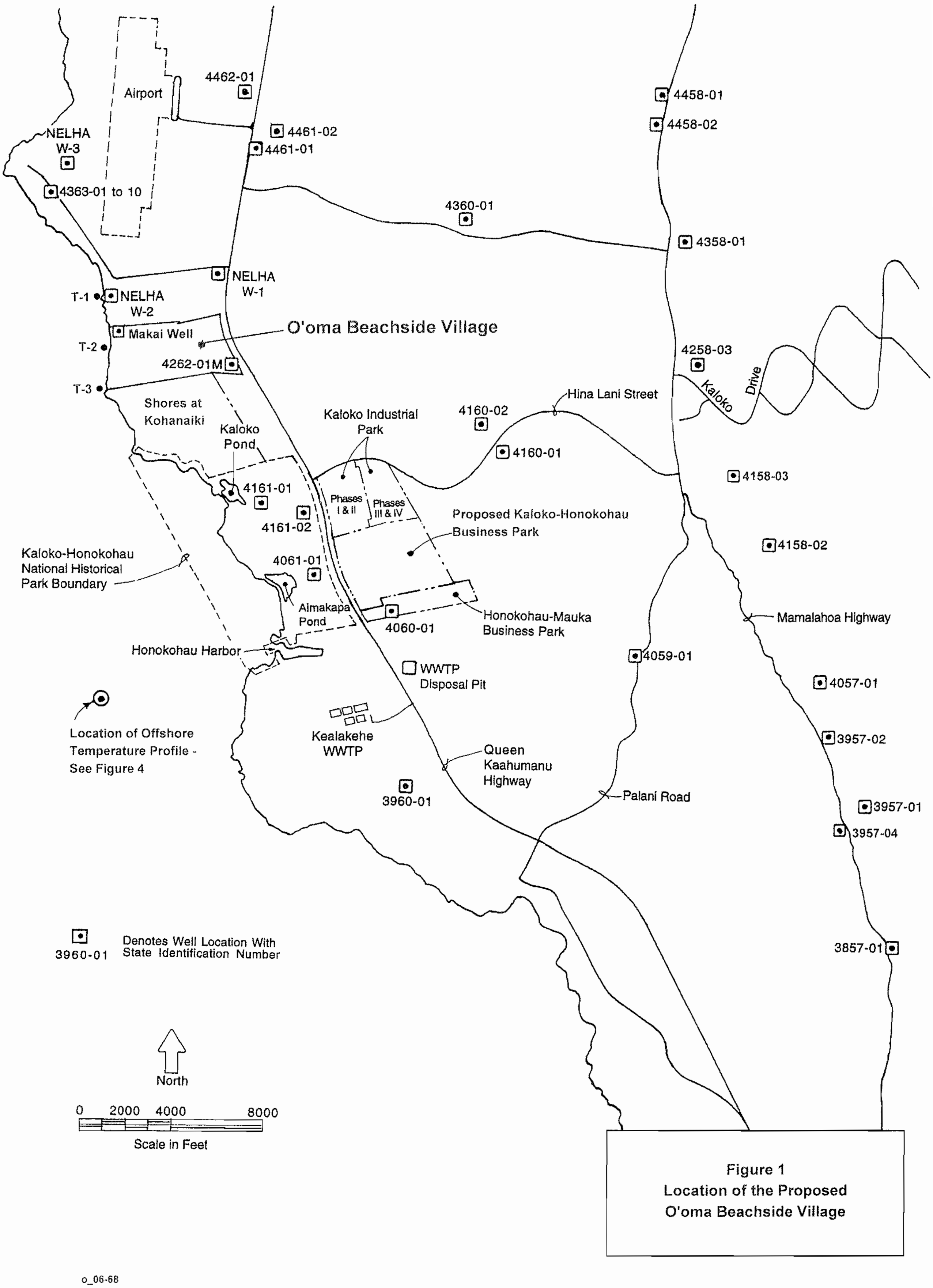


Figure 1
Location of the Proposed
O'oma Beachside Village

Wastewater Generation, Treatment, and Reuse. The project's private wastewater treatment plant (WWTP) will be located along its northern (NELHA) boundary and near the makai end of the residential development. Wastewater will be delivered to the WWTP via 6- and 8-inch lines. The WWTP will utilize a membrane bioreactor (MBR) system that will provide treatment to R-1 (tertiary) standards. The intention is to reuse the R-1 effluent for non-potable irrigation. Experience with developments such as proposed for O'oma has shown that actual wastewater generation as computed in Exhibit 6 and summarized in the tally above is not likely to provide all of the non-potable irrigation requirement. There are three reasons for this. First, the amount of wastewater generated will increase gradually over time as the project is built out and occupied whereas the non-potable irrigation amount is required at the outset. Second, the projections in Exhibit 6 are based on year-round full occupancy which is only likely to occur during selected seasonal periods. Third, actual wastewater generation is typically less than design standards.

The three aspects noted above mean that a supplemental source of non-potable irrigation will be required at the outset and probably will also be needed to some extent (perhaps seasonally) in the long term. It also means that during peak occupancy periods after the project's full build-out, a backup to irrigation reuse will be needed for disposal of excess effluent. In this generally dry area, this excess can probably be handled with additional storage. Otherwise, a disposal well within the WWTP site would be required.

Stormwater Collection and Disposal. Except for a couple of unpaved, 4-wheel drive roads, the 303-acre site is completely undeveloped. Rainfall on the site does not move across it as surface runoff. It is either evaporated back to the atmosphere, transpired back to the atmosphere by vegetation, or becomes groundwater recharge. Once the development is completed, the ground surface will be converted to the land use types tallied below. It has been estimated that approximately 36 percent of the site would be impervious, about 38 percent would be landscaped and irrigated, and the remaining 26 percent would be undisturbed or restored to its natural condition (refer to Exhibit 3 in the Appendix).

Land Surface Changes Based on the Project's Concept Land Use Plan

Land Surface Type	Approximate Acres	Approximate Percent of Site
Impervious Surfaces		
- Buildings	83	
- Roadways and Parking	26	
- Total of Impervious Surfaces	109	36
Landscaped and Irrigated Areas		
- Single Family Lots	16	
- All Other Areas	99	
- Total Landscaped and Irrigated Areas	115	38
Undisturbed Areas	79	26
Total Project Site	303	100

The stormwater drainage system will consist of catch basins in roadways, drain lines, and "drywells" in selected catch basins for disposal. Numerous such drywells throughout the project site are planned (Exhibit 8 in the Appendix).

Description of Water Resources in the Keahole to Kailua Area

Overview. Due to high permeabilities of the natural ground surface across the project site and on the upslope lands, surface runoff does not occur even during the most intense rainfalls. As a result, no natural gulches or waterways have been created and there are no drainage culverts in the section of Queen Kaahumanu Highway in front of the project site. This being the case, the discussion of the area's water resources and the project's potential impact on these resources focuses exclusively on groundwater.

Knowledge of groundwater conditions comes primarily from the wells shown on Figure 1 and listed in Table 1. These depict two distinctly different modes of groundwater occurrence. From the shoreline inland to the near vicinity of Mamalahoa Highway, groundwater occurs in a thin and brackish basal lens which "floats" on saline groundwater beneath it and is in hydraulic contact with seawater at the shoreline. Somewhere in a generally linear alignment approximately coincident with Mamalahoa Highway, there is an abrupt change from basal to high level groundwater of exceptionally low salinity. High level groundwater is a relatively recent (1990) discovery in North Kona. The geologic feature which causes groundwater to be impounded to high levels behind it is not yet known. In addition to it creating a substantial reservoir of potable quality water, this subsurface feature also controls the location and manner of groundwater movement into the downgradient basal lens. While the hydraulic relationship between the two groundwater bodies is not yet understood, it is undoubtedly the reason for the anomalous characteristics of basal groundwater in the Keahole to Kailua area.

Description of Basal Groundwater Occurrence. Salinity, temperature, water level, and water quality data from basal wells in the area all indicate that the flow rate is low compared to areas to the north of Keahole Point and south of Kailua Bay, that saltwater circulation at depth exerts considerable influence on temperature in the basal lens, and that formation permeabilities are exceptionally high. These aspects are described below.

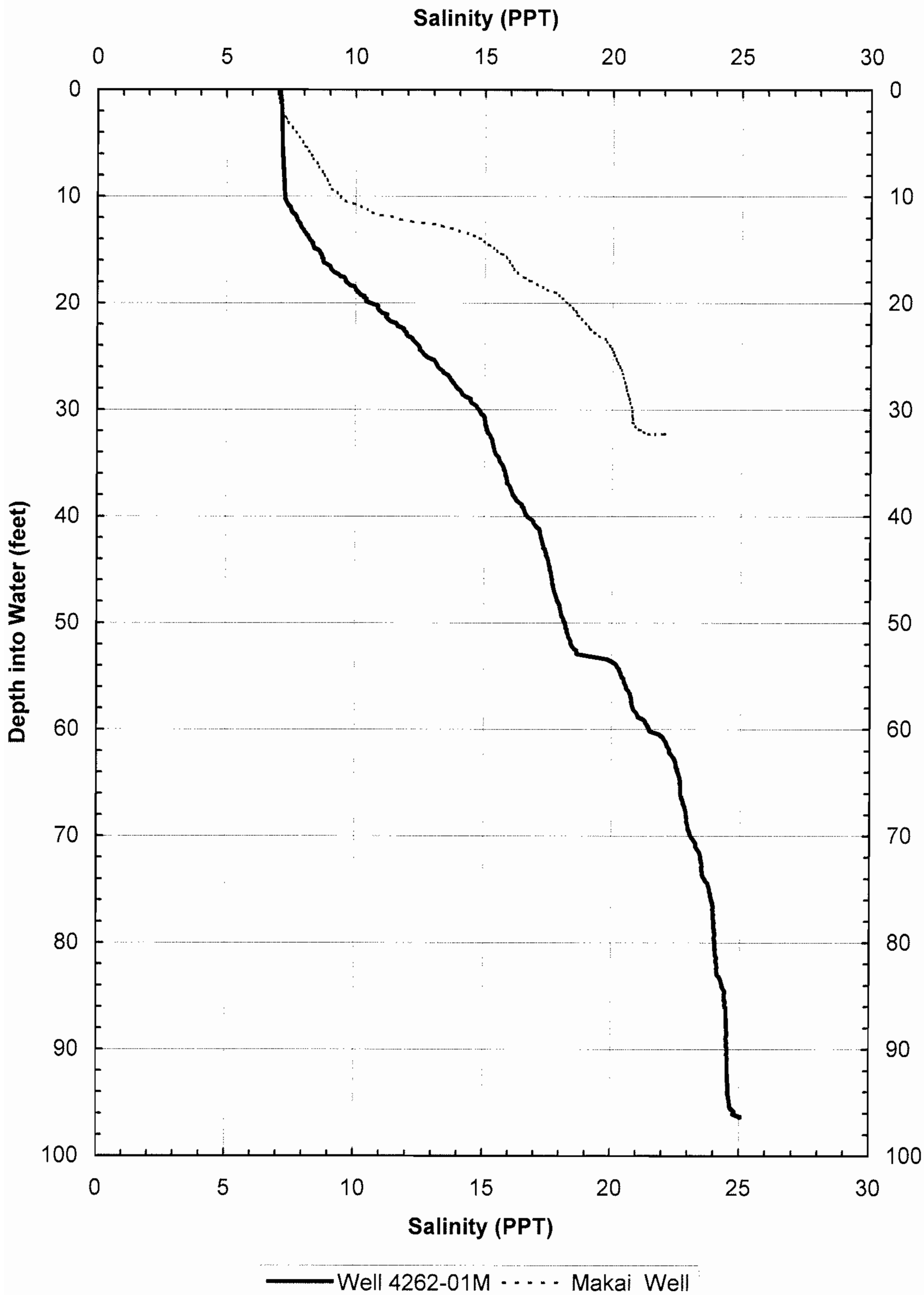
- The basal lens between the Old Kona Airport and Keahole Point is relatively saline, preventing it from being a significant source of irrigation supply unless it is extracted in small quantities from inland areas or it undergoes desalinization. There are two, small diameter monitor wells on the project site which provide information on basal groundwater beneath the site. At Well 4262-01M, which is located at the inland end of the property (refer to Figure 1), salinity in the upper 10 feet of the lens is 7.2 parts per thousand (PPT). This is about 20 percent of seawater salinity and equivalent to chlorides of about 4000 milligrams per liter (mg/l). This is too saline for irrigation except for seashore plants growing in well drained sand. Near the shoreline at the Makai monitor well, the lens is much thinner (refer to the comparative salinity profiles on Figure 2). Salinity, lens thickness, and the diffuse transition zone are all indicative of a modest groundwater flow. The best estimate of the mauka-to-makai rate of flow through the basal lens, made by the U.S. Geological Survey (Oki et al., 1999), is three (3) million gallons per day (MGD). Beneath the 0.5-mile wide project site, that would amount to a relatively modest 1.5 MGD.

Table 1

Available Data on Wells in the Keahole to Kailua Area

Well		Owner or Developer	Year Drilled	Ground Elevation (Ft. MSL)	Groundwater Level		Chloride Concentration		Water Temp. (° F.)	Present Use
State No.	Name				Level (Ft. MSL)	Date Measured	Value (MG/L)	Date Sampled		
Basal Wells of Brackish Salinity										
3960-01	--	Queen Liliuokalani Trust	1982	40			3,400	1982		Irrigation
4059-01	Palani	DWS	1958	800	1.72	1958	3,475	1958	67.5	None
4060-01	Quarry			120			2,214	Nov. 1995	66.7	None
4061-01	KAHO-1	National Park Service	1996	38	1.20	May 2000			68.6	Monitoring
4160-01	Kaloko Irr. 1	TSA International	1985	566	2.59	3-31-93	940	7-16-85	64.3	None
4160-02	Kaloko Irr. 2	TSA International	1985	543	2.45	4-26-95	955	11-25-85	64.6	None
4161-01	KAHO-3	National Park Service	1996	24	1.37	May 2000			67.4	Monitoring
4161-02	KAHO-2	National Park Service	1996	57	2.37	May 2000			66.6	Monitoring
4262-01M	Ooma	Kahala Capital	1992	90	1.68	March 1996	2,500	1993	66.0	Monitoring
4360-01	Kalaoa	DLNR - DOWALD	1968	863	2.54	4-26-95	740	9-27-68	69.2	None
4363-01 to 10	--	Uwajima					15,000		68.0	Aquaculture
4461-01	--	Alika Cooper	1990	165			2,600		71.6	Irrigation
4461-02	--	HELCO	1993	210			5,900	6-24-93	69.5	Future Cooling Water Supply
4462-02	--	State DOT - Airports	1993				3,825	1-28-93		None
--	W-1	NELHA	1988	105	0.81	6-18-91				Monitoring
--	W-2	NELHA	1988	8	1.25	6-18-91				Monitoring
--	W-3	NELHA	1988	21	0.95	6-18-91				Monitoring
Basal Wells of Potable Quality										
4458-01	Kau 1	Nansay	1991	1799	10.10	4-26-95	17	5-30-90	72.0	None
4458-02	Kau 2	Nansay	1992	1799	10.50	4-26-95	15	7-15-91	78.0 (?)	None
Wells Tapping High Level Groundwater										
3857-01	Waiaha	DWS	1993	1542	62.00	1993				Pump stuck in well; to be Abandoned
3957-01	Keopu Mauka	HASEKO	1993	1674	47.00	1993	10	1-22-93	70.0	DWS Potable Use
3957-02	Komo Monitor	USGS / DWS	1991	1600	42.80	1-20-93				Monitoring
3957-04	Doutor Coffee	Doutor Coffee 1	2001	1445	43.30	9-14-00	10	9-14-00	71.1	Coffee Production
4057-01	QLT-1	Queen Liliuokalani Trust	1994	1720	189.00	1-19-94	5.6	5-26-00	69.4	DWS Potable Use
4158-02	Honokohau	DWS	1992	1675	98.20	4-26-95	6.7	5-26-00	72.3	DWS Potable Use
4158-03	Palani 1	Palani Ranch	2007	1671	77..3	8-24-07	<10	8-25-07	71.9	Not Yet in Service
4258-03	Hualalai	DLNR - DOWALD	1993	1681	288.60	4-26-95	5.0	10-12-93	69.8	DWS Potable Use
4358-01	North Kalaoa	DLNR - DOWALD	1991	1799	236.00	1991	6.5	5-26-00	73.8	DWS Potable Use

Figure 2. Salinity Profiles of the Two Onsite Monitor Wells Taken on May 24, 2007



- Basal wells further inland than the two monitor wells on the O'oma site have chlorides of 950 MG/L (Wells 4160-01 and 02) to 3475 MG/L (Well 4059-01). Relative to the distances of these wells from the shoreline, their chloride levels are substantially higher than found in wells at similar inland distances in the areas north of Keahole Point and south of the Old Kona Airport.

- Temperatures are anomalously cold and decrease progressively with depth into groundwater, a characteristic illustrated by the temperature profiles of the two O'oma monitor wells (Figure 3). Typical surface temperatures in basal groundwater in the Keahole to Kailua area are 64° to 68° F. This is 5° to 10° colder than the temperature of high level groundwater directly inland. This difference, along with the progressive decrease in temperature with depth, show that the source of the low temperature is the saline groundwater beneath the basal lens. However, equivalent temperatures in the ocean offshore can only be found at a depth of more than 700 feet (Figure 4). This means that cold seawater is drawn inland at depth and returns seaward at mid-depth, mixing with and cooling the basal groundwater enroute. Basal groundwater temperatures this low are unique along the West Hawaii coastline.

- Permeabilities of lavas in the nearshore area are very high, resulting in considerable tidal variation in wells at significant distances inland. Figure 5 illustrates the tidal response in the two O'oma monitor wells in comparison to the ocean tide as measured in Honokohau Harbor. At the Makai Well, which is only about 450 feet from the shoreline, the water level variation is about 75 percent of the ocean and is lagged by about a half an hour. At Well 4262-01M which is 5500 feet from the shoreline, the water level variation is about 45 percent of the ocean tide and lagged by about 1.4 hours.

- Table 2 is a compilation of water quality data from wells in the area, including the onsite monitor wells. The quality of the water in the high level wells listed at the top of the table is presumably inland of the influence of man's activities. The relatively high nitrogen and phosphorus levels in these wells appear to simply be a natural occurrence in the region. In comparison to the "background" levels in these inland wells, the nutrient levels in the downgradient brackish basal wells reflect inputs to groundwater as it moves toward the shoreline. This is illustrated by the mixing line presentation of nitrates on Figure 6 which is based on the well data in Table 2 and the offshore ocean water quality data in Table 3. The mixing line on the figure depicts what the nitrate levels in groundwater would be in the basal lens if the high level groundwater was simply diluted with seawater. For most of the basal wells, nitrate levels are above the mixing line. This is indicative of nitrate enrichment by intervening inputs, either from undisturbed or developed lands. Those well samples which plot below the mixing line are indicative of nitrate depletion as groundwater moves through the basal lens.

Figure 3. Temperature Profiles of the Two Onsite Monitor Wells Taken on May 24, 2007

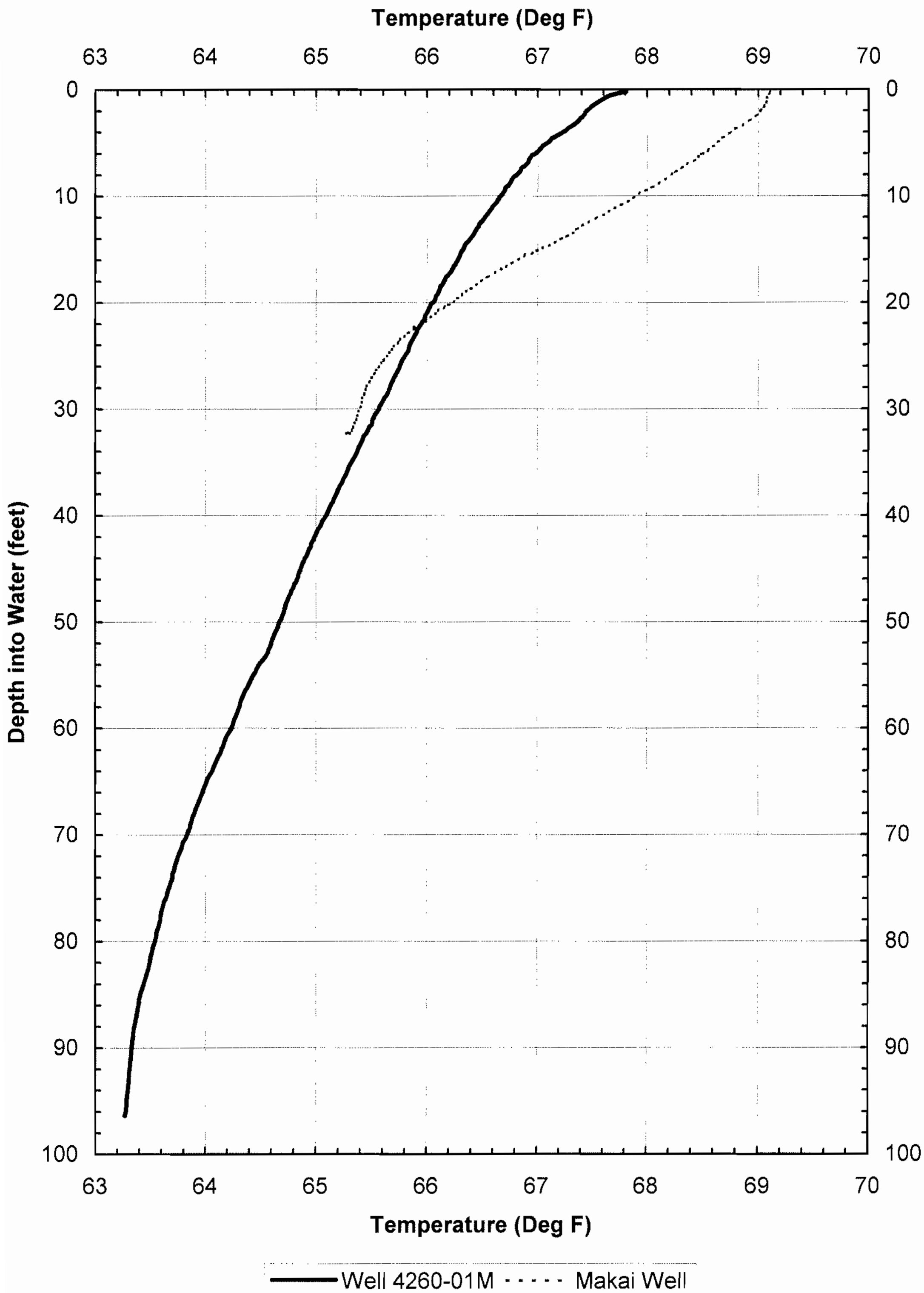


Figure 4
Comparative Ocean and Groundwater Temperature Profiles

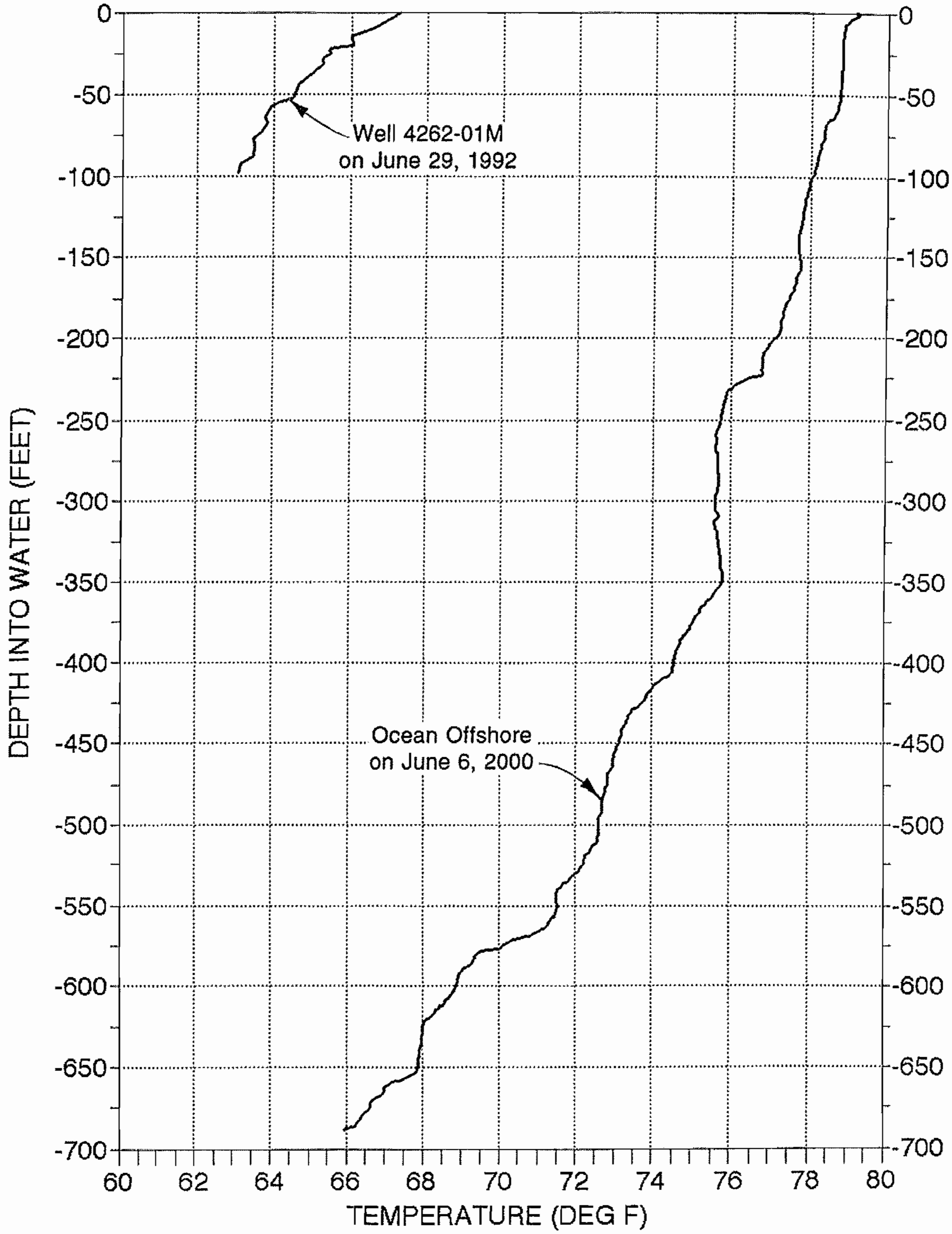


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Figure 5. Tidal Variation in Groundwater Beneath the O'oma Beachside Village Site

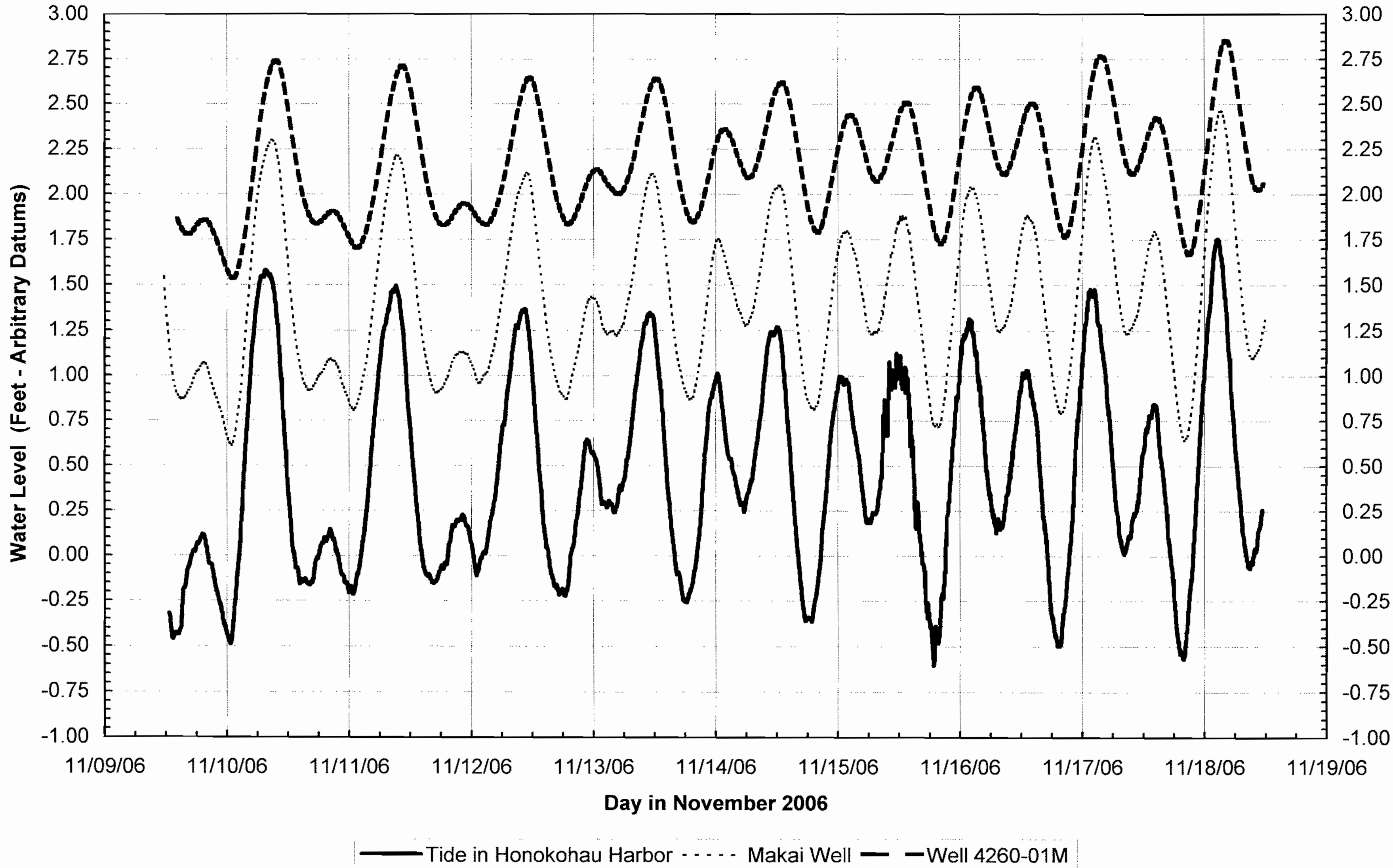

Table 2

Representative Groundwater Quality
From Wells in the Keahole to Kailua Area

Sampling Site		Date Sampled	Salinity (PPT)	Silica (µM)	Forms of Nitrogen (µM)				Forms of Phosphorus (µM)		
					NO_3	NH_4	TON	TN	PO_4	TOP	TP
High Level Potable Quality Wells											
4057-01		5-26-00	0.109	801	86.0	0.0	14.7	100.7	3.76	0.08	3.84
		7-20-01	0.079	776	85.1	0.0	35.1	120.2	3.83	3.16	6.99
4158-02		10-23-94	0.212	697	74.2	0.0	13.4	87.6	3.59	0.00	3.59
		5-26-00	0.144	844	80.1	0.0	14.5	94.6	3.64	0.20	3.84
		11-03-06	0.149	804	76.4	6.9	6.1	88.4	2.64	0.80	3.44
4258-03		6-02-00	0.165	833	70.2	1.2	19.4	90.8	3.85	0.50	4.35
4358-01		3-22-96	0.256	856	75.2	0.1	3.6	78.9	3.50	0.08	3.58
		5-26-00	0.182	908	71.8	0.0	11.9	83.7	3.40	0.24	3.64
		7-20-01	0.116	831	79.2	0.0	35.3	114.5	4.32	3.68	8.00
		11-03-06	0.172	805	66.9	7.6	6.6	81.1	3.84	0.56	4.40
Basal Wells of Brackish Quality											
4061-01	: Top	5-26-00	9.464	334	55.0	0.3	24.8	80.2	1.84	0.20	2.04
	: Top	6-10-00	9.463	304	56.2	3.5	32.1	91.8	1.44	2.96	4.40
	: Top	12-19-01	8.657	40	38.4	5.7	20.4	64.5	0.20	0.45	0.65
	: Top	11-14-07	10.015	301	67.1	2.7	33.2	103.0	1.65	0.60	2.25
	: Bottom	5-26-00	12.298	490	21.3	1.3	65.9	88.5	1.92	4.44	6.36
	: Bottom	6-10-00	10.655	477	54.4	1.4	38.2	94.0	2.64	3.36	6.00
	: Bottom	12-19-01	9.156	169	51.8	3.3	37.2	92.3	0.70	1.55	2.25
4161-01	: Top	5-26-00	6.259	672	75.0	0.2	14.8	90.0	4.36	0.04	4.40
	: Top	6-10-00	6.325	701	76.9	1.6	43.2	121.7	4.64	2.64	7.28
	: Top	12-19-01	6.305	652	79.4	4.2	0.1	83.7	4.35	0.07	4.42
	: Top	11-14-07	6.854	666	76.7	1.4	27.2	105.3	3.70	0.50	4.20
	: Bottom	5-26-00	6.548	694	77.3	0.3	16.0	93.6	4.52	0.08	4.60
	: Bottom	6-10-00	6.601	709	76.4	1.5	31.4	109.3	5.28	2.24	7.52
	: Bottom	12-19-01	6.413	629	76.3	1.8	5.4	83.5	4.05	0.20	4.25
4161-02	: Top	5-26-00	5.399	653	87.2	0.5	22.8	110.4	4.08	0.56	4.64
	: Top	6-10-00	5.361	691	104.3	5.1	42.2	151.6	9.04	2.88	11.92
	: Top	12-19-01	5.401	616	86.5	1.9	2.0	90.4	4.30	0.05	4.35
	: Top	11-14-07	5.382	651	100.4	1.9	31.6	133.9	3.20	1.15	4.35
	: Bottom	5-26-00	5.522	671	89.0	0.2	17.7	106.9	4.32	0.24	4.56
	: Bottom	6-10-00	5.883	696	89.7	0.6	32.5	122.8	5.20	2.32	7.52
	: Bottom	12-19-01	5.289	632	85.5	1.8	5.6	92.9	4.35	0.35	0.70
4160-02		5-15-94	1.734	670	68.6	0.3	2.9	71.8	5.89	0.03	5.92
		3-22-96	1.773	671	78.1	0.3	8.2	86.6	4.42	0.70	5.12
4262-01M	: Top	3-15-96	7.962	661	81.8	0.2	15.8	97.8	3.08	0.16	3.24
	: Top	6-02-00	7.783	672	89.7	1.5	26.6	117.8	5.30	0.75	6.05
	: Top	6-10-00	7.850	741	91.4	1.0	35.8	128.2	3.60	0.72	4.32
	: Top	11-03-06	7.293	640	81.2	3.5	24.8	109.5	2.32	1.28	3.60
	: Bottom	6-02-00	16.224	547	55.4	3.2	27.9	86.4	2.25	1.00	3.25
O'oma Makai Well		11-03-06	9.945	577	67.0	2.5	22.8	99.2	2.64	1.04	3.68
4461-02		3-15-96	4.946	752	79.4	0.3	12.3	92.0	3.84	0.04	3.88
Basal Wells of Saline Quality											
3960-01		10-23-94	25.543	318	28.1	0.3	4.9	33.3	1.49	0.02	1.15
		6-02-00	25.698	356	30.5	1.6	22.5	54.6	1.40	0.70	2.10
4363-04		6-02-00	26.695	291	65.6	0.9	21.6	88.1	3.80	0.50	4.30
		6-10-00	26.836	287	72.3	1.4	32.8	106.5	4.08	0.56	4.64

Note: All samples collected by Tom Nance Water Resource Engineering and analyzed by Marine Analytical Specialists.

Figure 6. Nitrate Additions in Brackish Basal Groundwater in the Keahole to Kailua Area

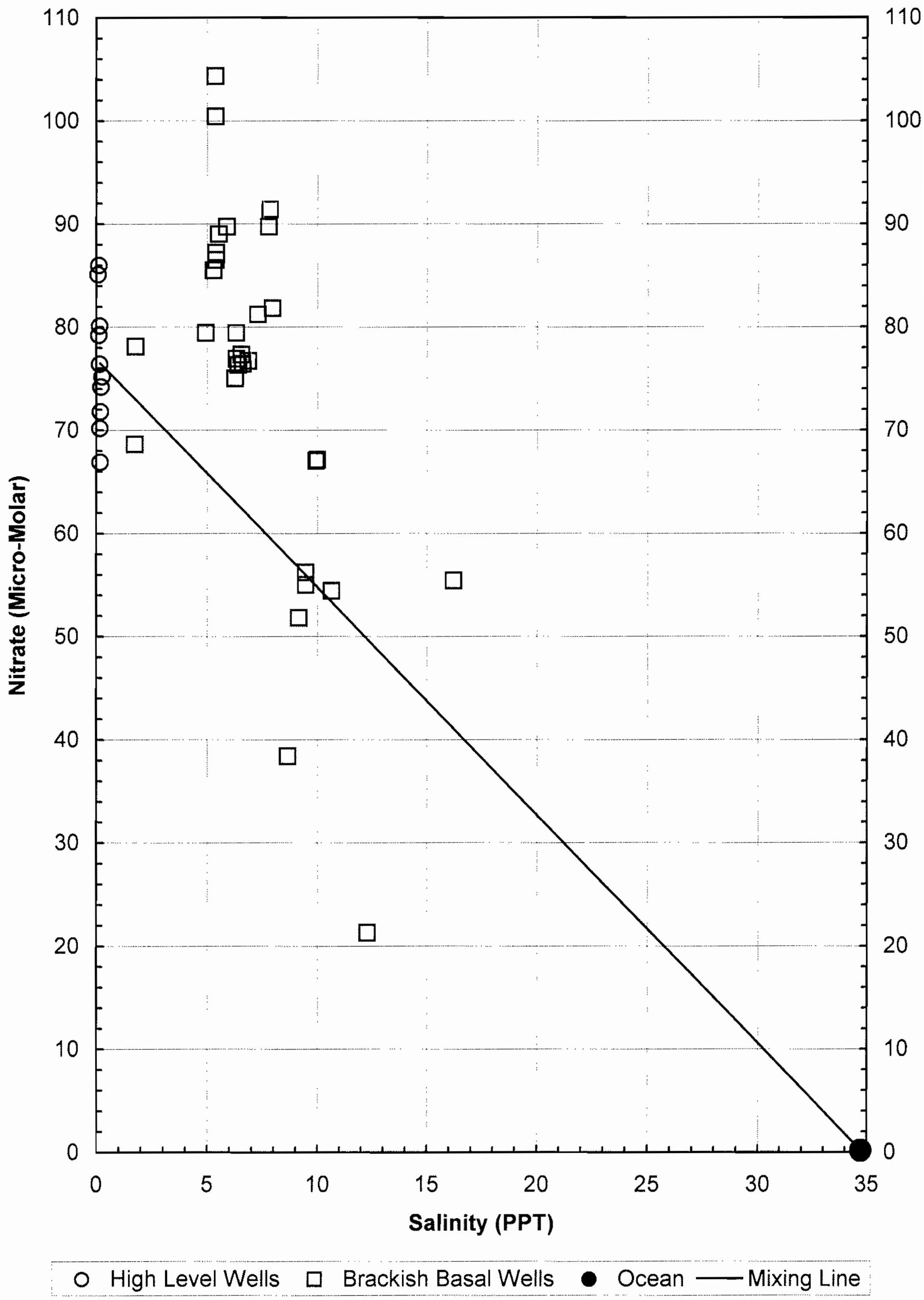

Table 3

Representative Shoreline Water Quality
in Front of the O'oma Beachside Village Project Site
(All Samples Taken on November 3, 2006)

Transect No.	Distance Offshore (Meters)	Salinity (PPT)	Silica (μM)	Forms of Nitrogen (μM)				Forms of Phosphorus (μM)		
				NO_3	NH_4	TON	TN	PO_4	TOP	TP
T-1	0	32.917	43.8	4.84	0.51	6.55	11.90	0.17	0.27	0.44
	1	31.482	74.9	8.95	0.34	7.95	17.20	0.50	0.38	0.88
	2	31.952	65.8	7.81	0.59	6.86	15.30	0.11	0.32	0.43
	5	31.987	64.4	7.48	0.40	6.73	14.61	0.27	0.27	0.54
	150 (Surface)	34.727	2.5	0.22	0.88	6.89	7.99	0.01	0.28	0.29
	150 (Bottom)	34.758	2.1	0.30	0.52	6.00	6.82	0.03	0.26	0.29
T-2	0	28.977	73.3	16.00	0.64	8.49	25.20	0.03	0.27	0.30
	1	33.123	30.6	1.92	0.54	6.99	9.50	0.03	0.30	0.33
	2	33.064	30.4	1.08	0.61	6.63	8.30	0.03	0.30	0.33
	5	33.205	30.5	1.82	0.43	7.49	9.74	0.03	0.29	0.32
	150 (Surface)	34.729	2.6	0.14	0.37	5.81	6.32	0.05	0.29	0.34
	150 (Bottom)	34.781	1.9	0.12	0.53	6.48	7.13	0.03	0.26	0.29
T-3	0	17.149	368.0	45.90	1.01	4.24	51.10	0.63	0.21	0.84
	1	28.751	109.0	11.40	1.24	10.50	23.10	0.04	0.32	0.36
	2	29.625	108.0	8.86	1.12	9.35	19.30	0.02	0.36	0.37
	5	29.642	101.0	8.35	0.71	7.58	16.60	0.03	0.30	0.33
	150 (Surface)	34.575	6.71	0.45	0.08	7.54	8.07	0.06	0.24	0.30
	150 (Bottom)	34.700	3.77	0.15	0.00	7.30	7.45	0.06	0.25	0.31
NELH Sources										
• Deep (Cold)		34.390	84.8	41.15	0.16	2.81	44.12	3.05	0.12	3.17
• Shallow (Warm)		34.690	2.9	0.24	0.26	4.57	5.07	0.13	0.22	0.35

Notes:
1. Refer to Figure 1 for the locations of Transects T-1, T-2, and T-3.
2. All samples from Transects T-1, T-2, and T-3 collected by Tom Nance Water Resource Engineering and/or Marine Research Consultants and analyzed by Marine Analytical Specialists.
3. NELH data are the averages of weekly samples by NELH from 1982 through 1999.

Attributes of High Level Groundwater in the Keahole to Kailua Area. Since the discovery of high level groundwater inland of Keauhou Bay in 1990, more than 20 wells have been completed above Mamalahoa Highway in North and South Kona. These wells encountered groundwater standing between 40 and 1280 feet above sea level (Oki et al., 1999:29 provides a good summary of water level data for most of these). Nine of these high level wells are within the area depicted on Figure 1 and three of these are nominally upgradient of the project site. Five of the nine have been outfitted with permanent pumps and are connected to DWS' North Kona system. A fifth well (No. 3957-04) provides water to Doutor Coffee. Attributes of high level groundwater inland of the project site, as demonstrated specifically by the three upgradient wells (Nos. 4158-03, 4258-03, and 4358-01 on Table 1), are as follows:

- Water levels range from about 70 to 290 feet above sea level, with no consistent pattern which might show a lateral direction of high level flow to the north or to the south.

- Chloride levels are typically less than 10 MG/L, essentially the same as found in high elevation rainwater.

- Compared to basal groundwater downgradient, temperatures are relatively warm, ranging from 69.8° to 73.8° F.

- Based on pump test results, permeabilities are less than found in the nearshore lavas but still sufficient to accommodate high capacity pumps of 350 to 1400 gallons per minute (GPM).

DWS' use of wells tapping high level groundwater in this area began in 1994 with the North Kalaoa Well (No. 4358-01). The Queen Liliuokalani Trust Well (No. 4057-01) was added in January 1997 and use of two others (Nos. 4158-02 and 4258-03) began in late 1998. Use of Well 3857-01 at Waiaha started in 2005. DWS' pumpage of these wells now averages more than 2.5 MGD. Groundwater responses when these wells are ultimately used to their full capacity may shed light on the unknown aspects of this groundwater occurrence, including the geologic feature which creates the high level water, the hydraulic relationships among the differing high level groundwater compartments, and where and how high level groundwater drains into the basal lens.

Analyses of the Project's Potential Impact on Water Resources

Based on the project's proposed water, wastewater, and stormwater systems described previously, there are a number of activities which will have an impact on groundwater resources. These activities are as follows:

- Use of deep saltwater wells to produce potable and irrigation supply by RO filtration;

- Disposal of the RO concentrate in deep disposal wells;

- Percolation of excess applied irrigation water to the underlying basal lens;

- Possible periodic disposal of excess, R-1 quality WWTP effluent in a disposal well if this is not simply handled with additional storage; and

- Collection of stormwater runoff and disposal in onsite drywells.

Actual Water Use and Wastewater Generation. Projected potable and irrigation water use (Exhibit 4) and wastewater generation (Exhibit 6) are generally based on County design standards. In West Hawaii, these standards have not proven to accurately portray actual water use and wastewater generation. To take a conservative approach to the analyses herein, the following adjustments to these design projections have been made:

- The estimated average potable consumption of 0.693 MGD at full build out has already been adjusted above County design standard rates (footnotes on page 1 of Exhibit 4). As such, this projection is assumed to be a good approximation without further adjustment.

- The common area, non-potable irrigation projection of an average of 0.405 MGD (page 2 of Exhibit 4) is based on a year-round irrigation rate on the order of 6000 GPD/acre. This too is greater than the County design standard of 4000 GPD/acre and is a reasonable approximation without further adjustment.

- The projected year-round average wastewater generation at full buildout is 0.479 MGD. It is based on County design standards (340 GPD per residential unit, for example) and the assumption of year-round full occupancy. Experience in West Hawaii has shown that actual wastewater generation as a year-round average is substantially less than the design standards. For this reason, the analyses herein assume that actual wastewater generation will be 70 percent of the projection based on County standards. This means that total wastewater generation at full build-out would be approximately 0.33 MGD. Since this is less than the anticipated 0.405 MGD non-potable irrigation requirement, the balance would be provided from the potable system. There will be wet weather periods, however, when the irrigation requirement will be negligible and wastewater will continue to be generated. Treated effluent storage at the WWTP on the order of three to six million gallons should avoid the need for subsurface disposal of the excess effluent.

Feedwater Supply, RO Desalination, and Concentrate Disposal. Based on the foregoing set of assumptions, the year-round average RO product supply at full build-out would amount to approximately 0.77 MGD (0.693 MGD for potable use and 0.075 MGD for the portion of non-potable irrigation not provided by R-1 quality WWTP effluent). If RO product recovery rate is 40 to 45 percent, the average feedwater supply rate would be 1.7 to 1.9 MGD. Whether or not this feedwater supply is seawater from NELHA or saltwater wells drawing water at depth below the basal lens, provision of this supply will have no impact on the basal groundwater as it moves toward and discharges at the shoreline.

The RO concentrate to be disposed of will amount to 55 to 60 percent of the feedwater supply or possibly as much as 1.1 MGD. This would be disposed of in wells that would deliver the concentrate into the saltwater zone below the basal lens. The concentrate would be hypersaline, with a salinity on the order of 60 parts per thousand (PPT) as compared to 35 PPT for seawater and 33 to 35 PPT for saline groundwater. Being of far greater density than the receiving groundwater, together with the horizontal-to-vertical anisotropy in the subsurface lava flows, the brine will move toward and into the marine environment without rising into and impacting basal groundwater. Discharge into the marine environment would be offshore at substantial distance and depth.

Percolation of Excess Applied Irrigation. Total irrigation use is approximated as the 0.40 MGD for (non-potable) common area irrigation and the portion of the 0.69 MGD of projected potable use that will be used for irrigation. As computed of page 1 of Exhibit 4, this latter amount is approximately 0.18 MGD. The total of both is approximately 0.58 MGD. It is assumed that about 15 percent of this or 0.87 MGD is applied in excess of the consumptive use by landscaping and percolates downward to the underlying basal lens. About 57 percent of this (0.33 MGD of the total applied of 0.58 MGD) would have originated as R-1 WWTP effluent with assumed nitrogen and phosphorus concentrations of 300 and 100 μM, respectively. The remaining 43 percent would have originated as potable water produced by RO treatment of saltwater. It would have negligible nutrient levels.

The percolate from excess irrigation will be "enriched" by fertilizers which will be dissolved into the irrigation water moves through the soil layer. The following set of assumptions have been used to estimate the ultimate impact on groundwater:

- The total landscaped area will be 115 acres (Exhibit 3).
- Nitrogen and phosphorus in fertilizers will be applied at averages of 3 and 0.5 pound/year/1000 square feet, respectively.
- Ten (10) percent of the applied nitrogen and 2 percent of the applied phosphorus will be dissolved and carried in percolate below the root zone.
- As the percolate travels through the vadose (unsaturated) zone to underlying groundwater, removal rates of nitrogen and phosphorus will be 80 and 95 percent, respectively (TNWRE, 2002).

Stormwater Collection and Disposal. Stormwater over the 224 acres of the site to be developed will either percolate directly into the ground (in natural and landscaped areas) or will be collected in a system of catch basins and drain lines and disposed of in drywells located throughout the developed area. The area that will deliver runoff to the drywells will be approximately 168 acres. As a first order approximation, the following assumptions to estimate the potential impact have been made:

- Half of the 15 inches of annual rainfall reaches the underlying groundwater at present. The balance is evaporated or transpired to the atmosphere. Development of the project will not change this amount. It computes to a year-round average of 0.12 MGD.
- Data on the quality of runoff from developed areas are scarce, but that which are available (TNWRE, 2002) indicate that nitrogen and phosphorus levels are actually relatively low (lower than the underlying groundwater, for example). Based on this, it is assumed that the nutrient

than the underlying groundwater, for example). Based on this, it is assumed that the nutrient levels in post-development runoff percolating to groundwater are increased by 20 μM and 2 μM for nitrogen and phosphorus, respectively.

- Removal rates in travel through the vadose zone are 80 and 95 percent for nitrogen and phosphorus.

Summary of the Project's Contributions to Basal Groundwater Discharging at the Shoreline. Compiled below is a summary of the project's potential contributions to the underlying basal lens which discharges into the marine environment along the shoreline. The totals indicate that the present relatively modest flow of 1.5 MGD beneath the half mile wide project site would be increased by about 0.09 MGD or six percent, that nitrogen in the groundwater would be increased by about six percent, and that phosphorus would be increased by about four percent.

Summary of Potential Nitrogen and Phosphorus Impacts by the O'oma Project to Underlying Basal Groundwater

Item	Flowrate (MGD)	Nitrogen (lbs/day)	Phosphorus (lbs/day)
Present (Ongoing) Groundwater Discharge...........	1.50	19.8	1.67
Excess Applied Irrigation			
• As RO Product Water................................	0.037	Negligible	Negligible
• As R-1 WWTP Effluent.............................	0.050	0.33	0.062
• As Dissolved Fertilizer..............................	In the Percolate	0.82	0.007
Percolating Stormwater...	No Change	0.058	0.003
Post-Development Totals......................................	1.587	21.088	1.742
% Increase Over Existing Conditions....................	5.8	6.1	4.3

The natural rate of groundwater flow beneath the half mile wide project site is estimated to be a modest 1.5 MGD. The project may increase this by about 0.087 MGD or six percent, an amount too small to be detect by water level monitoring. This amount will also have no significant impact to the use of groundwater by neighboring projects or the maintenance of anchialine pools and fishponds in the Kaloko-Honokohau National Park. Similarly, the contributions of nitrogen and phosphorus to the groundwater flowing beneath the project site will not impair present and foreseeable use of this resource. As documented by samples from the mauka onsite monitor well (Well 4262-01M on Table 2), the conservatively computed increases are well within the natural variability of concentrations of these nutrients in the underlying groundwater.

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Appendix

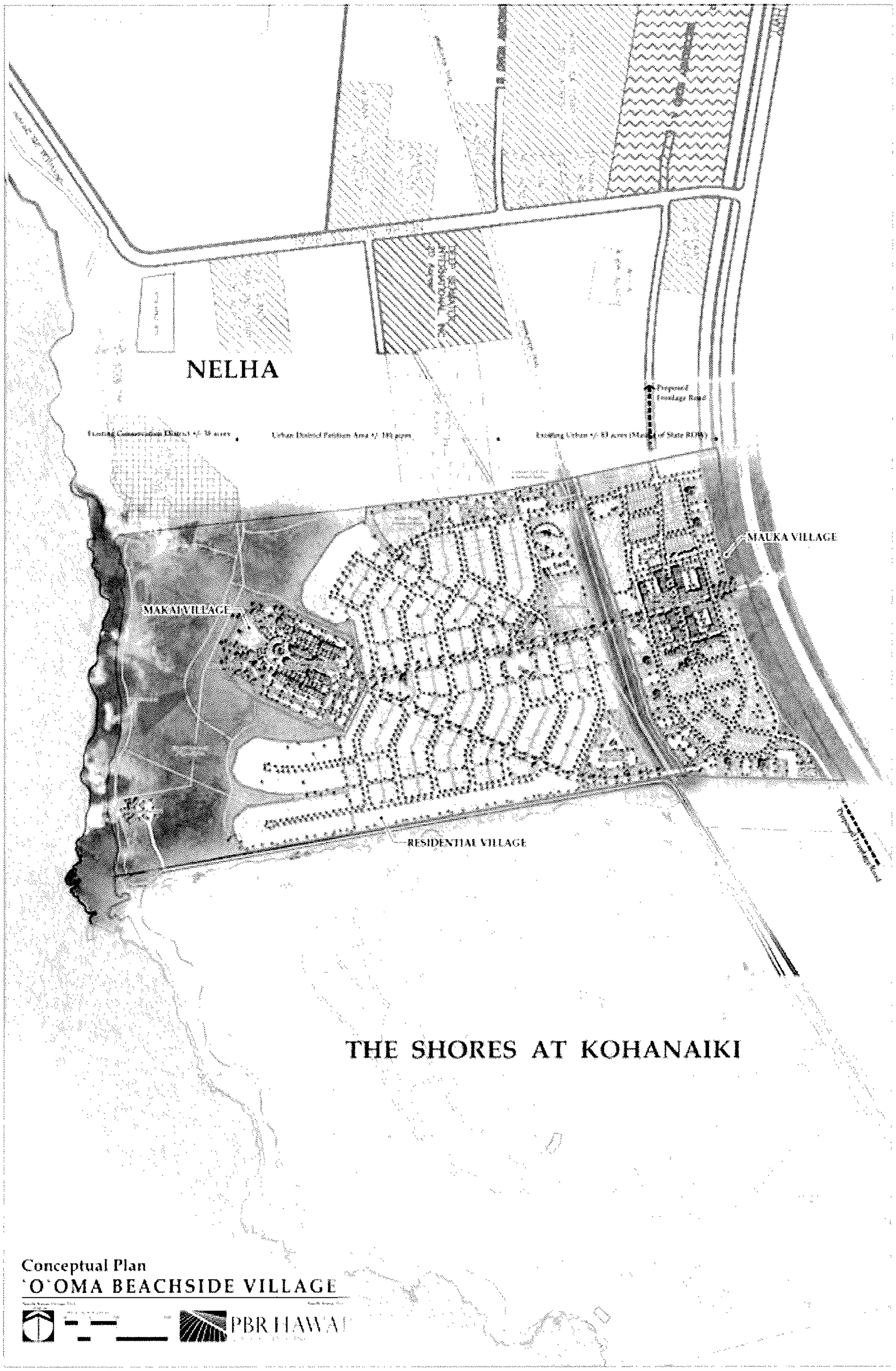
NELHA
MAKAI VILLAGE
MAUKA VILLAGE
RESIDENTIAL VILLAGE
THE SHORES AT KOHANAIKI
Conceptual Plan
'O'OMA BEACHSIDE VILLAGE
PBR HAWAII

Exhibit 1

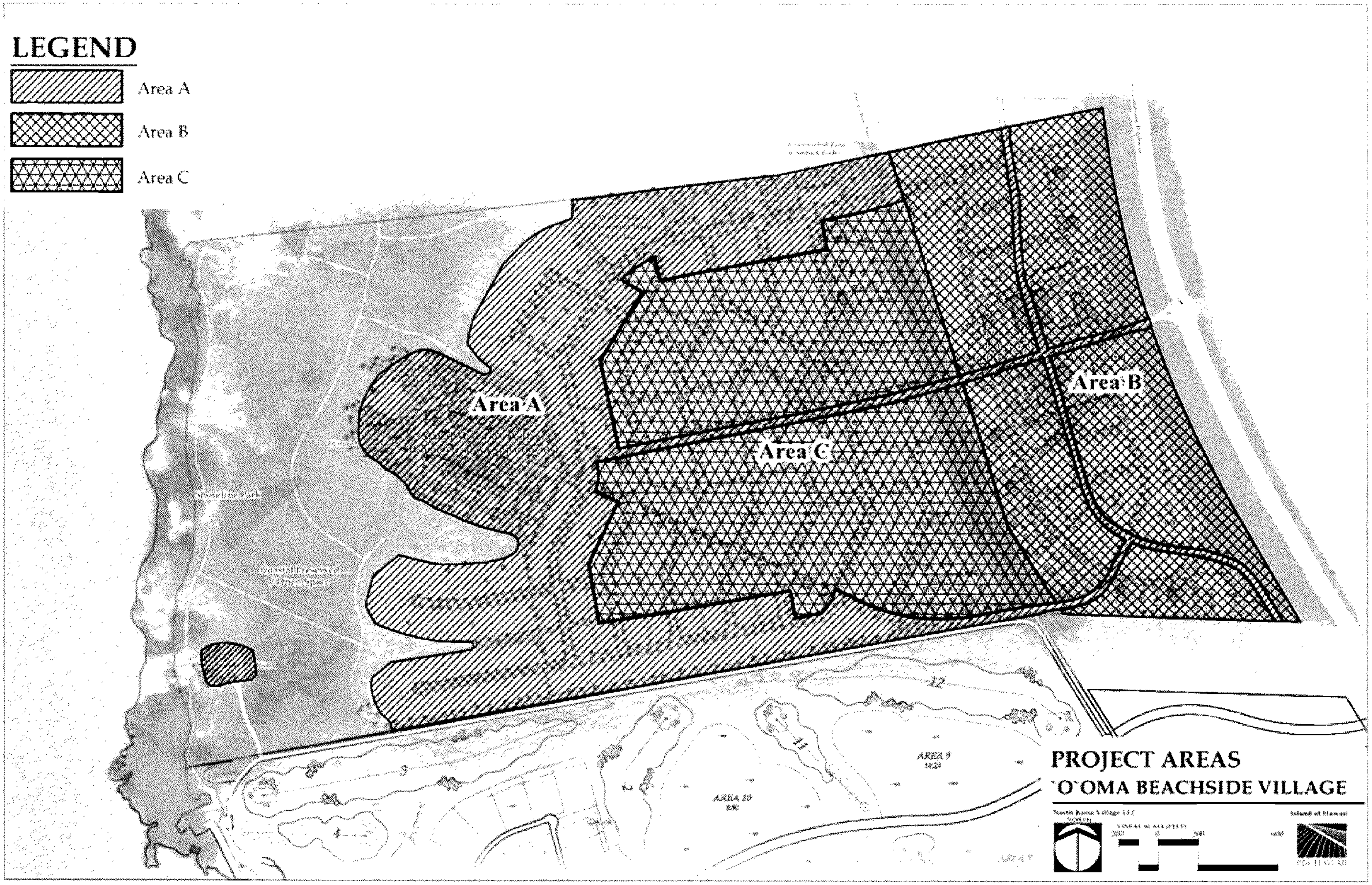
LEGEND
Area A
Area B
Area C
Area A
Area C
Area B
AREA 9
AREA 10
PROJECT AREAS
'O'OMA BEACHSIDE VILLAGE

Exhibit 2

Summary of Ground Surface

Ground Surface Categories		Approx. Acreages
The Impervious Surface Area	±	**109**
Road & Parking	±	26
Building Footprint	±	83
Undisturbed Area	±	**79**
Landscape Irrigated Area	±	**115**
On Single Family Lots	±	16
Other Landscape Common Area	±	99
TOTAL:	±	**303**

Exhibit 3

Potable Water Consumption Estimate

Land Uses by Area	Total Approx. Acreage (acres)	Approx. Units Count	Potable Demand Area (acres)	Landscape / Common Area (acres)	Approx. Commercial Floor Area (sq.ft.)	Estimated Potable Water Demand Rate	Estimated Average Daily Potable Water Demand (gpd)	Estimated Maximum Daily Potable Water Demand (gpd)
Area A								
Single Family Lot (9,000 - 15,000 sf)	22	70 - 85	22	0	-	900 GPD/DU*	76,500	114,750
Single Family Lot (5,000 - 6,000 sf)	12	90 - 100	12	0	-	550 GPD/DU**	55,000	82,500
Multi-Family Residential	5	45 - 60	3.5	1.5	-	400 GPD/DU	24,000	36,000
Makai Mixed-Use Village & Beachfront Restaurant	7		4	3	40,000	3,000 GPD/AC	12,000	18,000
Multi-Family & Mixed-Use Common Landscaping	(4.5)	-	4.5	-	-	3,000 GPD/AC	13,500	20,250
Residential Apartment on top of Commercial	-	35 - 60	-	-	-	400 GPD/DU	24,000	36,000
Ooma Canoe Club	2	-	1	1	10,000	3,000 GPD/AC	3,000	4,500
Road & Parking	26	-	-	13	-	-	-	-
Parks and Trails	6	-	-	6	-	-	-	-
Waste Water Treatment Plant	2	-	10 people	0	-	20 GPD/CAPITA	200	300
Mamalahoa Trail Undisturbed Zone / Setback Buffer	1	-	-	0.5	-	-	-	-
Community Pavilion	1	-	1	0.5	-	4,000 GPD / AC	4,000	6,000
Subtotal :	84	240 - 305	48	25.5	50,000		212,200	318,300
Area B								
Mauka Mixed-Use (Commercial below Residential)	14	-	12	2	135,000	3,000 GPD/AC	36,000	54,000
Mauka Mixed-Use (Residential Apartment on top of Commercial)	-	150 - 200	-	-	-	400 GPD/DU	60,000	120,000
Mauka Mixed-Use (Live-Work Units***)	4	50 - 70	2.8	1.2	-	400 GPD/DU	28,000	42,000
Multi-Family & Mixed-Use Common Landscaping	(9)	-	9	-	-	3,000 GPD/AC	27,000	40,500
Grocery Store	1	-	1	0	15,000	3,000 GPD/AC	3,000	4,500
Multi-Family Residential	19	195 - 250	13.2	5.8	-	400 GPD/DU	100,000	150,000
Charter School	3	-	1.5	1.5	-	4,000 GPD/AC	6,000	9,000
Road & Parking	10	-	-	5	-	-	-	-
Parks	3	-	-	3	-	-	-	-
Mamalahoa Highway Buffer	9	-	-	3.5	-	-	-	-
Subtotal :	63	395 - 520	39.5	22.0	150,000		280,000	420,000
Area C								
Single Family Lot (5,000 - 6,000 sf)	35	260 - 300	35	0	-	550 GPD/DU**	165,000	247,500
Multi-Family Residential	6	55 - 75	4	2	-	400 GPD/DU	30,000	45,000
Multi-Family Common Landscaping	(2)	-	2	-	-	3,000 GPD/AC	6,000	9,000
Community Park	7	-	-	7	-	-	-	-
Parks & Trails	7	-	-	7	-	-	-	-
Road & Parking	16	-	-	8	-	-	-	-
Mamalahoa Trail Undisturbed Zone / Setback Buffer	11	-	-	6	-	-	-	-
Subtotal :	82	315 - 375		30.0	0		201,000	301,500
Others								
Costal Preserved / Open Space	57	-		0	-	-	-	-
Shoreline Park (Excluding the Public Canoe Club)	17	-		6	-	-	-	-
Subtotal :	74	0		6.0	0			
TOTAL :	303	950 - 1,200		84	200,000		693,200	1,039,800

* Single Family Lot (9,000 - 15,000 sf) - assumes 30% of lot irrigated. 12,000sf x .30 = 3,600 / 43,560 = 0.083 acre x 6,000 gpd = 498 gpd + 400 gpd = 898 say 900 gpd/unit

** Single Family Lot (5,000 - 6,000 sf) - assumes 20% of lot irrigated. 5,500sf x .20 = 1,100 / 43,560 = 0.025 acre x 6,000 gpd = 150 gpd + 400 gpd = 550 gpd/unit

*** Live-Work units use multi-family standard (400 gpd/unit). No commercial areas included

Nonpotable Water Consumption Estimate

Land Uses by Phase	Total Approx. Acreage (acres)	Approx. Units Count	Non-Potable Landscape / Common Area (acres)	Estimated Nonpotable Water Demand Rate (gpd / acre)	Estimated Average Daily Non potable Water Demand (gpd)	Estimated Maximum Daily Nonpotable Water Demand (gpd)
Area A						
Single Family Lot (9,000 - 15,000 sf)	22	70 - 85	0	-	-	-
Single Family Lot (5,000 - 6,000 sf)	12	90 - 100	0	-	-	-
Multi-Family Residential	5	45 - 60	1.5**	-	-	-
Makai Mixed-Use Village & Beachfront Restaurant	7	-	3**	-	-	-
Multi-Family & Mixed-Use Common Landscaping*	(4.5)	-	-	-	-	-
Residential Apartment on top of Commercial	-	35 - 60	-	-	-	-
Ooma Canoe Club	2	-	1	6,000	6,000	9,000
Road & Parking	26	-	13	6,000	78,000	117,000
Parks and Trails	6	-	6	6,000	36,000	54,000
Waste Water Treatment Plant	2	-	0	-	-	-
Mamalahoa Trail Undisturbed Zone / Setback Buffer	1	-	0.5	6,000	3,000	4,500
Community Pavilion	1	-	0.5***	-	-	-
Subtotal :	**84**	**240 - 305**	**20.5**		**123,000**	**184,500**
Area B						
Mauka Mixed-Use (Commercial below Residential)	14	-	2**	-	-	-
Mauka Mixed-Use (Residential Apartment on top of Commercial)	-	150 - 200	-	-	-	-
Mauka Mixed-Use (Live-Work Units)	4	50 - 70	1.2**	-	-	-
Multi-Family & Mixed-Use Common Landscaping*	(9)	-	-	-	-	-
Grocery Store	1	-	0	-	-	-
Multi-Family Residential	19	195 - 250	5.8**	-	-	-
Charter School	3	-	1.5	6,000	9,000	13,500
Road & Parking	10	-	5	6,000	30,000	45,000
Parks	3	-	3	6,000	18,000	27,000
Mamalahoa Highway Buffer	9	-	3.5	6,000	21,000	31,500
Subtotal :	**63**	**395 - 520**	**13.0**		**78,000**	**117,000**
Area C						
Single Family Lot (5,000 - 6,000 sf)	35	260 - 300	0	-	-	-
Multi-Family Residential	6	55 - 75	2**	-	-	-
Multi-Family Common Landscaping*	(2)	-	-	-	-	-
Community Park	7	-	7	6,000	42,000	63,000
Parks & Trails	7	-	7	6,000	42,000	63,000
Road & Parking	16	-	8	6,000	48,000	72,000
Mamalahoa Trail Undisturbed Zone / Setback Buffer	11	-	6	6,000	36,000	54,000
Subtotal :	**82**	**315 - 375**	**28.0**		**168,000**	**252,000**
Others						
Costal Preserved / Open Space	57	-	0	-	-	-
Shoreline Park (Excluding the Public Canoe Club)	17	-	6	6,000	36,000	54,000
Subtotal :	**74**	-	**6.0**		**36,000**	**54,000**
TOTAL :	**303**	**950 - 1,200**	**68**		**405,000**	**607,500**

* Multi-Family & Mixed Use common area landscaping separated into this line item. These areas will be irrigated with potable water

** Landscape/Common Areas removed and reallocated into Multi-Family & Mixed-Use Common Landscaping

*** Community Pavilion to be irrigated with potable water

Exhibit 4 (Page 2 of 2)

'O'OMA BEACHSIDE VILLAGE

Water Demand Summary

SUMMARY:	AVERAGE DAILY DEMAND			MAXIMUM DAILY DEMAND		
AREA	POTABLE (gpd)	NON-POTABLE (gpd)	TOTAL (gpd)	POTABLE (gpd)	NON-POTABLE (gpd)	TOTAL (gpd)
Area A	212,200	123,000	335,200	318,300	184,500	502,800
Area B	280,000	78,000	358,000	420,000	117,000	537,000
Area C	201,000	168,000	369,000	301,500	252,000	553,500
Other	0	36,000	36,000	0	54,000	54,000
Sum Overall	**693,200**	**405,000**	**1,098,200**	**1,039,800**	**607,500**	**1,647,300**

Exhibit 5

'O'OMA BEACHSIDE VILLAGE

Wastewater Calculations

DESCRIPTION	Units	Area (acres)	Ave Flow (gpd)	Max Flow Factor	Dry I/I (gpd)	Design Ave (gpd)	Design Max (gpd)	Wet I/I (gpd)	Design Peak (gpd)	Reported Dsn. Peak (gpd)	Design Peak (cfs)
AREA A											
Single Family	185	34	59,200	5	3,700	**62,900**	299,700	42,500	342,200	343,000	0.53
Multi-Family	60	5	19,200	5	1,200	**20,400**	97,200	6,250	103,450	104,000	0.16
Mixed Use (R)	60	7	13,440	5	1,200	**14,640**	68,400	8,750	77,150	78,000	0.12
Mixed Use (C)	---	7	22,400	5	1,400	**23,800**	113,400	8,750	122,150	123,000	0.19
Commercial	---	3	9,600	5	600	**10,200**	48,600	3,750	52,350	53,000	0.08
TOTAL DEMAND (AREA A)						**131,940**	**627,300**			**701,000**	**1.08**
AREA B											
Single Family	0	0	0	5	0	**0**	0	0	0	0	0.00
Multi-Family	250	19	80,000	5	5,000	**85,000**	405,000	23,750	428,750	429,000	0.66
Mixed Use (R)	270	18	60,480	5	5,400	**65,880**	307,800	22,500	330,300	331,000	0.51
Mixed Use (C)	---	18	57,600	5	3,600	**61,200**	291,600	22,500	314,100	315,000	0.49
Commercial	---	1	3,200	5	200	**3,400**	16,200	1,250	17,450	18,000	0.03
School	---	3	3,000	5	600	**3,600**	15,600	3,750	19,350	20,000	0.03
TOTAL DEMAND (AREA B)						**219,080**	**1,036,200**			**1,113,000**	**1.72**
AREA C											
Single Family	300	35	96,000	5	6,000	**102,000**	486,000	43,750	529,750	530,000	0.82
Multi-Family	75	6	24,000	5	1,500	**25,500**	121,500	7,500	129,000	129,000	0.20
TOTAL DEMAND (AREA C)						**127,500**	**607,500**			**659,000**	**1.02**
OVERALL*											
Single Family	485	69	155,200	5	9,700	**164,900**	785,700	86,250	871,950	872,000	1.35
Multi-Family	385	30	123,200	5	7,700	**130,900**	623,700	37,500	661,200	662,000	1.02
Mixed Use (R)	330	25	73,920	5	6,600	**80,520**	376,200	31,250	407,450	408,000	0.63
Mixed Use (C)	---	25	80,000	5	5,000	**85,000**	405,000	31,250	436,250	437,000	0.68
Commercial	---	4	12,800	5	800	**13,600**	64,800	5,000	69,800	70,000	0.11
School	---	3	3,000	5	600	**3,600**	15,600	3,750	19,350	20,000	0.03
TOTAL DEMAND (OVERALL)						**478,520**	**2,271,000**			**2,469,000**	**3.82**

NOTE: The Overall sewer calculations are based upon the overall unit and area counts. These totals may differ from the sum of the three areas due to rounding.

Design Flows based on Average Daily Per Capita Flow

- 80 gallons per capita per day
- 4 persons per single family home
- 2.8 persons per apartment units (used for Mixed-Use)
- 4 persons per townhome/duplex unit
  (assumption on townhomes/duplex based on larger size units)
- 40 persons per acre for commercial and business areas

Pipe Hydraulics will be based on peak flow
Design peak flow is the sum of the design maximum flow and wet weather infiltration
Design maximum flow is the sum of the maximum flow and dry weather infiltration
Maximum flow is based on the average flow multiplied by a flow factor

Example Calculation: 185 single family units

Average Flow	185 units * 4 persons/unit * 80 gal/capita/day
	59,200 gallons/day
Max flow factor	5
Max flow	296,000 gallons/day
Dry I/I	185 units * 4 persons/unit * 5 gal/capita/day
	3,700 gallons/day
Design Ave	62,900 gallons/day
Design Max	299,700 gallons/day
Wet I/I	34 acres * 1250 gallons/acre/day
	42,500 gallons/day
Design Peak	342,200 gallons/day
say	343,000 gallons/day
=	0.53 cfs

Exhibit 6

'O'OMA BEACHSIDE VILLAGE

Storm Drain Calculations

Sample Calculations for 10 year design storm (See Attached Tables)

PAVED AREA - Sample Area 1A

$A = Q / CI$

"C" based on Table 1 (County of Hawaii Storm Drainage Standards)

C = infiltration + relief + vegetal cover + development type

- infiltration is negligible: 0.2
- relief is flat: 0.00
- vegetal cover is none: 0.0
- development type is residential: 0.40

$C = 0.6$

I = rainfall intensity

- one hour rainfall from Plate 1 is ~1.9 inches
- inlet concentration is ~12 min from Plate 3

I = 3.75in/hr (from Plate 4)

Q = 6 cfs (based on average capacity of 6' deep drywell)

A = 2.67 acres / drywell

'O'OMA BEACHSIDE VILLAGE

Existing Drainage Calculations

C values:			
Infiltration	0.0	high	From Table 1
Relief	0.0	flat	From Table 1
Vegetal Cover	0.05	poor	From Table 1
Development	0.15	agricultural	From Table 1
TOTAL C:	**0.20**		

Area ID	Length (ft)	Slope (%)	Tc (min)	I (in/hr)	C	Planimeter (si)	Meas. Area (acres)	Q=CIA (cfs)
1	800	3.75	8.8	4.75	0.2	17.84	19.7	**18.8**
2	1,450	2.41	11.6	3.65	0.2	11.53	12.7	**9.3**
3	2,050	2.44	38	2.6	0.2	32.22	35.5	**18.5**
4a	2,000	1.875	17.25	---	---	---	---	**---**
4b	2,000	1.875	17.25	2.5	0.2	105.34	115.8	**57.9**
5	500	1	27.8	2.75	0.2	2.93	3.3	**1.9**
6	2,150	1.75	17.3	3.35	0.2	54.92	60.5	**40.6**
7	2,400	2.71	20.25	3.08	0.5	48.03	52.9	**81.5**
							TOTAL:	**228.5**

'O'OMA BEACHSIDE VILLAGE

Developed Drainage Calculations

Area ID	Area Name	Area (acres)	Length (feet)	Slope %	Tc (min)	I (in/hr)	C	Area/Inlet (acres)	Q (cfs)	# CB or drywells
1A	A	7.5	1,375	1.96%	12.5	3.75	0.6	2.67	16.9	3
1B	A	4.4	1,265	1.82%	12.5	3.75	0.6	2.67	9.9	2
2	A	7.1	660	3.79%	8.4	3.85	0.6	2.60	16.5	3
3	A	6.2	353	4.82%	6.75	4.5	0.6	2.22	16.8	3
4	A	5.3	202	2.48%	6	4.65	0.6	2.15	14.8	6
5	A	5.7	385	3.12%	7.3	4.45	0.6	2.25	15.3	4
6	A	11.4	820	2.20%	10.25	3.85	0.6	2.60	26.4	9
7	A	2.1	406	2.96%	7.5	4.4	0.6	2.27	5.6	0
8	A	4.8	220	2.27%	6	4.65	0.6	2.15	13.4	3
9	A	2.9	245	1.63%	6.8	4.5	0.6	2.22	7.9	2
10	B	1.6	355	2.54%	7.4	4.4	0.6	2.27	4.3	1
11	B	1.9	478	3.77%	7.75	4.35	0.6	2.30	5	2
12	B	3.0	100	5.00%	5	4.9	0.6	2.04	8.9	2
13	B	2.1	145	3.45%	5	4.9	0.6	2.04	6.2	2
14	B	2.8	318	2.83%	7.2	4.45	0.6	2.25	7.5	3
15	B	3.7	435	2.76%	6.5	4.55	0.6	2.20	10.2	3
16	B	0.9	141	7.09%	6	4.65	0.6	2.15	2.6	1
17	B	7.3	573	2.97%	8.5	3.85	0.6	2.60	16.9	3
18	B	1.6	116	4.31%	5	4.9	0.6	2.04	4.8	2
19	B	5.1	596	3.02%	8.5	3.85	0.6	2.60	11.8	5
20	B	1.8	455	0.88%	10.2	3.85	0.6	2.60	4.2	1
21	B	1.3	240	3.33%	6	4.65	0.6	2.15	3.7	1
22	B	0.9	218	1.83%	6.5	4.55	0.6	2.20	2.5	1
23	B	2.0	387	2.07%	7.7	4.35	0.6	2.30	5.3	1
24	B	1.1	170	2.94%	5.2	4.85	0.6	2.06	3.3	1
25	B	2.1	240	0.83%	7.8	4.35	0.6	2.30	5.5	1
26	B	1.3	170	4.71%	5	4.9	0.6	2.04	3.9	1
27	B	3.3	363	3.03%	7.2	4.45	0.6	2.25	8.9	3
28	C	14.9	930	1.51%	11.9	3.75	0.6	2.67	33.6	6
29	C	4.6	336	1.49%	8	4.25	0.6	2.35	11.8	2
30	C	8.3	942	1.17%	12.9	3.65	0.6	2.74	18.2	5
31	C	13.6	1,087	1.84%	15.1	3.5	0.6	2.86	28.6	6
32	C	13.6	655	1.83%	10	3.9	0.6	2.56	31.9	8
33	C	7.7	752	1.86%	10.4	3.8	0.6	2.63	17.6	4
34	C	4.2	474	2.74%	7.8	4.35	0.6	2.30	11	3
	TOTAL	**168.1**							**411.7**	**103**

SUMMARY	Area A	Area B	Area C	TOTAL
CB/Drywell by Area	0	0	0	0
Additional for Rdwy	7	11	0	18
TOTAL CB/Drywell	**7**	**11**	**0**	**18**

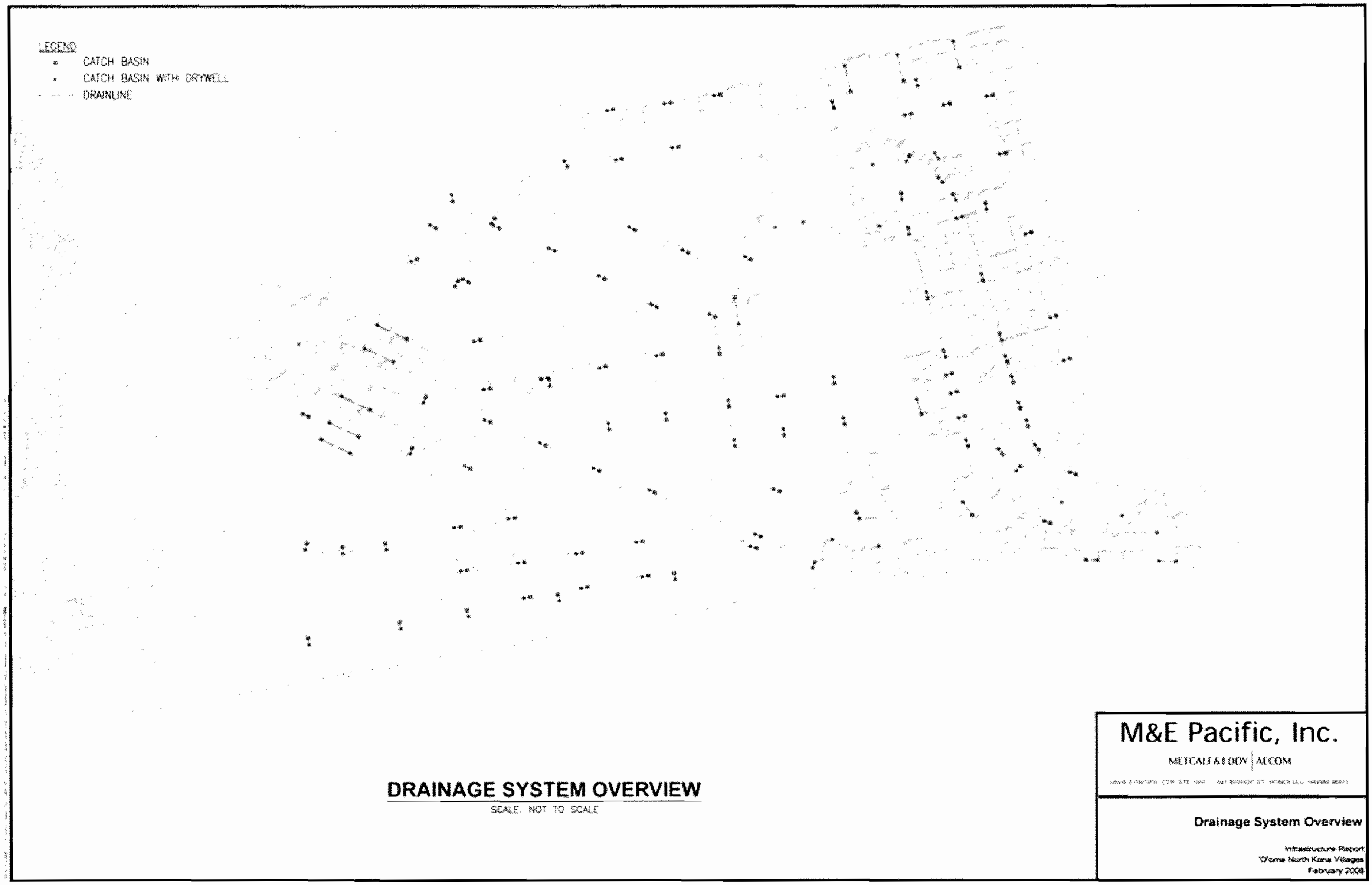
LEGEND
CATCH BASIN
CATCH BASIN WITH DRYWELL
DRAINLINE
DRAINAGE SYSTEM OVERVIEW
SCALE: NOT TO SCALE
M&E Pacific, Inc.
METCALF & EDDY | AECOM
Drainage System Overview
Infrastructure Report
'O'oma North Kona Villages
February 2008

Exhibit 8

Marine Environmental Assessment / Marine Water Quality Assessment

MARINE ENVIRONMENTAL ASSESSMENT
O'OMA BEACHSIDE VILLAGE
NORTH KONA, HAWAII

MARINE COMMUNITY STRUCTURE

Prepared for

O'oma Beachside Village LLC

Prepared by

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1039 Waakaua Pl.
Honolulu, HI 96822

May 2008

I. INTRODUCTION

The proposed O’oma Beachside Village is located on a 303-acre property in North Kona approximately one mile south of the Keahole Airport and seven miles north of Kailua- Kona. The property (project site) is bounded to the east by the Queen Kaahumanu Highway, on the west by the Pacific Ocean, and lies between the Natural Energy Laboratory of Hawaii Authority (NELHA) and Hawaii Ocean Science and Technology (HOST) Park to the north, and the Shores at Kohana’iki Development to the south (Figure 1).

O’oma Beachside Village will be a master-planned residential community with a full range of mixed uses including housing, mixed-use commercial, preserves, parks, trails, and shoreline access. In total, there will be 950 to 1,200 homes, which will include multi-family units, “live-work” or mixed-use homes, workforce, gap and affordable homes, and single-family home lots. With the exception of the shoreline park facilities, the entire O’oma Beachside Village community will be setback at least 1,100 feet from the shoreline. The proposed community will also include supporting infrastructure such as a wastewater treatment plant, water system, and power and communications systems.

While all planning and construction activities will place a high priority on maintaining the existing pristine nature of the marine environment, it is nevertheless important to address any potential impacts that may be associated with the planned community. None of the proposed land uses includes any direct alteration of the coastal areas or nearshore waters. In fact, the shoreline setback and coastal preserve area are specifically intended to preserve the coastal area as it exists at present. The potential exists, however, for the community to affect the composition and volume of groundwater that flows beneath the property, as well as surface runoff that may emanate from the community. As all groundwater that could be affected by the community subsequently reaches the ocean, it is recognized that there is potential for the community to affect the marine environment. This concern is especially critical owing to the close proximity of the NELHA and HOST Park facilities, where numerous mariculture operations rely on pristine ocean waters. In addition, the shoreline fronting the property is a recreational area and is utilized for surfing, swimming, and fishing. Therefore, evaluating the potential for alterations to water quality and marine life from material input from the community constitutes an important factor in the planning process.

In the interest of addressing these concerns and assuring maintenance of environmental quality, a marine water quality assessment and potential impact analysis of the nearshore areas off the O’oma Beachside Village property was conducted in November 2006. The rationale of this assessment was to determine the contribution of groundwater to the marine environments offshore of O’oma Beachside Village, and to evaluate the effects that this input has on water quality at the present time, prior to the commencement of any new construction activities. Combining this information with estimates of changes in groundwater and surface water flow rates and chemical composition that could result from the proposed community provides a basis to evaluate the potential future effects to the marine environment. Results of the combined evaluation have indicated that with respect to water quality, the O’oma Beachside Village will cause only small change from the present scenario, and that these changes would not result in conditions that are beyond the range of natural variability along the coast of West Hawaii.

However, regardless of the low potential for alteration of water quality, it has been deemed important to evaluate the existing condition of the nearshore marine biotic communities. Documentation of the existing conditions can provide an important baseline to evaluate future changes that may result from shoreline activities.

This report describes the results of the baseline survey of the nearshore marine communities. The survey is a continuation of previous work performed offshore of the O'oma property. In 1986, a "Baseline Assessment of the Marine Environment in the Vicinity of the O'oma II Resort Development" provided a detailed description of the physical and biological setting fronting the property. This baseline was repeated in 1990 and again in 2002. The strategy of the present report was to replicate as closely as possible the 1986, 1990 and 2002 surveys. Replicating surveys over an interval of approximate twenty-years, using the same techniques in the same locations, provides a descriptive and quantitative baseline of biotic communities off the proposed development that addresses change over time as well as space. Such a characterization of biotic assemblages can provide a basis for estimating alteration of community structure as a result of modifying land uses mauka of the shoreline. This baseline will also serve to identify any specific biotic communities that may be especially susceptible (or resistant), to the potential alterations that may result from the planned development. As this aspect of the survey will be repeating the investigations conducted in 1986 - 2006, it will provide information on the degree of natural variability in community structure.

An important part of this investigation is to provide an evaluation of the degree of natural stresses (sedimentation, wave scour, freshwater input, etc.) that influence the nearshore marine environment in the area that could be potentially influenced by the proposed project. Typically, water quality and the composition of nearshore marine communities are intimately associated with the magnitude and frequency of these stresses, and any impacts caused by the proposed project may either be mitigated in large part, or amplified, by natural environmental factors. Therefore, evaluating the range of natural stress is a prerequisite for assessing the potential for additional change to the marine environment owing to shoreline modification.

Marine community structure can be defined as the abundance, diversity, and distribution of stony and soft corals, motile benthos such as echinoderms, and pelagic species such as reef fish. In the context of time-series surveys, the most useful biological assemblages for direct evaluation of environmental impacts to the offshore marine environment are benthic (bottom-dwelling) communities. Because benthos are generally long-lived, immobile, and can be significantly affected by exogenous input of sediments and other potential pollutants, these organisms must either tolerate the surrounding conditions within the limits of adaptability or die.

As members of the benthos, stony corals are of particular importance in nearshore Hawaiian environments. Corals compose a large portion of the reef biomass and their skeletal structures are vital in providing a complex of habitat space, shelter, and food for other species. Since corals serve in such a keystone function, coral community structure is considered the most "relevant" group in the use of reef community structure as a means of evaluating past and potential impacts associated with land development. For this reason, and because alterations in coral communities are easy to identify, observable change in coral population parameters is a practical and direct method for obtaining the information for determining the effects of stress in the marine environment. In addition, because they comprise a very visible component of the nearshore environment, investigations of reef fish assemblages are presented.

II. METHODS

All fieldwork was carried out on December 26-27, 2006, and was conducted from a 22-foot boat. Biotic structure of benthic (bottom dwelling) communities inhabiting the reef environment was evaluated by establishing a descriptive and quantitative baseline between the shoreline and the 20 meter (m) (~60 foot) depth contour. Initial qualitative reconnaissance surveys were conducted that covered the area off the O'oma property from the shoreline out to the limits of coral reef formation. These reconnaissance surveys were useful in making relative comparisons between areas, identifying any unique or unusual biotic resources, and providing a general picture of the physiographic structure and benthic assemblages occurring throughout the region of study.

Following the preliminary survey, four quantitative transect sites were selected offshore of the development area at approximately the same sites as in the 1986-2002 surveys (see Figure 1). Station 1 was located at the northern property boundary, Stations II and III were located in the central area, and Station IV was located off Puhili Point, at the southern boundary of the property. At each station, three transect sites were selected, one in each of the dominant reef zones. Each transect was oriented parallel to depth contours so as to bisect a single reef zone at depths of approximately 6, 10 and 20 m. Care was taken to place transects in random locations that were not biased toward either peak or low coral cover. In total, twelve quantitative transects were conducted.

Quantitative benthic surveys were conducted by stretching a 50-m long surveying tape in a straight line over the reef surface. An aluminum quadrat frame, with dimensions of 1 m by 0.66 m, was sequentially placed over 10 random marks on the transect tape so that the tape bisected the long axis of the frame. At each quadrat location a digital color photograph recorded the segment of reef area enclosed by the quadrat frame. In addition, a diver knowledgeable in the taxonomy of resident species visually estimated the percent cover and occurrence of organisms and substratum type within the quadrat frame. No attempt was made to disturb substrata to observe organisms, and no attempt was made to identify and enumerate cryptic species dwelling within the reef framework. Only macrofaunal species greater than approximately 2 centimeters were noted.

Following the period of fieldwork, a grid divided into 100 equally sized units was overlain on each quadrat image, and units of bottom cover for each benthic faunal species and bottom type were recorded. Results of the photo-quadrats were combined with the in-situ cover estimates and community structure parameters (percent cover, species diversity) were calculated. The photo-quadrat transect method is a modification of the technique described in Kinzie and Snider (1978), and has been employed in numerous field studies of Hawaiian reef communities (e.g. Dollar 1979, Grigg and Maragos l974), and has proven to be particularly useful for quantifying coverage of attached benthos such as corals and large epifauna (e.g., sea urchins, sea cucumbers). This method provides for accurate estimates of abundance of organisms that cover a large percentage of the reef surface through photographic coverage, as well as occurrence of very small and/or rare organisms that are not visible in photographs. Few, if any other methods provide for such accurate characterization of both extremes of benthic community structure.

While this methodology is quantitative for the larger exposed fauna, many coral reef invertebrates are cryptic or nocturnal. Coupled with the generally small size of cryptic invertebrates, quantitative assessment of these groups requires methodologies that are beyond the scope of the present assessment.

Assessment of reef fish community structure was not conducted in 2002 and not repeated in 2006. As the transect tape was being laid along the bottom, all fish observed within a band approximately 2 meters wide along the transect path were identified by species name. Care was taken to conduct the fish surveys so that the minimum disturbance was created by divers, ensuring the least possible dispersal of fish. Only readily visible individuals were included in the census. No attempt was made to seek out cryptic species or individuals sheltered within coral. This transect method is an adaptation of techniques described in Hobson (1974).

III. RESULTS AND DISCUSSION

1. Physical Structure

The main structural feature of the approximately one-half mile of shoreline of the O'oma area is a basaltic ledge of pahoehoe lava with interspersed pockets of white calcareous sand. The intertidal platform, which is constantly subjected to the wash of waves, is flooded in places to form tidepools. None of these pools, however, appeared to be separated from the ocean on a permanent basis so they are not classified as "anchialine" (at least one true anchialine pond has been noted inland of the shoreline within a sinkhole, and surrounded by a grove of trees, and a single pond was observed at the bottom of a small sinkhole on a lava dome near the southern boundary of the O'oma Beachside Village property).

Rimming many of the shoreline pools formed in the basalt bench are dense bands of the intertidal seaweeds *Anhfeltia concinna* and *Ulva fasciata*. The submerged portions of the intertidal pools are lined with various forms of encrusting red algae, and contain numerous urchins of the species *Echinometra matheai, Echinostrephus aciculatus*, and *Colobocentrotus atratus*, as well as numerous juvenile reef fish. The seaward edge of the lava shoreline is composed of either basaltic boulder fields, or vertical sea cliffs 1 to 2 m in height. The one exception is a small area at the northern border of the property where a small sandy beach reaches the shoreline.

Beyond the shoreline, the structure of the offshore environment at O'oma generally conforms to the pattern that has been documented as characterizing much of the west coast of the Island of Hawaii (Dollar 1982). The zonation scheme consists of three predominant regions. Beginning at the shoreline and moving seaward, the shallowest zone beyond the shoreline is comprised of a seaward extension of the basaltic shoreline bench, along with scattered basaltic boulders that have entered the ocean after breaking off from the shoreline. *Pocillopora meandrina*, a sturdy hemispherical coral is the dominant colonizer of the nearshore area. This species is able to flourish in areas that are physically too harsh for most other species, particularly due to wave stress. The shallow transects conducted off O'oma all traversed the *Pocillopora meandrina*-boulder zone.

Seaward of the nearshore boulder zone, bottom structure is composed predominantly of a gently sloping reef bench composed of basalt, interspersed with lava extrusions and sand channels. In some areas, the bench is characterized by high relief in the form of undercut ledges and basaltic pinnacles. Fine-grained calcareous sediment also comprises a component of bottom cover. Water depth in this mid-reef zone ranges from about 6 to 15 m. As wave stress in this region is substantially less than in the shallower areas, and suitable hard substrata abound, the area provides an ideal locale for colonization by attached benthos, particularly reef corals, and generally the widest assortment of species and growth forms are encountered in this region. The intermediate depth transects at each survey station were located on the reef bench.

The seaward edge of the reef platform (at a depth of about 18 m) is marked by an increase in slope to an angle of approximately 20-30 degrees. In the deep slope zone, substratum changes from the solid continuation of the island mass to an aggregate of generally unconsolidated sand and rubble. The predominant coral cover in the slope zone is typically interconnected mats of *Porites compressa* or "finger coral", which grow laterally over unconsolidated substrata. Throughout the O'oma coastline, however, the growth of *P. compressa* has been greatly reduced by breakage from the concussive force of waves. Such breakage was especially evident at Transect Site 1, where cover of *P. compressa* on the 20 m transects was only about 3% of bottom cover. Moving down the reef slope, coral settlement and growth cease at a depth of approximately 25 m; beyond this depth the bottom consists mostly of sand, with occasional basaltic outcrops. The deep transects at each survey station were located on the upper portions of the reef slope.

2. Biotic Community Structure

A. Coral Communities

Table 1 shows abundance estimates of invertebrates observed throughout the region of study during the 2006 survey. The predominant taxon of macrobenthos (bottom-dwellers) throughout the reef zones off the O'oma property are Scleractinian (reef-building) corals. Results of quantitative line transects conducted within the three dominant reef zones provide a data base characterizing coral community structure. Table 2 shows the quantitative summary of coral community structure from the all four transect surveys (1986,1990, 2002 and 2006), while Appendices A-1 - A-4 show individual photo-quadrats for the 2006 data set.

During the 2006 survey, nine species of hermatypic, or reef-building "stony" corals, and one ahermatypic "soft coral" were encountered on transects, while the number of coral species on a single transect ranged from three to seven. The dominant species on all of the O'oma transects was *Porites lobata*, which accounted for about 66% of total coral cover, and 31% of bottom cover in 2006. The second and third most abundant species *Pocillopora meandrina* and *Porites compress* accounted for 15% and11% of coral cover. Thus, these three species comprised about 92% of living coral cover. In total, coral cover on transects accounted for 47% of bottom cover in 2006.

On the deep reef transects off O'oma surveyed in 2006, *P. compressa* accounted for relatively small percentages of bottom cover (range of 3.1% to 18.2%). In 2002, *P. compressa* cover was slightly lower (0.2% - 16.3%). With the exception of Station I-V in 1986 (31.2%) and 1990 (37.9%), cover of P. compressa has been consistently low on 20 m transects. Such low levels of *P. compressa* cover suggest relatively recent storm events that resulted in substantial damage to the mats of finger coral. With four benthic surveys spanning approximately a twenty-year period, it is possible to compare long-term changes to coral community structure. Figure 2 depicts coral community structure in histograms at each transect during each of the four surveys. Table 3 summarized coral community parameters from the 1986, 1990, 2002 and 2006 surveys, as well as the differences between the surveys. Differences in community structure parameters are in part an inevitable result of imprecision of relocation of transect locations. It is also apparent, however, that differences between years also is indicative of major processes that have influenced community structure.

In 1986, coral cover at all of the O'oma survey sites was noticeably reduced compared to other nearby areas. The decrease was attributed to the physical destruction of coral colonies brought on by a severe winter storm that occurred in February of 1986. The direction of wave propagation (from the northwest) was such that breaking waves estimated at 5-8 m in height directly impacted the O'oma site. It was apparent the greatest effects of the storm waves occurred at the deep reef zones, which are generally below the depth of destructive water motion.

Total coral cover in 1986 estimated from transects was approximately 20% of bottom cover. In 1990, total cover increased to 37%. Only one of the twelve transects (I-15') exhibited higher cover in 1986 compared to 1990. Of the eleven transects, where cover increased in 1990, the greatest increases occurred in the mid-reef zones, where total cover increased from between 14% to 43% during the years between surveys. The number of species remained unchanged on four transects, and increased in 1990 on seven transects. Species cover diversity increased on six transects.

When the 2002 data set is compared to the earlier data, it can be seen that the coral community is increased in cover compared to both the 1986 and 1990 data. Total pooled coral cover increased with each survey, from 20% of bottom cover in 1986, to 37% in 1990, to 45% in 2002. When coral cover on each transect was compared, cover increased on ten of the twelve transects between 1990 and 2002, and on eleven transects between 1986 and 2002. The largest and most consistent increase in cover occurred in the reef platform zone (10 m) where there was an increase between each survey on at all four sites (Figure 2, Table 3). Between 1986 and 2002, coral cover increased from between 26.7% of bottom cover (Site I) to 57% at Site 3 (Table 3). In the shallow boulder zone, there were also consistent increases with a single exception (1986-1990 Site I).

Between 2002 and 2006, total coral cover increased slightly from 45% to 47%. However, cover decreased on eight of the twelve transects, and increases on four transects. Changes were not consistent within zones. When the 1986 and 2006 data are compared coral cover more than doubled (20% to 47%) with a consistent increase in total cover in 2006 on eleven of the twelve transects (increases ranging from 10% to 57%). The only transect with higher cover in 1986 relative to 2006 was I-20 m, where cover during 2006 consisted of only 12% coral and the remainder primarily rubble.

A good indication of the relatively calm period without destructive storms between the surveys was the relatively high percentage of *Pocillopora eydouxi* on the reef platform in 2002 and 2006. This species occurs as a large hemispherical branching growth form that is easily broken by concussive force of breaking waves. In 2002, *P. eydouxi* occurred on all of the reef bench transects (6 and 10 m), while in 2006 it occurred on five of the eight reef bench transects. In contrast, in 1986 and 1990 this species was not encountered on any of the survey transects.

The consistent increase in coral cover with time is also evident on the three deep slope transects (20 m). At Sites II, III and IV there are increases in cover with time. However, at Site I, the lowest cover occurred during the most recent survey, and there was a substantial decrease from 72% to 19% cover between 1990 and 2002 (Table 2). These data indicate that recovery from storm stress does not occur at same rate in all reef zones, or even within the same zone in different areas. Recovery of the mats of *Porites compressa* on the deep slope zone has been substantially slower than the shallow reef bench zones. In addition, during the 2002 survey at Site 1 there was some evidence of physical alteration of the bottom from activities associated with installing a new pipeline for the Natural Energy Lab.

While number of species showed no consistent pattern of change through the entire transect set, coral cover diversity increased on ten of the twelve transects in 2002 compared to both 1986 and 1990 (Table 3). Thus, there is a consistent increase in both coral cover and coral cover diversity over the 1986-2002 interval. Between 2002 and 2006, coral cover diversity decreased or remained constant on all but one transect. Decreased diversity often occurs as a result of domination of coral cover by species with competitive superiority for occupying space. On Hawaiian reefs, coral diversity often decreases during community succession as species of Porites, (primarily *P. lobata*) dominate available substratum. As cover of *P. lobata* on the O'oma reefs increased by about 10% (in terms of coral cover) between 2002 and 2006, the competitively superiority of this species may be responsible for the decrease diversity throughout the reef community.

B. Benthic Macroinvertebrates

Other than corals, the dominant group of macroinvertebrates inhabiting the reef surface off O'oma are the sea urchins (Class Echinoidea). Table 1 summarizes the occurrence of sea urchins at all of the survey stations. The most common urchin is *Echinometra matheai*, which occurred in all reef zones. *E. matheai* are small urchins that are generally found within interstitial spaces bored into basaltic and limestone substrata. *E. matheai* were most abundant at the mid-reef transects where the number of individuals ranged from 4 to 56. This species was least abundant on the reef slope transects. *Echinostrephus aciculatus* is another small urchin with thin spines that is found in bored holes on the reef surface.

Tripneustes gratilla and *Heterocentrotus mammillatus* are other species of urchins that occurred on transects. Both of these urchins occur as larger individuals (compared with *E. matheai*) that are generally found on the reef surface, rather than within interstitial spaces.

Sea cucumbers (Holothurians) observed during the survey consisted of three species, *Holothuria atra*, *H. nobilis*, and *Actinopyga obesa*. Individuals of these species were distributed sporadically across the mid-reef and deep reef zones (Table 1). The most common starfish (Asteroidea) observed on the reef surface were *Linckia* spp. Several crown-of-thorns starfish (*Acanthaster planci*) were observed feeding on colonies of *Pocillopora meandrina*. Numerous sponges were also observed on the reef surface, often under ledges and in interstitial spaces. The green conical-shaped sponge *Iotrocha protea* was observed throughout the mid-depth reef zones.

While frondose benthic algae are conspicuously rare on the reefs of West Hawaii encrusting red calcareous algae (*Porolithon* spp., *Peysonellia rubra, Hydrolithon* spp.) were abundant throughout the reefs off O’oma. These algae were abundant on bared limestone surfaces, and on the nonliving parts of coral colonies. While very rare several species of frondose algae observed on the reef included *Valonia* sp., *Lyngbya majuscula* and *Galauxura* spp.

The design of the reef survey was such that no cryptic organisms or species living within interstitial spaces of the reef surface were enumerated. Since this is the habitat of the majority of mollusks and crustacea, detailed species counts were not included in the transecting scheme. No dominant communities of these classes of biota were observed during the reef surveys at any of the study stations.

C. Reef Fish Community Structure

Reef fish community structure was largely determined by the topography and composition of the benthos. Transect results are presented in Table 5. On individual transects, the numbers of species ranged from 14 to 40 in 2002.

The reef fish community off O’oma is typical of that found along most of the Kona Coast, as described by Hobson (1974), and Walsh (1984). Fish community structure can be divided into six general categories: juveniles, planktivorous damselfishes, herbivores, rubble-dwelling fish, swarming tetrodonts, and surge-zone fish.

Juvenile fish belonged mostly to the family Acanthuridae (surgeon fish), with representatives from the families Labridae (wrasses), Mullidae (goat fish) and Chaetodontidae (butterfly fish). Juveniles were most abundant on the deepest transects of the reef slope zone (60 feet) in areas dominated by finger coral (*P. compressa*), or basalt boulders. The complex habitat created by the spreading growth form of *P. compressa* provides shelter for small fish. Apparent storm damage to the mats of finger coral in the deep slope zone in many areas appeared to lower substantially the percentage of living finger coral. Because the coral framework was not completely flattened, habitat complexity was partially maintained in the aftermath of the storm event(s). It is apparent that fish abundance is not related directly to composition of intact living coral, but rather to the degree of shelter afforded by coralline structures, whether alive or dead.

Planktivorous damselfish, principally of the genus *Chromis* were abundant in all areas surveyed, and often comprised more than a quarter of the total number of individuals encountered along transects. Agile chromis (*Chromis agilis*) were very abundant along the outer edge of the shelf and in deeper water, whereas blackfin chromis (*C. vanderbilti*) was the primary shallow water species.

Herbivores, primarily the yellow tang (lau'i-pala, *Zebrasoma flavescens*) and goldring surgeonfish (kole, *Ctenochaetus strigosus*) were also abundant. On the shallower reef terrace, adult whitebar surgeonfish (maikoiko, *Acanthurus leucopareius*), orangeband surgeonfish (na'ena'e, *A. olivaceus*), brown surgeonfish (ma'i'i'i, *A. nigrofuscus*) and parrotfish (uhu, *Scarus* spp.) were also common. In areas where coral rubble was abundant, common fish included potters angelfish (*Centropyge potteri*), and several species of wrasses, notably fourline wrasse *(Psuedochilinus tetrataenia*), eightline wrasse (*P. octotaenia*), and yellowtail wrasse (aki-lolo, *Coris gaimard*).

The inner surge zone along the wave- swept basalt terraces supported a large number of fish, principally herbivores such as rudderfish (nenue, *Kyphosus bigibbus*), surgeonfish (*Acanthurus* spp.), and unicornfish (mostly umaumalei, *Naso lituratus*). Saddle wrasse (hinalea lau-wili, *Thalassoma duperrey*) were also abundant in the surge zone. Black durgon (humuhumu-ele'ele, *Melanichthys niger*) and pinktail durgon (humuhumu-hi'u-kole, *M. vidula*) were also observed congregating in the water column over the reef platform.

Several species of "food fish" (taken by subsistence and/or recreational fishermen) were observed during the survey. Schools of several hundred individuals of goatfish (weke, *Mulloidichthys flavolineatus*), and blue-lined snapper (taape, *Lutjanus kasmira*) were observed while diving. Numerous grand-eyed porgeys (mu, *Monotaxis grandoculis*) were observed. Rocky ledges and large coral heads sheltered fair numbers of squirrelfish (u'u, *Myripristes berndti*). Other food fishes included parrotfish (uhu, *Scarus spp.*), goatfish (moana kea and malu, *Parupaneus* spp.), jacks (papio, *Caranx melamphygus*), and grouper (roi, *Cephalopholus argus*). None of these species were particularly abundant. Orange-eyed surgeonfish (kole, *Ctenochaetus strigosus*), while abundant, were generally not large enough to be considered suitable as "food fish".

Overall, fish community structure at O'oma is fairly typical of the assemblages found in undisturbed Hawaiian reef environments. The lack of abundance of food fish indicates that the area has been subjected to moderate amounts of fishing pressure. The southern half of the property has been designated as an area where aquarium reef fish collection is prohibited. While not quantitatively assessed, it appeared that fish targeted by collectors were more abundant in the southern transects (Sites III, IV) than the northern transects (Sites I and II).

D. Anchialine Pond

Several anchialine ponds have been identified near the southern boundary of the property. By definition, anchialine ponds are areas of exposed groundwater with no surface connection to the ocean. In 2006, the single pond located on the O'oma property was observed the bottom of a small sinkhole on a lava dome with a floor elevation several meters lower than the surrounding lava fields. This pond was not identified in previous studies. The area of exposed water was on the order of one square meter. No sediment was present on the floor of the pond, and the water column was extremely clear. It is well known that nutrient concentrations within anchialine ponds vary considerable as a function of tidal oscillation with results in variable mixing of groundwater and marine waters. As a result, anchialine ponds are not nutrient limited, and thrive under a wide range of salinities and nutrient concentrations. The pond on the O'oma site was populated with numerous native herbivorous red shrimp or opae'ula (*Halocardina rubra*), and was devoid of exotic fishes, indicating that the pond is pristine in nature.

During the 1990-92 and 2002 surveys of the O'oma site, another anchialine pool was also identified in the same general area as the one observed in 2006. However, the reported description in these earlier surveys indicated that the anchialine pond was under a dense canopy of trees, and the pond was reportedly lined with sediment and plant detritus. The water column throughout the pond was extremely clear, with no apparent turbidity from suspended sediments or phytoplankton. Even with the thick sediment layer in the pond, red shrimp or opae'ula (*Halocardina rubra*) and glass shrimp (*Palaemon debilis*) were abundant in 2002. The three snails common to anchialine ponds (*Assiminea* sp. *Melania* sp. and *Theodoxus cariosa*) were also observed. As in 2006, alien fish species, which occur in many anchialine pools on West Hawaii, and are known to prey on native shrimp, were not observed in the pond in 2002.

Examination of the area in 2008 revealed marshy areas under the canopy of trees at the southern corner of the property, but no exposed water that could be considered a pond matching the description from 1990-92 and 2002. It was noted in 2002 that the pond appeared to be in a final stage of senescence, and would soon be entirely filled in. Documentation of the life history of anchialine ponds in Hawaii has shown that such infilling is part of the natural progression of these ponds. It is possible that in the four year interval, infilling of the senescent pond was complete, essentially eliminating this pond. Further examination of the area during varying stages of the tide will indicate if indeed the pond under the canopy of trees is still viable or if it has sedimented in.

E. Protected Marine Species

Several species of marine animals that occur in Hawaiian waters have been declared threatened or endangered by Federal jurisdiction. The threatened green sea turtle (*Chelonia mydas*) occurs commonly along the Kona Coast, and turtles are frequently observed on beaches throughout the area. The endangered hawksbill turtle (*Eretmochelys imbricata*) is known infrequently from waters off the Kona Coast. While turtles undoubtedly occur in the nearshore areas off O'oma, no individuals were observed during the course of the 2006 survey.

Populations of the endangered humpback whale (*Megaptera novaeangliae*) are known to winter in the Hawaiian Islands from December to April. The present survey was conducted in December, when whales are present in Hawaiian waters. However, the scope of the survey was limited to depth contours shallower than 20 m, which is not within the typical whale habitat.

The Hawaiian Monk Seal, (*Monachus schauinslandi)*, is an endangered earless seal that is endemic to the waters off of the Hawaiian Islands. Monk seals commonly haul out of the water onto sandy beaches to rest. Hence, while there is no greater potential for haul out to the beaches fronting the

O'oma Beachside Village than any other area, there is a probability that seals will haul out on these beaches. No individuals were observed on the beach or in the water during the course of the present survey. As there are no plans for any modification of the shoreline, and with established of the shoreline preservation area, there are no physical factors that will result in modification of seal behavior. The major factor that could affect seal behavior is interaction with humans. Typically when seals haul out, authorized Federal or State agencies may establish a safety zone by placement of temporary fencing and signs indicating proper treatment of the animals. At present, the O'oma area is heavily used for recreational purposes, which is not likely to change. Any additional activity by people using the beach area as a result of the Beachside Villages will not qualitatively change usage of the shoreline by humans. Hence, the best management protocol to ensure the absence of negative effects to seals is establishment of a protocol to notify the appropriate authorities as soon as possible to establish buffer zones with appropriate signage.

IV. CONCLUSIONS

Implementation of the proposed O’oma Beachside Village would involve grading, vegetation removal, new construction, and other land use changes. There are no plans, however, for alteration of the shoreline, or offshore environments in any manner. In fact, the shoreline area will be protected by a wide shoreline setback and coastal preserves area. Considerations of the changes to water chemistry as a result of alteration of groundwater flow and composition will not change the existing character of the marine environment to an extent that will alter biotic community structure (see Reports by Tom Nance Water Resources Engineering, and Marine Research Consultants). In summary, the proposed project does not appear to present the potential for alteration of the offshore environments. None of the proposed development activities has the potential to induce large changes in physico-chemical properties that could affect biotic community structure.

As described above, the reefs off O’oma are constantly exposed to natural stresses, primarily from storm waves that are the major forcing function determining the make-up of Hawaiian reef communities that occur on exposed shorelines. If some unexpected event related to shoreline development did occur, the resulting impact would likely be negligible in comparison to impacts caused by natural factors. The relatively flat grade of the property precludes any surface runoff from land to the ocean (S. Bowles, T. Nance, personal communication). Hence with proper BMPS, even expected changes associated with a temporary situation of increased sedimentation during the construction phase at O’oma will not result in sediment discharge to the ocean. As a result, there is essentially no potential for noticeable change to the nearshore community generated by the construction process. Observations of the response of marine ecosystems to shoreline development at Princeville on Kauai (Grigg and Dollar 1980, Dollar and Grigg 2004)), and Mauna Lani in South Kohala (Dollar and Grigg 2004) indicate that marine environments are not necessarily impacted by shoreline development.

It can be concluded that as long as reasonable steps are taken in construction practices, there should be no adverse impacts to the marine environment. If mandated, an ongoing monitoring program will assess if shoreline activities at O'oma are resulting in changes to nearshore water quality. Such changes in water quality would be indicative of potential changes to marine community structure. Thus, any changes in water quality owing to shoreline development would trigger mitigative action, hopefully at a level below that capable of inducing change in biotic structure.

V. SUMMARY

1. Assessment of the benthic and reef fish community structure off the proposed O'oma Beachside Village was conducted in December 2006. Twelve transects were evaluated at four stations located offshore of the property. Transect surveys were repeated at approximately the same locations as a previous survey of the same region conducted in 1986, 1990 and 2002, allowing for comparison of conditions over a twenty-year interval.

2. Physical structure of the nearshore region consists predominantly of narrow sand beaches that abut rocky basaltic shorelines that form the land-sea interface. The reef area is divided into three major zones; a shallow nearshore zone characterized by basaltic boulders and substantial water motion from breaking waves, a mid-reef zone which comprises the major "reef-building area", and a deep reef slope. Substrata on the shallow and mid-reef consist predominantly of solid limestone and basalt, while substrata on the deep reef slope are predominantly sand and coral rubble.

3. In general, the coral communities off O'oma are typical of the type that occurs throughout much of the west Hawaii coastline. In 2006, nine coral species were encountered on transects, and total coral cover was approximately 47% of bottom cover, which represents and increase of about 2% from 2002, and 27% from 1989. The dominant coral species at all sites was *Porites lobata*, which comprised approximately 60% of total coral cover in all four surveys.

4. Comparison of coral cover between 1986, 1990, 2002 and 2006 indicates a consistent increase in cover on the reef bench zones with time. The increase is likely a result of coral community recovery from a large storm event that occurred just prior to the 1986 survey. With no other significant storms occurring in the twenty years between studies, the coral community is recovering in terms of increasing bottom cover and species diversity. The pattern of change over time is less consistent on the reef slope, where much of the delicate finger coral was destroyed by the concussive force of waves in the 1986 storm. Recovery of coral cover in the deep slope zone is also apparent except at Site I, which may reflect damage to the reef from pipeline construction activities associated with NELHA.

5. Reef fish community structure at O'oma is fairly typical of the assemblages found in Hawaiian reef environments, and is characterized by six general categories: juveniles, plantivorous damselfishes, herbivores, rubble-dwellers, swarming tetrodonts, and surge-zone fishes. The presence of some food fishes indicates that the area has been subjected to low to moderate amounts of fishing pressure, both by aquarium fish collectors and fishermen. Fish were more abundant at the two transect sites (III and IV) located in the region which prohibits aquarium fish collecting.

6. It does not appear that the planned O'oma Beachside Village has the potential to cause adverse impacts to the marine environment. Stresses from natural forces (particularly storm waves) that are presently the dominant factors in influencing community structure are substantially greater than those

that could result from shoreline development. The absence of plans to modify the shoreline or nearshore environment eliminates the potential for direct alteration of ecosystems. Secondary impacts associated with changes to water quality from changes to groundwater chemistry associated with the development do not present the potential for changes based on estimates of changes to groundwater dynamics that will result from the project. The relatively low change in shoreline slope extending from the shoreline mauka precludes surface runoff from land to the ocean. In addition, similar existing projects that have been monitored for decades reveal no changes to marine environmental quality.

7. The O'oma Beachside Village does not have any likelihood of changing the present situation with respect to protected and endangered species, particularly turtles and Hawaiian Monk Seals. The complete lack of any shoreline modification, as well as establishment of a shoreline preserve area will ensure that the beach resources remain unchanged from present conditions. As a result, use of the beaches for haul-out areas by turtles or seals will not be altered from the present situation. The best mitigative measures to ensure that there are no effects to endangered or protected species by human interaction are appropriate signage and establishment of protective buffer zones established by trained personnel from State and/or Federal agencies.

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ASSESSMENT OF
MARINE WATER CHEMISTRY
O'OMA BEACHSIDE VILLAGE
NORTH KONA, HAWAII

Prepared for

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by

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I. INTRODUCTION AND PURPOSE

The proposed O'oma Beachside Village is located on a 303-acre property in North Kona approximately one mile south of the Keahole Airport and seven miles north of Kailua- Kona. The property (project site) is bounded to the east by the Queen Kaahumanu Highway, on the west by the Pacific ocean, and lies between the Natural Energy Laboratory of Hawaii Authority (NELHA) and Hawaii Ocean Science and Technology (HOST) Park to the north, and the Shores at Kohana'iki Development to the south (Figure 1).

O'oma Beachside Village will be a master-planned residential community with a full range of mixed uses including housing, mixed-use commercial, preserves, parks, trails, and shoreline access. In total, there will be 950 to 1,200 homes, which will include multi-family units, “live-work” or mixed-use homes, workforce, gap and affordable homes, and single-family home lots. With the exception of the shoreline park facilities, the entire O'oma Beachside Village community will be setback at least 1,100 feet from the shoreline. The proposed community will also include supporting infrastructure such as a wastewater treatment plant, water system, and power and communications systems.

While all planning and construction activities will place a high priority on maintaining the existing pristine nature of the marine environment, it is nevertheless important to address any potential impacts that may be associated with the planned community. None of the proposed land uses includes any direct alteration of the coastal areas or nearshore waters. In fact, the shoreline setback and coastal preserve area are specifically intended to preserve the coastal area as it exists at present. The potential exists, however, for the community to affect the composition and volume of groundwater that flows beneath the property, as well as surface runoff that may emanate from the community. As all groundwater that could be affected by the community subsequently reaches the ocean, it is recognized that there is potential for the community to affect the marine environment. This concern is especially critical owing to the close proximity of the NELHA and HOST Park facilities, where numerous mariculture operations rely on pristine ocean waters. In addition, the shoreline fronting the property is a recreational area and is utilized for surfing, swimming, and fishing. Therefore, evaluating the potential for alterations to water quality and marine life from material input from the community constitutes an important factor in the planning process.

In the interest of addressing these concerns and assuring maintenance of environmental quality, a marine water quality assessment and potential impact analysis of the nearshore areas off the O'oma Beachside Village property was conducted in November 2006. The rationale of this assessment was to determine the contribution of groundwater to the marine environments offshore of O'oma Beachside Village, and to evaluate the effects that this input has on water quality at the present time, prior to the commencement of any new construction activities. Combining this information with estimates of changes in groundwater and surface water flow rates and chemical composition that could result from the proposed community provides a basis to evaluate the potential future effects to the marine environment. Predicted changes in groundwater composition and flow rates have been supplied by Tom Nance Water Resource Engineering (TNWRE 2008). Results of the combined evaluation will indicate the degree of change to the marine environment that could occur as a result of O'oma Beachside Village.

The property is somewhat unique in that the O'oma Beachside Village represents at least the third iteration of proposed development on the property. During two separate earlier proposed scenarios in 1990-1992 and 2002 similar marine assessment programs were carried out by Marine Research Consultants. In 1990-92, four surveys were conducted between October 1990 and March 1992. Further consideration of these data in the present report will consist of the geometric means of these four surveys. Hence, by repeating similar sampling protocols in 2006, it is possible to evaluate not only the existing state of marine water quality at the site, but also to assess if any changes have occurred over the past fourteen years. The assessment program can also serve as a baseline if future permitting requirements include a repetitive monitoring program during the course of construction and operation of O'oma Beachside Village.

II. METHODS

Three transect survey sites were established in the vicinity of the O'oma property for the initial monitoring program in 1990. For the 1990-1992 program, Site 1 was located off the public bathhouse located to the north of the northern property boundary. During subsequent increments of monitoring, Sampling Site 1 was moved south to the northern boundary of the property. Site 2 is located off the approximate center of the property; and Site 3 is located near the southern boundary at Puhili Point (Figure 1). Sites 2 and 3 were in the same locations for all three surveys.

All fieldwork was conducted on November 3, 2006. Water quality was evaluated at each site on transects that were oriented perpendicular to the shoreline and depth contours. In 2006 water samples were collected at ten locations on each transect from just seaward of the shoreline to approximately 150 meters (m) offshore (0, 1, 2, 5, 10, 15, 20, 30, 50, 150 m). Such a sampling scheme was designed to span the greatest range of salinity with respect to potential freshwater efflux at the shoreline. Sampling was more concentrated in the nearshore zone because this area receives the majority of groundwater discharge, and hence is most important with respect to identifying the effects of shoreline modification. The sampling locations (in terms of distance from shore) were altered slightly in 2006 based on results of surveys from the 1992 and 2002 monitoring programs in order to best characterize the nearshore area which is affected by input from land. These changes in distances from shore where samples were collected does not affect to capability to compare water quality between the three survey periods.

Owing to the shallow depth of the near-shore shelf, at stations from the shoreline extending to 30 m from shore, a single sample was collected within 20 cm of the sea surface by swimmers working from shore. At stations 50 and 150 m from the shoreline samples were collected at two depths; a surface sample was collected within approximately 20 (cm) of the sea surface, and a bottom sample was collected within 1 m of the sea floor.

A sample was also collected from an anchialine pond located approximately 50 m behind the shoreline near the southern boundary of the property. In order to determine chemical concentrations in unaltered groundwater, samples were also collected from a variety of high level and brackish wells in the Keahole-Kailua corridor (see report by Tom Nance Water Resources Engineering for locations of wells and results of well water analyses).

Water quality parameters evaluated included the ten specific criteria designated for open coastal waters in Chapter 11-54, Section 06 (d)(Area-Specific criteria for the Kona (west) coast of Island of Hawaii). Open Coastal waters) of the State of Hawaii Department of Health (DOH) Water Quality Standards. These criteria include: total dissolved nitrogen (TDN), nitrate + nitrite nitrogen (NO_3^- + NO_2^-, hereafter referred to as NO_3^-), ammonium nitrogen (NH_4^+), total dissolved phosphorus (TDP), orthophosphate phosphorus (PO_4^{-3}), Chlorophyll a (Chl _a_), turbidity, temperature, pH and salinity. In addition, silica (Si) was also reported because these parameters are sensitive indicators of biological activity and the degree of groundwater mixing.

Surface water samples were collected by filling pre-rinsed, 1-liter polyethylene bottles. “Deep” water samples were collected using a Niskin-type oceanographic sampling bottle. The bottle is lowered to the desired sampling depth (approximately 1-2 off the bottom) with spring-loaded endcaps held open so water can pass freely through the bottle. At the desired sampling depth, a weighted messenger released from the surface triggers closure of the endcaps, isolating a volume of water.

Subsamples for nutrient analyses were immediately placed in 125-milliliter (ml) acid-washed, triple rinsed, polyethylene bottles and stored on ice. Analyses for Si, NH_4^+, PO_4^{3-}, and NO_3^- were performed of filtered subsamples with a Technicon Autoanalyzer using standard methods for seawater analysis (Strickland and Parsons 1968, Grasshoff 1983). TDN and TDP were analyzed in a similar fashion following digestion. Dissolved organic nitrogen (DON) and dissolved organic phosphorus (DOP) were calculated as the difference between TDN and dissolved inorganic N, and TDP and dissolved inorganic P, respectively.

Water for other analyses was subsampled from 1-liter polyethylene bottles and kept chilled until analysis. Chl *a* was measured by filtering 300 ml of water through glass-fiber filters; pigments on filters were extracted in 90% acetone in the dark at -20^{o} C for 12-24 hours. Fluorescence before and after acidification of the extract was measured with a Turner Designs fluorometer. Salinity was determined using an AGE Model 2100 laboratory salinometer with a readability of 0.0001‰ (ppt). Turbidity was determined using a 90-degree nephelometer, and reported in nephelometric turbidity units (NTU) (precision of 0.01 NTU).

In-situ field measurements included water temperature and pH using a field meter with a readability of 0.01°C and 0.01 pH units. Dissolved oxygen was measured with a Royce Model 91 field meter. Vertical profiles of salinity, temperature and depth were acquired using a RBR-620 CTD calibrated to factory standards.

All fieldwork was conducted by Dr. Steven Dollar. All laboratory analyses were conducted by Marine Analytical Specialists located in Honolulu, HI (Labcode: HI 00009). This analytical laboratory possesses acceptable ratings from EPA-compliant proficiency and quality control testing.

III. RESULTS

1. General Overview

Tables 1 and 2 show results of all water chemistry analyses for samples collected off the O'oma Beachside Village property in November 2006. Table 1 shows concentrations of dissolved nutrients in micromolar (µM) units; Table 2 shows concentrations in micrograms per liter (µg/L). Similar tables for surveys in 1992 and 2002 are shown in Appendix A.

Concentrations of eight dissolved nutrient constituents in surface and deep samples are plotted as functions of distance from the shoreline in Figure 2. Values of salinity, turbidity, Chl *a* and turbidity as functions of distance from shore are shown in Figure 3. Several patterns of distribution are evident in Tables 1 and 2 and Figures 2 and 3. It can be seen in Figure 2 that at all three transects, the dissolved nutrients Si, NO_3^- and TN display distinctly elevated concentrations in the samples collected within about 30 m from the shoreline at all three sites. Salinity displays the opposite trend, with sharply lower concentrations in the nearshore samples at all three sites (Figure 3). While these gradients are evident at all three sites, they are most pronounced at Site 3 and least pronounced at Site 2.

These patterns are a result of concentrated input of groundwater to the ocean near the shoreline. Low salinity groundwater, which typically contains high concentrations of Si and NO_3^-, percolates to the ocean at the shoreline, resulting in a nearshore zone of mixing. In many areas of the Hawaiian Islands, such groundwater percolation results in steep horizontal gradients of increasing salinity and decreasing nutrients moving seaward. PO_4^{3-} is also generally elevated in groundwater relative to ocean water. However, the patterns of horizontal gradients of concentrations of PO_4^{3-} do not show the same uniformly progressive decreases with distance from shore as Si and NO_3^-. Horizontal gradients of TDN and TDP reflect the patterns of NO_3^- and PO_4^{3-}, respectively.

At the open coastal sampling stations off O'oma, the zone of mixing is relatively small, and the gradients are less pronounced than at other areas of West Hawaii where semi-enclosed embayments occur.

Water chemistry parameters that are not associated with groundwater input (NH_4^+, DON, DOP) do not show a pattern of decreasing concentration with respect to distance from the shoreline. Rather, these constituents do not occur in any consistent pattern across the horizontal ranges of the sampling area.

Similar to the patterns of dissolved inorganic nutrients (Si and NO_3^-), the distribution of Chl *a* also displays peaks near the shoreline. Beyond 30 m from the shoreline, the concentration of Chl *a* in surface waters is essentially constant across the sampling scheme (Figure 3). Turbidity is slightly higher in the nearshore samples on all transects, with a peak value at the shoreline of Transect 2 (Figure 3). Temperature showed a distinct trend of increase with distance from shore at all three transects (Figure 3). The distinct cooling at the shoreline is likely a result of cool groundwater discharge.

It can be seen in Tables 1 and 2 that chemical concentrations at the most seaward sampling stations (150 m from shore) at all three sites are similar, and represent open coastal ocean waters with little influence from land.

2. Conservative Mixing Analysis

A useful treatment of water chemistry data for interpreting the extent of material input from land is application of a hydrographic mixing model. In the simplest form, such a model consists of plotting the concentration of a dissolved chemical species as a function of salinity. The concept of using such mixing models which scale nutrient concentrations to salinity is utilized by the State of Hawaii Department of Health for establishing a unique set of water quality standards for the West Coast of the Island of Hawaii [Hawaii Administrative Rules, §11-54-06 (d)].

Figure 4 shows plots of the concentrations of Si, NO_3^-, PO_4^{3-}, and NH_4^+ as functions of salinity for the samples collected at each transect site in November 2006. Each graph also shows a conservative mixing lines constructed by connecting the endmember concentrations of open ocean water collected at the same time as the other water samples, and groundwater from four high level potable well located upslope of the O'oma Beachside Village property (See Table 2 in TNWRE 2008).

Comparison of the curves produced by the distribution of data with conservative mixing lines provides an indication of the origin and fate of the material in question.

If the parameter in question displays purely conservative behavior (i.e., no input or removal from any process other than physical mixing), data points should fall on, or near, the conservative mixing line. If however, external material is added to the system through processes such as leaching of fertilizer nutrients to groundwater, data points will fall above the mixing line. If material is being removed from the system by processes such as biological uptake, data points will fall below the mixing line.

Dissolved Si represents a check on the method as this material is present in high concentrations in groundwater, low concentration in open coastal waters, and is not a major component of fertilizer or sewage effluent. In addition, Si is not utilized rapidly within the nearshore environment by biological processes. It can be seen in Figure 4 that with the exception of several data points at the lowest salinities, all other data points for all three transect sites fall in a linear array close to the conservative mixing line. Linear regression of the concentrations of Si as a function of salinity indicates that for all three transects, there is a highly significant R^2 (proportion of variation explained) of 0.97-0.99 indicating that the concentration of Si is dependant on salinity.

The Y-intercept of the regression of Si as a function of salinity can be interpreted as the predicted nutrient concentration at a salinity of zero. As groundwater has salinity close to zero, the Y-intercept can be used to evaluate the relationship between upslope groundwater and groundwater that is entering the ocean at the shoreline. When the average concentration of Si from the four potable wells upslope of O'oma and average concentration of open coastal water are plotted versus salinity, the Y-intercept is 815 µM. The upper and lower 95% confidence limits of the Y-intercepts of the regression lines of Si vs. salinity for the three transects are 762-808 µM (Transect 1); 378-484 µM (Transect 2) and 681-744 (Transect 3). Hence, if Si is a truly conservative tracer, it can be determined that there is a slight reduction of Si near the shoreline at all three transects. Even though regression statistics indicate slight depletion in Si concentrations in the ocean relative to upslope groundwater at two of the three transects, the extremely high R^2 supports the conclusion that Si is behaving as a conservative tracer and that well water sampled from the upslope wells is similar in composition to groundwater entering the ocean off the O'oma Beachside Village property.

The plots of NO_3^- versus salinity show a slightly different distribution than Si. All of the data points for Transect 1 fall slightly above the conservative mixing line, and all but one data point from each of Transects 2 and 3 fall below the mixing line. Linear regressions of these data indicate significant R^2s of 0.93 - 0.99 for each of the three transects indicating that the concentrations of NO_3^- are functions of salinity. The average concentration of NO_3^- in the four potable wells is 77 µM. The upper and lower confidence limits of the Y-intercepts of the concentrations of NO_3^- versus salinity for the three transects are 86-99 µM (Transect 1), 74-114 µM (Transect 2), and 76-98 µM (Transect 3). Hence, only on Transect 1 is there a subsidy of NO_3^- in the nearshore ocean relative to what would be predicted from mixing of natural groundwater and open coastal water.

While PO_4^{3-} is also generally found in groundwater in higher concentrations than open coastal water, it occurs in far lower concentrations compared to NO_3^-, owing in part to a high absorptive affinity of phosphorus in soils or rock. It can be seen in Figure 4 that when plotted as functions of salinity, concentrations of PO_4^{3-} do not prescribe linear patterns similar to Si and NO_3^-. Linear regression of PO_4^{3-} versus salinity is not statistically significant (P=0.05) for data from Transects 2 and 3 indicating that these concentrations are not functions of salinity. The mean value of the concentration of PO_4^{3-} in potable wells upslope of O'oma (3.6 µM) is within the range of the 95% confidence limits of the linear regression fitted through the data from Transect 1 (0.29-6.03 µM) indicating that the concentrations of PO_4^{3-} in the ocean are the result of mixing of groundwater and open ocean water endmembers.

Plots of concentrations of NH_4^+ versus salinity show different relationship than Si, NO_3^- and PO_4^{-3}. Plots of concentrations of NH_4^+ versus salinity exhibit no linear trends with respect to salinity (Figure 4). Data from Transects 1 and 2 do not result in statistically significant linear regression. In addition, the highest values of NH_4^+ on these two transects occurred at the highest salinities, suggesting that the source of most of the NH_4^+ in the nearshore ocean is not from the land but rather from biological processes occurring in the ocean. The situation is different at Transect site 3. If the single anomalous data point at the shoreline is omitted, the regression of the distribution of NH_4^+ data as a function of salinity is significant with a Y-intercept equal to the concentration in upslope well water.

3. Temporal Changes

As noted above, similar marine surveys have been conducted off the O'oma property in 1990-1992 and 2002. Comparison of the results of these surveys with the work in 2006 provides an indication of changes in nutrient characteristics over the fourteen year interval. Figure 5 shows mixing plots of Si, NO_3^-, PO_4^{3-}, and NH_4^+ as functions of salinity for the pooled samples from the three transects collected during each survey set. Comparison of the slopes of the mixing lines provides a valid indicator of changes between surveys with respect to input of nutrients to the coastal ocean.

Table 3 shows linear regression statistics for each nutrient as a function of salinity for each survey year. For Si, NO_3^- and PO_4^{3-} the upper confidence limits Y-intercept in 2006 are lower than in 1990-92. The upper confidence limit of the slope of NO_3^- is lower than in 1990-92. The regression for NH_4^+ and PO_4^{3-} in 2002 are non-significant, making any comparisons invalid. The overall results of the time-course comparison indicate that there have not been consistent increases or decreases in input of the nutrients to the ocean over the course of the three increments of monitoring.

4. Compliance with DOH Criteria

The West Coast of the Island of Hawaii has area specific water quality standards [Chapter §11-54-6(d)]. The major difference between these specific criteria and the general criteria for open coastal waters for the rest of the state is the consideration that high nutrient groundwater mixes with oceanic water within the nearshore zone. As a result, area specific criteria for nutrients that occur in high concentrations in groundwater relative to ocean water (NO_3^-, TDN, PO_4^+, and TDP) are evaluated by two criteria based on salinity. In areas where nearshore marine water salinity is greater than 32‰, specific criteria for geometric means apply. Geometric means are calculated at each sampling station from three values collected on three sampling dates, spaced within a 14-day period. For samples with salinity below 32‰, compliance with the DOH criteria is defined by the slope of the regression line of the nutrient concentration as a function of salinity. Slopes greater than the "not to exceed" values stated in the standards are deemed out of compliance. (Note that for the present assessment, three separate samplings within a 14-day period were not conducted).

It can be seen in Tables 1 and 2 that each transect had at least one sample with salinity less than 32‰. Hence, it can be interpreted that the relevant DOH compliance criteria are the regression statistics shown in §11-54-6(d)(1)(ii). Table 4 shows the slopes and upper and lower 95% confidence limits of linear regressions of NO_3^-, TDN, PO_4^{3-}, and TDP as functions of salinity from each of the three ocean transects. Also shown in Table 4 are the "compliance slopes" listed in the West Hawaii area specific water quality standards. As stated in the WQS, *"…the absolute value of the upper 95% confidence limit for the calculated sample regression coefficient (i.e., slope) shall not exceed the absolute value listed in the regulations."* When linear regression analyses are performed with data in units of µg/L , the absolute values of confidence limits of the slope of the regression line of NO_3^- vs. salinity exceeded the absolute values of the specific criteria slope (-31.92) only on Transect 1. None of the upper confidence limits for TDN, PO_4^{3-} or TDP on the three transects exceeded the respective specific criteria slopes (Table 4).

Considering dissolved nutrients with salinities greater than 32‰, only a single values of PO_4^{3-} and TDP exceeded the DOH geometric mean standard. However, many of the samples exceeded the geometric mean criteria for NO_3^- and TDN (Tables 1 and 2). As there is presently no development on the O'oma property, these "exceedances" can be considered a result of natural conditions. To illustrate this likelihood, it can also be seen in Figure 4 that concentrations of NO_3^- in samples with salinities above 32‰ fall in a linear array along the mixing lines. Hence, the "cut-off" of 32‰ to separate compliance evaluation by using mixing line regressions and geometric means does not appear to be a justifiable boundary to differentiate between methods of determining compliance. Samples with salinities of 32‰ are comprised of about 9% freshwater and 91% seawater. With such a mixture the geometric mean standard can be exceeded solely as a result of mixing of uncontaminated groundwater and ocean water.

The area specific DOH standards for West Hawaii also include three parameters (NH_4^+, Chl *a* and turbidity) that are not subjected to the conditions of salinity based on the 32‰ boundary. Rather, the specific geometric mean criteria apply to all values of these parameters regardless of salinity. It can be seen in Tables 1 and 2 that all values of NH_4^+ on Transects 1 and 2, and all on Transect 3 within 10 m of the shoreline exceed the geometric mean standard. Similarly, most of the values of turbidity and Chl *a* within the nearshore zone exceed standards. As stated above, with no development presently on the O'oma site, the offshore conditions represent essentially the natural setting of the area. It is apparent that the geometric mean values that are presently DOH compliance criteria do not fully take into account the natural setting of at least some nearshore areas in West Hawaii.

5. Anchialine Pond

Anchialine ponds have been identified on the O'oma property near the southern boundary. By definition, anchialine ponds are areas of exposed groundwater with no surface connection to the ocean. During fieldwork for the present report (2008), a single pond was observed at the bottom of a small sinkhole on a lava dome with a floor elevation several meters lower than the surrounding lava fields. This pond was not identified in previous studies. The area of exposed water was on the order of one square meter. No sediment was present on the floor of the pond, and the water column was extremely clear, as evidenced by the measure of turbidity of 0.12 ntu (Tables 1 and 2). Salinity of the pond was measured at 15‰, with a concentration of NO_3^- of 107 µM. It is well known that nutrient concentrations within anchialine ponds vary considerable as a function of tidal oscillation with results in variable mixing of groundwater and marine waters. As a result, anchialine ponds are not nutrient limited, and thrive under a wide range of salinities and nutrient concentrations. The pond on the O'oma site was populated with numerous native herbivorous red shrimp or opae'ula (*Halocardina rubra*), and was devoid of exotic fishes, indicating that the pond is pristine in nature.

During the 1990-92 and 2002 surveys of the O'oma property, another anchialine pool was also identified near the southern boundary. However, the reported description in these earlier surveys indicated that the anchialine pond was under a dense canopy of trees, and the pond was reportedly lined with sediment and plant detritus. The water column throughout the pond was extremely clear, with no apparent turbidity from suspended sediments or phytoplankton. Even with the thick sediment layer in the pond, red shrimp or opae'ula (*Halocardina rubra*) and glass shrimp (*Palaemon debilis*) were abundant in 2002. The three snails common to anchialine ponds (*Assiminea* sp. *Melania* sp. and *Theodoxus cariosa*) were also observed. As in 2008 alien fish species, which occur in many anchialine pools on

West Hawaii, and are known to prey on native shrimp, were not observed in the pond in 2002.

Examination of the area in 2008 revealed marshy areas under the canopy of trees at the southern corner of the property, but no exposed water that could be considered a pond matching the description from 1990-92 and 2002. It was noted in 2002 that the pond appeared to be in a final stage of senescence, and would soon be entirely filled in. Documentation of the life history of anchialine ponds in Hawaii has shown that such infilling is part of the natural progression of these ponds. It is possible that in the four year interval, infilling of the senescent pond was complete, essentially eliminating this pond. Further examination of the area during varying stages of the tide will indicate if indeed the pond under the canopy of trees is still viable or if it has sedimented in.

IV. DISCUSSION and CONCLUSIONS

The purpose of this assessment is to assemble the information to make valid evaluations of the potential for impact to the marine environments from the proposed O'oma Beachside Village community. The information collected in this study provides the basis to understand the processes that are operating in the nearshore ocean, so as to be able to address any concerns that might be raised in the planning process.

The proposed O'oma Beachside Village does not include any plans for any direct alteration of the shoreline or offshore areas. Rather, the shoreline area will be protected by a 1,000 foot shoreline setback and coastal preserves area. Therefore, potential impacts to the marine environment can only be considered from activities on land that may result in delivery of materials (primarily fresh water and nutrients) to the ocean through infiltration to groundwater on land with subsequent discharge to the ocean, and surface runoff. To evaluate the possible magnitude of these processes, a report has been prepared by Tom Nance Water Resource Engineering entitled "*Assessment of the Potential Impact on Water Resources of the Proposed O'oma Beachside Village in North Kona, Hawaii*" (TNWRE 2008). For the purposes of analyses of impact on water resources on the property, it was assumed that rather than utilize high level groundwater, irrigation and potable water would be supplied to the community by onsite reverse osmosis (RO) desalting. Recovery rate of the RO process is on the order of 40-45% of the saline feedwater supply, with the remaining 55-60% brine disposed of in deep onsite wells.

With respect to the potential impacts this process may have on the existing groundwater setting, TNWRE (2008) provides the following summary:

1) Whether or not the saline feedwater supply is seawater from NELHA or onsite saltwater wells drawing water at depth below the basal lens, such supply will have

no impact on the basal groundwater as it moves across the property and discharges at the shoreline.

2) The 55-60% of the initial feedwater that will become hypersaline RO concentrate will be disposed of in onsite wells that would deliver the concentrate into the saltwater zone below the basal lens. The concentrate, with a salinity on the order of 60‰ is substantially denser than either open coastal seawater (salinity of 35‰) or saline groundwater (salinity of 33-35‰). Owing to the greater density, as well as the horizontal-to-vertical anisotropy of the subsurface lava flows, the brine concentrate will flow seaward without rising into basal groundwater. Discharge into the marine environment would be at a substantial distance offshore.

3) Owing to the high permeability of the lavas comprising the entire property, surface stormwater runoff never reaches the ocean regardless of storm intensity. This condition will not change under the development scenario. At present, about half of the 15 inches of annual rainfall that occurs on the property percolates to the underlying groundwater. Development of the community will not result in any change to the stormwater percolation rate. Additional nutrient concentrations to percolating stormwater will be of a very small magnitude.

4) About 15% of the 0.58 MGD (million gallons per day) of total irrigation water is projected to be in excess of consumptive use by landscaping and will percolate downward to the underlying basal lens. Irrigation water would be comprised of a combination of R-1 WWTP effluent and potable RO water. Evaluation of the impacts of this percolate is based on total landscaped area of 115 acres and nitrogen and phosphorus fertilizer application rates of 3 and 0.5 lb. per year per 1,000 sq. feet, respectively. Based on past work in West Hawaii, it is assumed that 10% of applied nitrogen and 2% of applied phosphorus percolates past the root zone, and removal rates of nitrogen and phosphorus within the unsaturated vadose zone are 80% and 95%, respectively.

5) Using these estimates of changes in composition and inputs/withdrawals, TNWRE (2008) computed the total project-related changes to the underlying basal lens which discharges into the marine environment along the shoreline. At the present relatively modest flow of 1.5 MGD beneath the one-half mile wide property, total flowrate would increase about 6% (1.59 MGD). Such an increase is too small a magnitude to be detectable by water level monitoring. The additional groundwater flux would have no significant effect to the use of groundwater by neighboring projects or the functioning of anchialine pools or fishponds in the Kaloko Honokohau National Park.

6). On a weight basis, nitrogen and phosphorus are projected to increase in groundwater by about 6%, and 4%, respectively. TNWRE states that these contributions of nitrogen and phosphorus to groundwater flowing beneath the property will not impair present and foreseeable use of this resource.

Further evaluation of the potential changes to groundwater composition also indicate that there is little or no potential for alteration of the marine environment. Converted to a molar basis, the projected increases of 6% would result in a change of the average high level groundwater TN concentration from 83 to 88 µM (based on data in Table 2 of TNWRE 2008). Similarly, TP would increase in high level groundwater from 4.6 to 4.8 µM. Such changes would cause no impact to the marine environment for several reasons. First, the average TN concentration in existing basal wells of brackish quality in the Keahole to Kailua area (shown in Table 2 in TNWRE) is about 100 µM, which is 12 µM higher than the maximal potential increase in high level groundwater water resulting from the project. As groundwater from brackish water wells is diluted with ocean water with considerably lower nitrogen concentrations, it is apparent that the projected increases are well within the existing range of nutrient concentrations presently in groundwater discharging at the shoreline. Similarly the average concentration of TP in high level groundwater is about 4.6 µM. Increasing this concentration by the projected 4% as a result of the O'oma project results in a concentration of about 4.7 µM, which is nearly exactly the same as the concentration in brackish wells from Keahole to Kailua.

With respect to the additional nutrient concentration in marine waters, it can be seen in Figures 4 and 5 that with the exception of a two outliers with salinities of about 17‰ and 22‰, the lowest measured salinities at the shoreline are about 29‰. This salinity represents a dilution of groundwater with ocean water of about 83%. Hence, the 6% projected N increase to groundwater would result in only about a 1% increase at the shoreline. The shoreline fronting the entire property consists of a basaltic reef bench that is continually exposed to waves. As a result, physical processes rapidly mix seaward flowing groundwater with oceanic water, essentially diluting the groundwater to background ocean levels within meters of the shoreline. At a distance of 10 m (33 feet) from the shoreline, the average salinity on the three transects surveyed for this study was about 32‰, which represents a mixture of about 9% groundwater and 91% ocean water. Dilution of the projected 6% increase in nutrients by 91% results in nutrient increases of about 0.5% in the nearshore area beyond the basaltic bench where coral communities occur. In addition, these calculations do not take into account the increased groundwater flowrate (~6%) which would further dilute the projected increase in nutrient loading.

Such small changes are well within the natural variability of the groundwater-marine water mixing regimes on the coast of West Hawaii. In addition, these subsidies are small in comparison to other documented situation in West Hawaii where anthropogenic inputs have been quantified. For example, leaching of golf course nutrients resulted in an increase over natural flux of about 116% N and 22% P to a semi-enclosed embayment (Keauhou Bay). While these increases are orders of magnitude greater than predicted at O'oma, there was no measurable nutrient uptake within the Bay, and no alteration of biotic composition (Dollar and Atkinson 1992). Similarly, nutrients subsidies resulted in increased N and P flux to anchialine ponds at Waikoloa of about 229% and 400%, respectively. Even with such high nutrient subsidies to ponds that reflect substantial nutrient subsidies to groundwater, offshore sites at Waikoloa downgradient from these ponds on wave-exposed coastlines showed no input over natural sources (Dollar and Atkinson 1992). As the wave-exposed shorelines at Waikoloa are probably less turbulent than off the O'oma community, it can be expected that the small changes in groundwater nutrient concentrations will likewise have no effect to the marine environment.

In addition to consideration of effects from nutrient additions, it is also important to consider the potential effect of sedimentation that may occur as a result of construction activities. The property is presently comprised of extensive areas of exposed soil and rock, with relatively little vegetative groundcover. During the construction phases, it is likely that permit regulations will limit the area of excavation at any one time, and require dust control measures. In addition, the predominant direction of wind (land breezes) generated by thermal convection from solar heating of the land mass is inland, resulting in transport of dust inland, and not toward the ocean. As a result, it appears that there is little potential for significant input of sediment to the marine environment resulting from the proposed project.

All of these considerations indicate that the proposed O'oma Beachside Village community will not have any significant negative effect on water quality in the coastal ocean offshore of the property. Because of substantial buffers at the shoreline, lack of potential for surface runoff and sediment effects, small projected groundwater subsidies, and the wide variation in nutrient concentrations within the entirely of West Hawaii, as well as the strong mixing characteristics of the nearshore environment, changes to the marine environment as a result of O'oma Beachside Village will likely be undetectable, with no alteration from the present conditions.

V. SUMMARY

1. Evaluation of nearshore water chemistry off the proposed O'oma Beachside Village property was carried out in November 2006. Thirty-seven water samples were collected along three transects oriented perpendicular to shore, extending from the shoreline to a distance of approximately 150 m offshore. Samples were also collected in an anchialine pond near the southern boundary of the property. Analysis of fourteen water chemistry constituents included all specific constituents in DOH water quality standards. Sampling was similar to that conducted off the same site in 1992 and 2002.

2. Several dissolved nutrients (Si, NO_3^-, TDN) displayed distinct horizontal gradients with highest values closest to shore and lowest values at the most seaward sampling locations. Correspondingly, salinity was lowest closest to the shoreline. While these patterns were detectable at all three sampling sites, they were most pronounced at Site 3 located at the southern boundary of the property, and least pronounced at Site 2, located in the center of the property.

3. Water chemistry constituents that are not major components of groundwater (NH_4^+ , DON, DOP) did not display discernible gradients with respect to distance from the shoreline, or depth in the water column. Chl *a* and turbidity were generally elevated in nearshore samples with decreasing values moving seaward.

4. Application of a hydrographic mixing model to the water chemistry data was used to indicate if increased nutrient concentrations are the result of mixing of natural groundwater with oceanic water, or are the result of inputs from activities on land. The model indicates that during the 2006 survey there were external subsidies of NO_3^- nitrogen to the ocean only at one transect location (Transect 1). There was no input of PO_4^{-3} or NH_4^+ from activities on land that could subsidize groundwater nutrient concentrations. The overall lack of discernible nutrient subsidies in the nearshore groundwater-ocean water mixing zone indicates that there is presently no substantial input to the ocean from any sources of nutrients such as fertilizers or sewage effluent from upslope of the site.

5. Comparative results from the monitoring surveys conducted in 1990-92, 2002 and 2006 using mixing plots indicates that there has been no pattern of progressively increasing or decreasing input of materials to the nearshore ocean over the fourteen year interval.

6. Application of a linear regression model which is a component of DOH water quality standards specific for West Hawaii showed an exceedance for NO_3^- on Transect 1. Comparison of measurements of water chemistry with DOH criteria for samples with salinities below 32‰ reveal numerous exceedances of geometric mean standards. Such exceedances are likely the result of the natural influence of land on the coastal ocean, which is not accounted for the DOH standards.

7. With potable and irrigation water supplied by desalination of marine waters, there will be no adverse affect to groundwater resources in areas in the vicinity of the project. Evaluations of changes to groundwater flux and composition resulting from the project performed by Tom Nance Water Resources Engineering indicate that there will be a potential increase of groundwater flow of about 6% over present conditions in the one-half mile of coastline fronting the property. Accompanying the increase in flow rates are relatively small increases in nutrient loading of 6% for nitrogen and 4% for phosphorus. When these increases are applied to high level groundwater above the property, nutrient concentrations are lower than in brackish

wells along the Keahole-Kona corridor. In addition, dilution of groundwater at the shoreline and within the nearshore zone by turbulent mixing will result in little or no change to groundwater-marine water dynamics. Even if measured concentrations of nutrients are increased by the projected amounts with the development in place, nearshore waters are so well-mixed that there is little likelihood that concentrations will increase beyond the present ranges of conditions.

9. Overall, results of the water chemistry analysis indicate that there does not appear to be any potential for project-related negative to marine waters off the O'oma Beachside Village property. Changes of land use associated with the O'oma Beachside Village should not change water quality of the offshore area to any discernible extent.

10. The water quality study conducted for this report can serve as an initial baseline for any monitoring programs that may be required for the O'oma Beachside Village.

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FIGURE 1. Map of North Kona showing location of O'oma Beachside Village and three water quality monitoring transects located offshore of the property. Also shown are the locations of the Natural Energy Laboratory of Hawaii to the north of the O'oma site, and The Shores at Kahanaiki and the Kaloko-Honokohau National Park to the south.

TABLE 1. Water chemistry measurements from ocean samples collected along three transects off of the O'oma Beachside Village project site sampled on November 3, 2006. Nutrient concentrations are shown in micromolar units (µM). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep; BDL=below detection limit. Also shown are the State of Hawaii, Department of Health (DOH) area-specific geometric mean criteria for the Kona (west) coast of the Island of Hawaii. Shaded and boxed values exceed geometric mean criteria for waters with salinity greater than 32‰. Red line separates samples with salinities of less the 32‰. For location of sampling transect sites, see Figure 1.

TRANSECT SITE	STA. NO.	DFS (m)	PO_4^{3-} (µM)	NO_3^- (µM)	NH_4^+ (µM)	Si (µM)	DOP (µM)	DON (µM)	TDP (µM)	TDN (µM)	TURB (NTU)	SAL (ppt)	CHL a (µg/L)	TEMP (deg.C)	O2 (%sat)	pH
OOMA 1	1S	0	0.17	4.84	0.51	43.80	0.27	6.55	0.44	11.90	0.20	32.917	0.69	26.64	106.4	8.25
	2S	1	0.50	8.95	0.34	74.91	0.38	7.95	0.88	17.24	0.29	31.482	0.74	26.76	105.3	8.27
	3S	2	0.11	7.81	0.59	65.84	0.32	6.86	0.43	15.26	0.21	31.952	0.56	26.89	107.0	8.27
	4S	5	0.27	7.48	0.40	64.42	0.27	6.73	0.54	14.61	0.13	31.987	0.91	26.99	107.5	8.27
	5S	10	0.09	6.76	0.36	63.76	0.41	8.20	0.50	15.32	0.20	32.048	0.94	27.00	106.4	8.26
	6S	15	0.04	5.74	0.25	51.65	0.29	7.09	0.33	13.08	0.14	32.655	0.71	27.01	104.3	8.25
	7S	20	0.03	5.59	0.36	47.12	0.28	6.25	0.31	12.20	0.12	32.839	0.63	27.06	104.8	8.24
	8S	30	0.03	4.00	0.44	38.82	0.35	6.60	0.38	11.04	0.14	33.147	0.39	27.09	103.5	8.22
	9S	50	0.03	0.58	0.64	7.09	0.27	5.72	0.30	6.94	0.10	34.548	0.20	27.10	108.1	8.16
	9D	50	0.02	BDL	0.90	2.94	0.27	5.86	0.29	6.76	0.08	34.721	0.17	27.23	107.2	8.15
	10S	150	0.01	0.22	0.88	2.49	0.28	6.89	0.29	7.99	0.07	34.727	0.15	27.25	105.1	8.15
	10D	150	0.03	0.30	0.52	2.11	0.26	6.00	0.29	6.82	0.10	34.758	0.14	27.24	105.2	8.16
OOMA 2	1S	0	0.03	16.04	0.64	73.34	0.27	8.49	0.30	25.17	0.78	28.977	1.22	26.89	105.2	8.07
	2S	1	0.03	1.92	0.54	30.63	0.30	6.99	0.33	9.45	0.18	33.123	0.40	27.01	105.8	8.26
	3S	2	0.03	1.08	0.61	30.38	0.30	6.63	0.33	8.32	0.18	33.064	0.87	27.01	104.6	8.33
	4S	5	0.03	1.82	0.43	30.54	0.29	7.49	0.32	9.74	0.14	33.205	0.28	27.04	106.3	8.24
	5S	10	0.03	0.54	0.62	14.28	0.28	6.37	0.31	7.53	0.11	34.081	0.34	27.10	104.5	8.23
	6S	15	0.03	0.41	0.77	11.55	0.28	5.97	0.31	7.15	0.10	34.233	0.73	27.13	105.5	8.22
	7S	20	0.02	0.18	0.75	8.85	0.26	6.50	0.28	7.43	0.08	34.408	0.28	27.19	106.4	8.21
	8S	30	0.02	0.21	0.77	7.31	0.28	7.14	0.30	8.12	0.09	34.521	0.34	27.20	101.2	8.18
	9S	50	0.02	0.19	0.52	5.99	0.27	6.90	0.29	7.61	0.08	34.605	0.38	27.23	104.5	8.18
	9D	50	0.03	0.15	0.59	2.91	0.27	5.33	0.30	6.07	0.07	34.720	0.13	27.33	102.2	8.16
	10S	150	0.05	0.14	0.37	2.62	0.29	5.81	0.34	6.32	0.08	34.729	0.12	27.24	105.5	8.16
	10D	150	0.03	0.12	0.53	1.94	0.26	6.48	0.29	7.13	0.06	34.781	0.14	27.22	104.3	8.16
OOMA 3	1S	0	0.63	45.87	1.01	368.06	0.21	4.24	0.84	51.12	0.13	17.149	0.44	26.54	107.4	8.18
	2S	1	0.04	11.36	1.24	108.57	0.32	10.54	0.36	23.14	0.15	28.751	0.27	26.99	105.5	8.28
	3S	2	0.02	8.86	1.12	107.60	0.35	9.35	0.37	19.33	0.22	29.265	2.00	27.01	104.8	8.31
	4S	5	0.03	8.35	0.71	100.98	0.30	7.58	0.33	16.64	0.15	29.642	0.64	27.21	106.3	8.32
	5S	10	0.06	8.43	0.65	102.21	0.25	8.33	0.31	17.41	0.13	29.618	0.46	27.14	105.3	8.32
	6S	15	0.04	5.55	0.14	78.99	0.28	9.17	0.32	14.86	0.13	30.853	0.46	27.15	108.4	8.34
	7S	20	0.06	1.84	0.06	32.97	0.28	7.28	0.34	9.18	0.10	33.332	0.39	27.21	103.1	8.29
	8S	30	0.09	1.50	0.22	24.85	0.27	6.43	0.36	8.15	0.09	33.777	0.45	27.22	104.3	8.26
	9S	50	0.37	0.34	0.07	6.59	0.02	7.50	0.39	7.91	0.09	34.595	0.22	27.27	108.8	8.19
	9D	50	0.09	0.22	0.11	4.22	0.21	7.00	0.30	7.33	0.07	34.720	0.13	27.26	107.6	8.17
	10S	150	0.06	0.45	0.08	6.71	0.24	7.54	0.30	8.07	0.07	34.575	0.13	27.25	105.8	8.14
	10D	150	0.06	0.15	BDL	3.77	0.25	7.30	0.31	7.45	0.08	34.700	0.15	27.24	105.7	8.15
W HI WQS (GEO MEAN)			0.16	0.32	0.18				0.40	7.14	0.10	*	0.30	**	***	****
ANCHIALINE POOL			6.64	106.56	0.64	1,002.48	0.32	41.60	6.96	148.80	0.12	15.02	0.27			7.74

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary more than one degree Celsius from ambient conditions.
*** Dissolved oxygen shall not be less than 75% saturation.
****pH shall not deviate more than 0.5 units from a value of 8.1.

TABLE 2. Water chemistry measurements from ocean samples collected along three transects off of the O'oma Beachside Village project site sampled on November 3, 2006. Nutrient concentrations are shown in units of micrograms per liter (μg/L). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep; BDL=below detection limit. Also shown are the State of Hawaii, Department of Health (DOH) area-specific geometric mean criteria for the Kona (west) coast of the Island of Hawaii. Shaded and boxed values exceed geometric mean criteria for waters with salinity greater than 32‰. Red line separates samples with salinities less than 32‰. For transect site locations, see Figure 1.

TRANSECT SITE	STA. NO.	DFS (m)	PO_4^{3-} (μg/L)	NO_3^- (μg/L)	NH_4^+ (μg/L)	Si (μg/L)	DOP (μg/L)	DON (μg/L)	TDP (μg/L)	TDN (μg/L)	TURB (NTU)	SAL (ppt)	CHL a (μg/L)	TEMP (deg.C)	O2 (%sat)	pH
OOMA 1	1S	0	5.27	67.76	7.14	1,231	8.37	91.70	13.64	166.60	0.20	32.917	0.69	26.64	106.4	8.25
	2S	1	15.50	125.30	4.76	2,105	11.78	111.30	27.28	241.36	0.29	31.482	0.74	26.76	105.3	8.27
	3S	2	3.41	109.34	8.26	1,850	9.92	96.04	13.33	213.64	0.21	31.952	0.56	26.89	107.0	8.27
	4S	5	8.37	104.72	5.60	1,810	8.37	94.22	16.74	204.54	0.13	31.987	0.91	26.99	107.5	8.27
	5S	10	2.79	94.64	5.04	1,792	12.71	114.80	15.50	214.48	0.20	32.048	0.94	27.00	106.4	8.26
	6S	15	1.24	80.36	3.50	1,451	8.99	99.26	10.23	183.12	0.14	32.655	0.71	27.01	104.3	8.25
	7S	20	0.93	78.26	5.04	1,324	8.68	87.50	9.61	170.80	0.12	32.839	0.63	27.06	104.8	8.24
	8S	30	0.93	56.00	6.16	1,091	10.85	92.40	11.78	154.56	0.14	33.147	0.39	27.09	103.5	8.22
	9S	50	0.93	8.12	8.96	199	8.37	80.08	9.30	97.16	0.10	34.548	0.20	27.10	108.1	8.16
	9D	50	0.62	BDL	12.60	83	8.37	82.04	8.99	94.64	0.08	34.721	0.17	27.23	107.2	8.15
	10S	150	0.31	3.08	12.32	70	8.68	96.46	8.99	111.86	0.07	34.727	0.15	27.25	105.1	8.15
	10D	150	0.93	4.20	7.28	59	8.06	84.00	8.99	95.48	0.10	34.758	0.14	27.24	105.2	8.16
OOMA 2	1S	0	0.93	224.56	8.96	2,061	8.37	118.86	9.30	352.38	0.78	28.977	1.22	26.89	105.2	8.07
	2S	1	0.93	26.88	7.56	861	9.30	97.86	10.23	132.30	0.18	33.123	0.40	27.01	105.8	8.26
	3S	2	0.93	15.12	8.54	854	9.30	92.82	10.23	116.48	0.18	33.064	0.87	27.01	104.6	8.33
	4S	5	0.93	25.48	6.02	858	8.99	104.86	9.92	136.36	0.14	33.205	0.28	27.04	106.3	8.24
	5S	10	0.93	7.56	8.68	401	8.68	89.18	9.61	105.42	0.11	34.081	0.34	27.10	104.5	8.23
	6S	15	0.93	5.74	10.78	325	8.68	83.58	9.61	100.10	0.10	34.233	0.73	27.13	105.5	8.22
	7S	20	0.62	2.52	10.50	249	8.06	91.00	8.68	104.02	0.08	34.408	0.28	27.19	106.4	8.21
	8S	30	0.62	2.94	10.78	205	8.68	99.96	9.30	113.68	0.09	34.521	0.34	27.20	101.2	8.18
	9S	50	0.62	2.66	7.28	168	8.37	96.60	8.99	106.54	0.08	34.605	0.38	27.23	104.5	8.18
	9D	50	0.93	2.10	8.26	82	8.37	74.62	9.30	84.98	0.07	34.720	0.13	27.33	102.2	8.16
	10S	150	1.55	1.96	5.18	74	8.99	81.34	10.54	88.48	0.08	34.729	0.12	27.24	105.5	8.16
	10D	150	0.93	1.68	7.42	55	8.06	90.72	8.99	99.82	0.06	34.781	0.14	27.22	104.3	8.16
OOMA 3	1S	0	19.53	642.18	14.14	10,342	6.51	59.36	26.04	715.68	0.13	17.149	0.44	26.54	107.4	8.18
	2S	1	1.24	159.04	17.36	3,051	9.92	147.56	11.16	323.96	0.15	28.751	0.27	26.99	105.5	8.28
	3S	2	0.62	124.04	15.68	3,024	10.85	130.90	11.47	270.62	0.22	29.265	2.00	27.01	104.8	8.31
	4S	5	0.93	116.90	9.94	2,838	9.30	106.12	10.23	232.96	0.15	29.642	0.64	27.21	106.3	8.32
	5S	10	1.86	118.02	9.10	2,872	7.75	116.62	9.61	243.74	0.13	29.618	0.46	27.14	105.3	8.32
	6S	15	1.24	77.70	1.96	2,220	8.68	128.38	9.92	208.04	0.13	30.853	0.46	27.15	108.4	8.34
	7S	20	1.86	25.76	0.84	926	8.68	101.92	10.54	128.52	0.10	33.332	0.39	27.21	103.1	8.29
	8S	30	2.79	21.00	3.08	698	8.37	90.02	11.16	114.10	0.09	33.777	0.45	27.22	104.3	8.26
	9S	50	11.47	4.76	0.98	185	0.62	105.00	12.09	110.74	0.09	34.595	0.22	27.27	108.8	8.19
	9D	50	2.79	3.08	1.54	119	6.51	98.00	9.30	102.62	0.07	34.720	0.13	27.26	107.6	8.17
	10S	150	1.86	6.30	1.12	189	7.44	105.56	9.30	112.98	0.07	34.575	0.13	27.25	105.8	8.14
	10D	150	1.86	2.10	BDL	106	7.75	102.20	9.61	104.30	0.08	34.700	0.15	27.24	105.7	8.15
W HI WQS (GEO MEAN)			5.00	4.50	2.50				12.50	100.00	0.10	*	0.30	**	***	****
ANCHIALINE POOL			205.84	1,492	8.96	28,170	9.92	582.40	215.76	2,083.20	0.12	15.02	0.27			7.74

* Salinity shall not vary more than ten percent form natural or seasonal changes considering hydrologic input and oceanographic conditions.
** Temperature shall not vary more than one degree Celsius from ambient conditions.
*** Dissolved oxygen shall not be less than 75% saturation.
****pH shall not deviate more than 0.5 units from a value of 8.1.

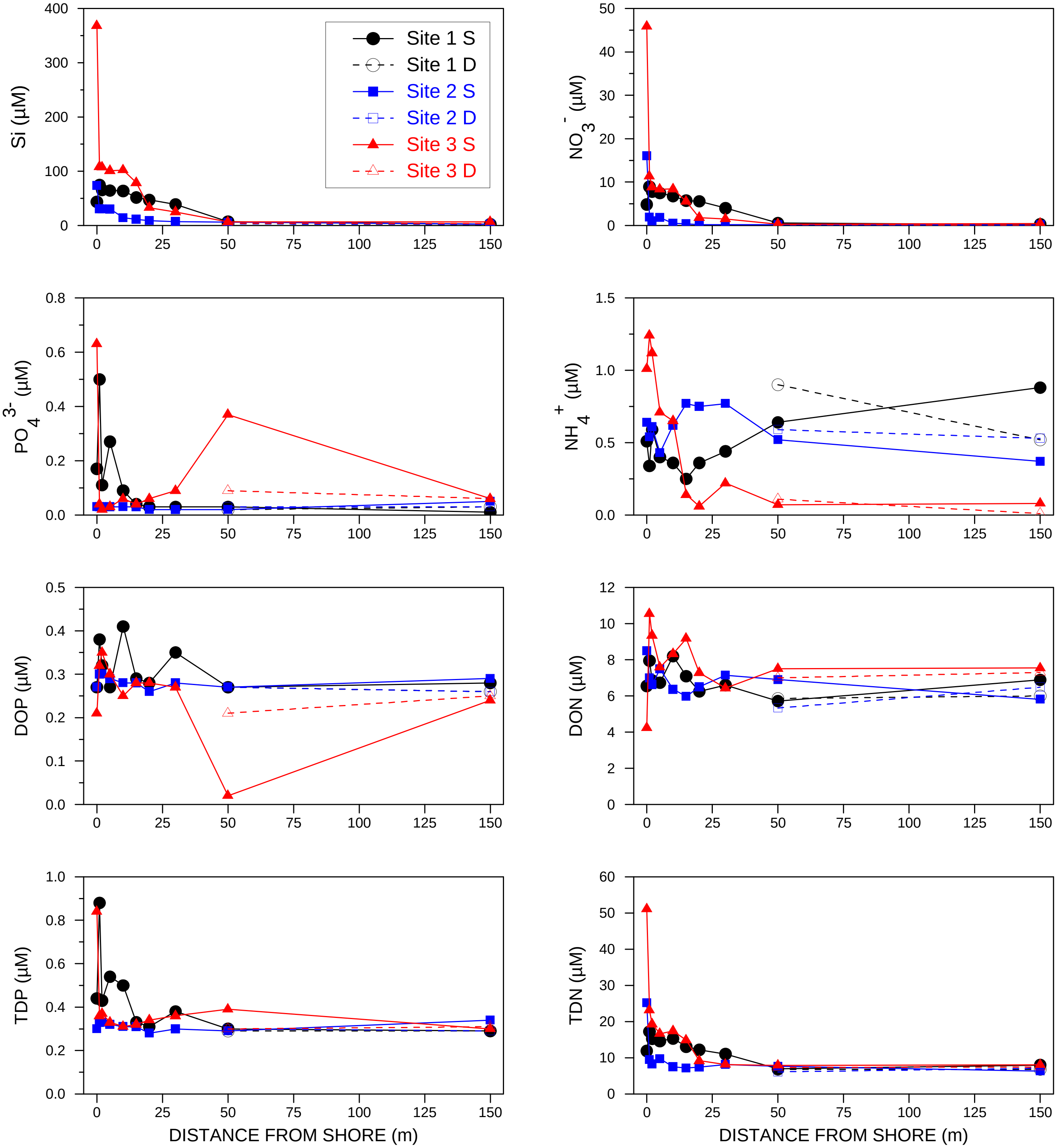

FIGURE 2. Plots of dissolved nutrients in surface (S) and deep (D) samples collected along transects offshore of the O`oma Beachside Village project on November 3, 2006 as a function of distance from the shoreline. For transect locations, see Figure 1.

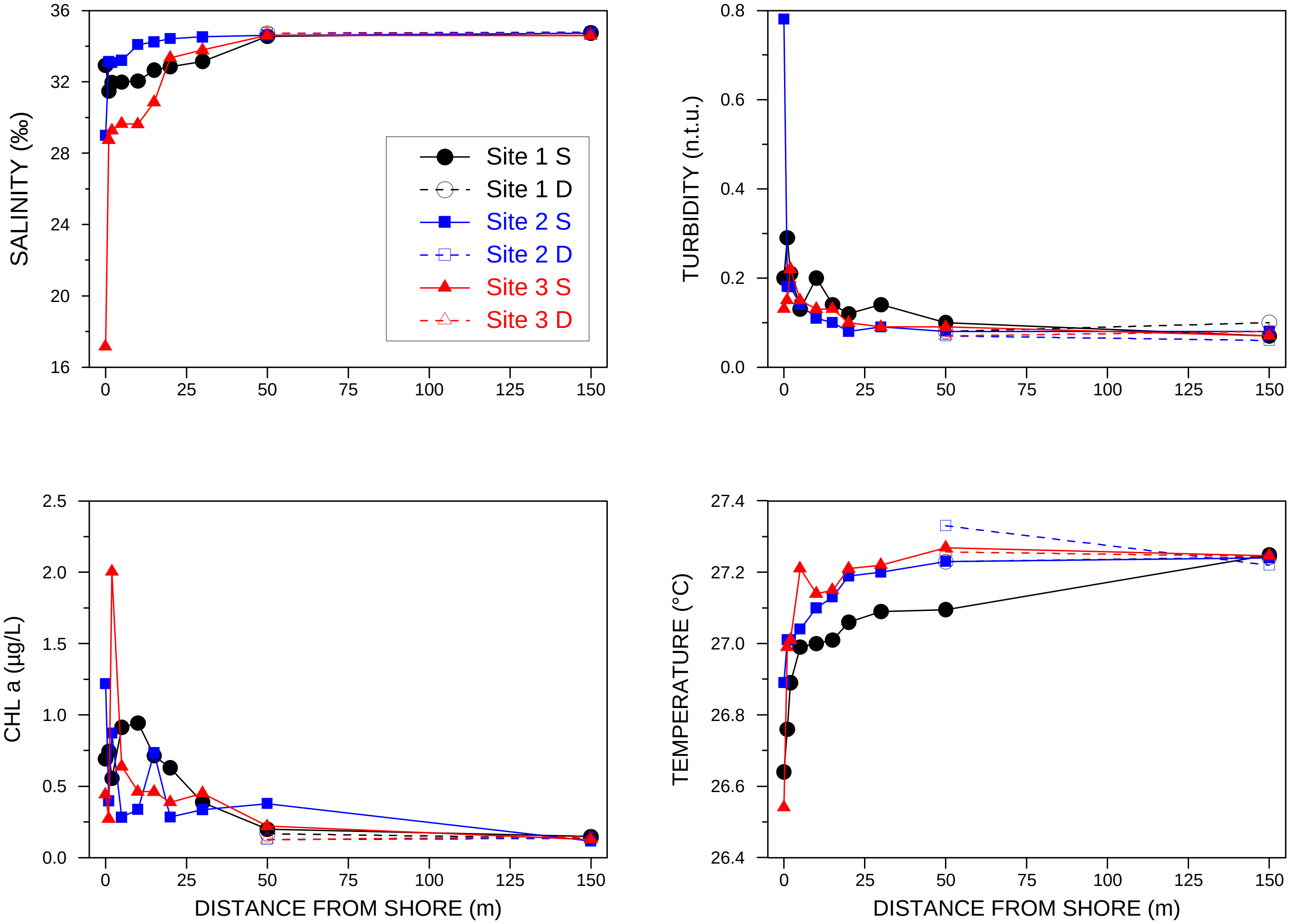

FIGURE 3. Plots of water chemistry constituents in surface (S) and deep (D) samples collected along three transects offshore of the O`oma Beachside Village project on November 3, 2006 as a function of distance from the shoreline. For transect locations, see Figure 1.

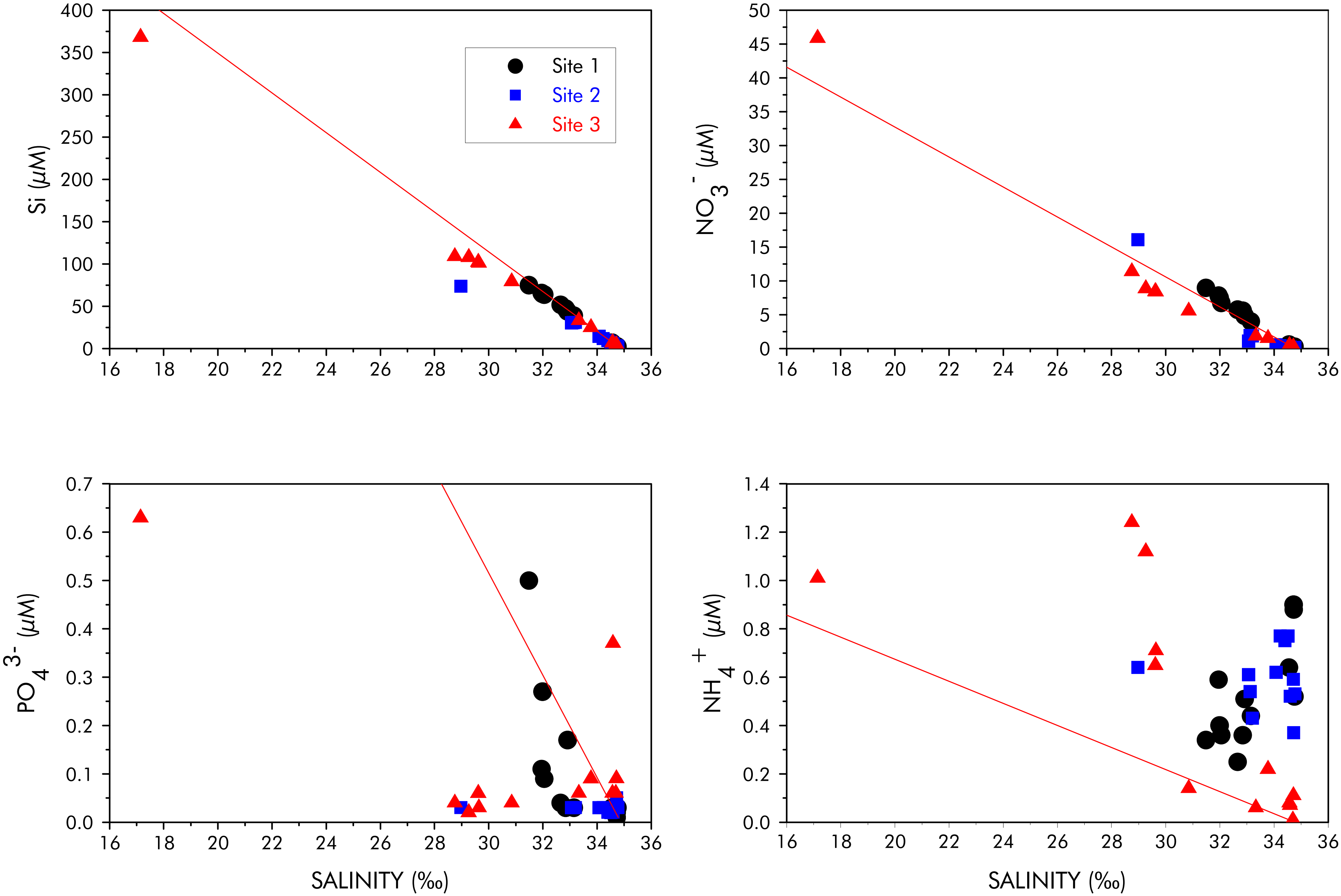

FIGURE 4. Mixing plots showing concentration of dissolved nutrients from samples collected along transects offshore of the O`oma Beachside Village project in November 2006 as functions of salinity. Straight line in each plot is the conservative mixing line constructed by connecting the concentrations in open ocean water with the averaged concentration measured in four high-level groundwater wells upslope of the sampling area (see TNWRE 2008). For transect locations, see Figure 1.

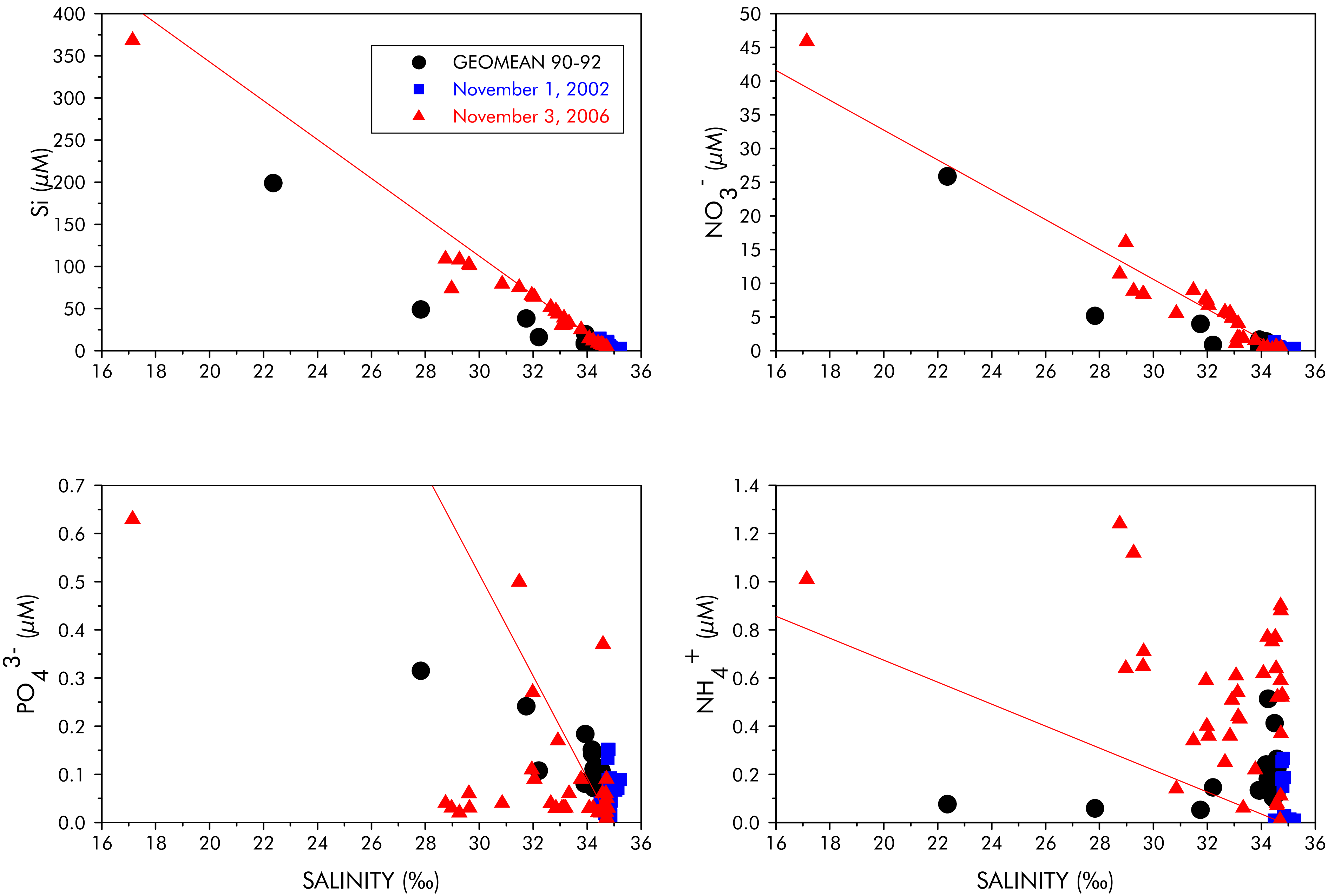

FIGURE 5. Mixing plots showing concentration of dissolved nutrients from all samples collected along three transects offshore of the O`oma Beachside Village project in 1990-1992, November 2002 and November 2006 as functions of salinity. Straight line in each plot is the conservative mixing line constructed by connecting the concentrations in open ocean water with the averaged concentration measured in four high-level groundwater wells located upslope of the sampling area (see TNWRE 2008). For transect locations, see Figure 1.

TABLE 3. Linear regression statistics for nutrient concentrations plotted as a function of salinity from pooled transect data off of the O'oma Beachside Village site in 1990-92, 2002 and 2006. "*" indicates non-significant F (P=0.05).

NUTRIENT	YEAR	R^2	Signif. F	SLOPE	LOWER 95% CI	UPPER 95% CI	Y-INTERCEPT	LOWER 95% CI	UPPER 95% CI
Si	1990-92	0.95	0.00	-20.1	-22.0	-18.3	694	634	754
	2002	0.60	0.00	-17.1	-21.9	-12.2	600	430	770
	2006	0.98	0.00	-19.9	-21.1	-18.8	695	659	731
NO_3^-	1990-92	0.93	0.00	-2.95	-3.31	-2.66	102.1	91.3	112.9
	2002	0.37	0.00	-1.17	-1.70	-0.64	41.0	22.6	59.4
	2006	0.95	0.00	-2.49	-2.70	-2.27	85.5	78.6	92.4
PO_4^{3-}	1990-92	0.94	0.00	-0.09	-0.10	-0.08	3.16	2.07	3.46
	2002	0.02	0.36*	0.04	-0.06	0.15	-1.51	-5.00	1.99
	2006	0.32	0.00	-0.03	-0.04	-0.01	0.91	0.45	1.36
NH_4^+	1990-92	0.16	0.02	0.01	0.00	0.01	-0.09	-0.33	0.15
	2002	0.03	0.29*	-0.11	-0.31	0.10	3.84	-3.30	10.99
	2006	0.19	0.01	-0.04	-0.07	-0.01	1.78	0.80	2.77

TABLE 4. Slopes of linear regressions of nutrient concentrations (in units of μg/L) as functions of salinity for surface samples on three transects offshore of the O'oma Beachside Village. Also shown are DOH compliance slopes. Underlined values indicate absolute value of upper confidence limit exceeding the DOH compliance slope.

NUTRIENT	DOH	TRANSECT 1			TRANSECT 2			TRANSECT 3		
	SLOPE	SLOPE	LOWER CI	UPPER CI	SLOPE	LOWER CI	UPPER CI	SLOPE	LOWER CI	UPPER CI
NO_3^-	-31.92	-37.48	-40.41	<u>-34.55</u>	-38.67	-47.06	-30.28	-36.31	-41.50	-31.12
TDN	-40.35	-41.64	-47.58	-35.70	-43.86	-53.11	-34.62	-35.25	-38.43	-32.06
PO_4^{3-}	-3.22	-2.87	-5.58	-0.16	-0.01	-0.14	0.12	-0.77	-1.54	-0.01
TDP	-2.86	-3.63	-6.50	-0.76	0.00	-0.28	0.29	-0.85	-1.23	-0.46

APPENDIX A

Tables of Water Quality Data 1990-2002
O'oma, North Kona Hawaii

TABLE A1. Geometric mean data from water chemistry measurements off the O'oma II property collected during four monitoring surveys in October 1990, May and November 1991 and March 1992. Nutrient concentrations shown in micromolar units (μM). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Measurements below detection limit were not included in mean calculations. For sampling station locations, see Figure 1.

STATION NO.		DFS (m)	PO4 (μM)	NO3 (μM)	NH4 (μM)	Si (μM)	TOP (μM)	TON (μM)	TP (μM)	TN (μM)	TURB (ntu)	SALINITY (o/oo)	CHL a (μg/L)	TEMP (deg C)	pH
OOMA-1	1S	1	2.38	76.92	0.06	508.89	0.05	4.9	2.45	82.4	0.15	11.867	0.07	23.6	8.08
	2S	5	0.88	25.86	0.08	198.87	0.10	6.4	1.05	33.7	0.14	22.358	0.09	24.5	8.17
	3S	10	0.32	5.17	0.06	48.84	0.15	7.4	0.58	16.9	0.12	27.835	0.08	25.5	8.18
	3D	10	0.24	3.98	0.05	38.23	0.16	6.5	0.46	12.9	0.11	31.744	0.14	25.8	8.17
	4S	50	0.18	1.64	0.13	19.81	0.19	6.7	0.38	8.6	0.16	33.930	0.04	26.5	8.18
	4D	50	0.15	0.66	0.24	9.68	0.19	6.3	0.35	7.6	0.12	34.173	0.07	26.3	8.17
	5S	100	0.14	1.38	0.13	11.41	0.21	5.9	0.35	7.2	0.10	34.185	0.08	26.3	8.17
	5D	100	0.11	0.35	0.20	5.23	0.21	6.4	0.33	6.9	0.10	34.455	0.08	26.4	8.17
	6S	200	0.11	1.18	0.18	8.75	0.22	6.0	0.34	7.2	0.12	34.240	0.09	26.4	8.17
	6D	200	0.09	0.25	0.19	3.71	0.24	6.0	0.34	6.4	0.10	34.528	0.08	26.3	8.17
OOMA-2	1S	1	0.10	0.29	0.10	6.01	0.24	5.4	0.37	6.0	0.12	34.430	0.08	26.4	8.18
	2S	5	0.09	0.13	0.19	3.88	0.22	6.0	0.31	6.4	0.15	34.532	0.07	26.3	8.17
	3S	10	0.11	0.87	0.15	16.08	0.16	5.4	0.27	8.1	0.14	32.204	0.10	26.2	8.20
	3D	10	0.08	0.31	0.13	8.57	0.17	5.2	0.26	5.9	0.11	33.911	0.09	26.3	8.21
	4S	50	0.08	0.31	0.18	6.45	0.22	4.9	0.32	5.4	0.14	34.436	0.07	26.3	8.17
	4D	50	0.08	0.19	0.15	5.59	0.23	5.3	0.31	5.7	0.13	34.460	0.09	26.3	8.17
	5S	100	0.11	0.24	0.20	3.82	0.23	6.8	0.34	7.2	0.09	34.532	0.08	26.5	8.17
	5D	100	0.08	0.06	0.15	2.91	0.24	6.4	0.33	6.6	0.09	34.558	0.08	26.3	8.16
	6S	200	0.09	0.04	0.17	2.62	0.24	6.1	0.35	6.3	0.10	34.590	0.08	26.4	8.17
	6D	200	0.08	0.04	0.23	2.34	0.26	6.7	0.35	7.0	0.11	34.596	0.07	26.3	8.16
OOMA-3	1S	1	0.10	0.12	0.25	3.83	0.21	7.8	0.32	8.2	0.16	34.524	0.13	26.9	8.19
	2S	5	0.08	0.08	0.41	4.06	0.20	8.0	0.28	8.6	0.13	34.490	0.10	26.6	8.18
	3S	10	0.07	0.41	0.51	8.50	0.27	7.2	0.37	8.3	0.14	34.251	0.14	26.6	8.22
	3D	10	0.09	0.29	0.23	8.36	0.20	6.5	0.30	7.3	0.13	34.155	0.09	26.6	8.19
	4S	50	0.11	0.15	0.20	4.94	0.21	5.7	0.32	6.1	0.10	34.506	0.08	26.4	8.16
	4D	50	0.10	0.15	0.14	4.42	0.20	5.4	0.30	5.7	0.12	34.528	0.07	26.4	8.17
	5S	100	0.10	0.12	0.12	3.15	0.20	5.5	0.30	5.7	0.12	34.562	0.08	26.5	8.17
	5D	100	0.10	0.06	0.15	2.43	0.22	5.8	0.32	6.1	0.11	34.580	0.07	26.4	8.16
	6S	200	0.08	0.07	0.27	2.53	0.23	6.0	0.35	6.3	0.12	34.579	0.07	26.4	8.16
	6D	200	0.08	0.09	0.22	2.11	0.24	6.1	0.32	6.6	0.11	34.588	0.06	26.2	8.16
DOH GEOM. MEAN STDS.				0.25	0.14				0.52	7.86	0.20		0.15		

TABLE A2. Geometric mean data from water chemistry measurements off the O'oma II property collected during four monitoring surveys in October 1990, May and November 1991 and March 1992. Nutrient concentrations shown in units of micrograms per liter (μg/L). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep. Measurements below detection limit were not included in mean calculations. For sampling station locations, see Figure 1.

STATION NO.		DFS (m)	PO4 (μM)	NO3 (μM)	NH4 (μM)	Si (μM)	TOP (μM)	TON (μM)	TP (μM)	TN (μM)	TURB (ntu)	SALINITY (o/oo)	CHL a (μg/L)	TEMP (deg C)	pH
OOMA-1	1S	1	73.78	1076.94	0.83	14299.72	1.58	68.2	76.07	1153.3	0.15	11.867	0.07	23.6	8.08
	2S	5	27.17	362.02	1.07	5588.24	3.16	89.6	32.44	472.3	0.14	22.358	0.09	24.5	8.17
	3S	10	9.77	72.38	0.82	1372.34	4.60	103.6	18.03	237.2	0.12	27.835	0.08	25.5	8.18
	3D	10	7.49	55.73	0.74	1074.33	4.81	91.6	14.14	181.1	0.11	31.744	0.14	25.8	8.17
	4S	50	5.71	22.92	1.86	556.65	5.88	93.3	11.84	119.8	0.16	33.930	0.04	26.5	8.18
	4D	50	4.70	9.20	3.37	272.10	5.91	88.6	10.76	106.8	0.12	34.173	0.07	26.3	8.17
	5S	100	4.42	19.26	1.88	320.60	6.42	82.9	10.88	100.7	0.10	34.185	0.08	26.3	8.17
	5D	100	3.52	4.87	2.75	147.07	6.63	89.1	10.28	96.2	0.10	34.455	0.08	26.4	8.17
	6S	200	3.45	16.58	2.53	245.76	6.96	84.2	10.49	100.9	0.12	34.240	0.09	26.4	8.17
	6D	200	2.73	3.46	2.72	104.38	7.59	83.7	10.45	89.0	0.10	34.528	0.08	26.3	8.17
OOMA-2	1S	1	3.25	4.02	1.45	168.79	7.47	75.4	11.48	84.7	0.12	34.430	0.08	26.4	8.18
	2S	5	2.64	1.86	2.62	108.94	6.67	84.4	9.56	89.7	0.15	34.532	0.07	26.3	8.17
	3S	10	3.34	12.16	2.04	451.79	4.83	75.9	8.25	112.8	0.14	32.204	0.10	26.2	8.20
	3D	10	2.50	4.30	1.88	240.76	5.34	72.7	7.96	82.7	0.11	33.911	0.09	26.3	8.21
	4S	50	2.57	4.31	2.50	181.26	6.80	68.0	9.92	75.7	0.14	34.436	0.07	26.3	8.17
	4D	50	2.33	2.62	2.07	157.02	7.16	74.5	9.74	80.1	0.13	34.460	0.09	26.3	8.17
	5S	100	3.34	3.42	2.80	107.25	7.25	95.4	10.68	100.5	0.09	34.532	0.08	26.5	8.17
	5D	100	2.60	0.87	2.04	81.72	7.49	89.0	10.31	92.7	0.09	34.558	0.08	26.3	8.16
	6S	200	2.78	0.54	2.34	73.56	7.46	84.8	10.94	87.8	0.10	34.590	0.08	26.4	8.17
	6D	200	2.39	0.63	3.21	65.73	7.93	93.5	10.74	97.5	0.11	34.596	0.07	26.3	8.16
OOMA-3	1S	1	3.23	1.70	3.46	107.64	6.61	108.8	9.95	115.2	0.16	34.524	0.13	26.9	8.19
	2S	5	2.34	1.18	5.78	114.17	6.22	111.4	8.63	120.5	0.13	34.490	0.10	26.6	8.18
	3S	10	2.21	5.75	7.19	238.88	8.45	100.4	11.41	115.9	0.14	34.251	0.14	26.6	8.22
	3D	10	2.87	4.01	3.22	234.84	6.30	90.8	9.36	102.6	0.13	34.155	0.09	26.6	8.19
	4S	50	3.27	2.06	2.84	138.87	6.45	79.5	9.80	85.5	0.10	34.506	0.08	26.4	8.16
	4D	50	3.05	2.08	1.99	124.25	6.15	75.7	9.26	79.8	0.12	34.528	0.07	26.4	8.17
	5S	100	2.99	1.63	1.66	88.63	6.24	76.5	9.24	79.7	0.12	34.562	0.08	26.5	8.17
	5D	100	3.04	0.87	2.16	68.36	6.71	81.5	9.93	84.8	0.11	34.580	0.07	26.4	8.16
	6S	200	2.59	0.94	3.71	71.20	7.23	83.3	10.85	88.3	0.12	34.579	0.07	26.4	8.16
	6D	200	2.33	1.26	3.08	59.21	7.30	85.6	9.96	92.7	0.11	34.588	0.06	26.2	8.16
DOH GEOM. MEAN STD			0.00	3.50	1.96	0	0	0	16.12	110.04	0.20		0.15		

TABLE A3. Water chemistry measurements from ocean water off of the O'oma II Development on November 1, 2002. Also shown are result a sample taken from an anchialine pond near the southern boundary of the project site. Nutrient concentrations are expressed as micromoles (μM). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep; BDL=below detection limit; OO= open ocean.

TRANSECT SITE	STA. NO.	DFS (m)	PO_4^{3-} (μM)	NO_3^- (μM)	NH_4^+ (μM)	Si (μM)	TOP (μM)	TON (μM)	TP (μM)	TN (μM)	TURB (NTU)	SAL (ppt)	CHL a (μg/L)	TEMP (deg.C)	O2 (%sat)	pH
OOMA 1	0 S	0.1	0.13	0.31	0.25	9.96	0.25	15.51	0.38	16.07	0.28	34.77	0.45	27.40	100.00	8.28
	5 S	1	0.15	0.28	0.18	10.87	0.20	13.38	0.35	13.84	0.15	34.77	0.43	27.40	101.00	8.27
	10 S	1	0.04	1.31	BDL	14.53	0.35	13.93	0.39	15.24	0.06	34.48	0.18	26.60	97.00	8.16
	10 D	7	0.02	0.13	BDL	5.44	0.32	15.05	0.34	15.18	0.12	34.84	0.11	26.80	101.00	8.17
	25 S	1	0.02	0.58	BDL	9.55	0.29	14.90	0.31	15.48	0.09	34.66	0.13	26.70	94.00	8.16
	25 D	14	0.01	0.04	BDL	3.91	0.28	15.47	0.30	15.51	0.10	34.88	0.10	26.80	97.00	8.17
	50 S	1	0.01	0.43	BDL	8.77	0.31	13.65	0.32	14.08	0.07	34.70	0.12	26.80	98.00	8.16
	50 D	17	0.07	0.04	0.01	3.75	0.23	12.32	0.30	12.37	0.18	34.88	0.10	26.90	97.00	8.17
	100 S	1	0.02	0.37	BDL	8.91	0.29	12.53	0.31	12.90	0.17	34.69	0.13	26.80	98.00	8.17
	100 D	29	0.06	0.07	BDL	3.74	0.25	13.86	0.30	13.93	0.07	34.88	0.11	26.80	101.00	8.17
	500 S	1	0.07	0.04	BDL	3.29	0.28	15.22	0.35	15.26	0.09	34.89	0.10	26.70	98.00	8.09
	500 D	56	0.09	0.04	BDL	2.98	0.22	14.59	0.31	14.63	0.09	34.90	0.11	26.90	94.00	8.14
OOMA 2	0 S	0.1	0.06	0.07	0.19	4.42	0.22	14.05	0.28	14.31	0.26	34.85	0.16	27.70	99.00	8.19
	5 S	1	0.06	0.07	0.02	4.34	0.24	13.73	0.29	13.83	0.15	34.85	0.25	27.10	101.00	8.20
	10 S	1	0.06	0.10	0.03	4.34	0.21	13.43	0.28	13.56	0.21	34.84	0.11	26.60	89.00	8.08
	10 D	6	0.04	0.07	0.02	3.96	0.26	14.58	0.31	14.67	0.05	34.84	0.12	26.80	88.00	8.14
	25 S	1	0.09	0.23	0.18	5.84	0.22	14.25	0.31	14.66	0.04	34.78	0.12	26.70	88.00	8.14
	25 D	7	0.08	0.07	0.01	4.18	0.22	14.49	0.30	14.58	0.07	34.84	0.11	26.70	87.00	8.14
	50 S	1	0.08	0.11	0.02	4.48	0.25	14.14	0.33	14.26	0.05	34.83	0.13	26.30	86.00	8.16
	50 D	9	0.07	0.08	0.01	3.72	0.18	12.58	0.24	12.66	0.03	34.85	0.10	26.70	84.00	8.16
	100 S	1	0.07	0.05	BDL	3.94	0.23	11.58	0.30	11.63	0.35	34.85	0.11	26.60	87.00	8.17
	100 D	14	0.09	0.05	0.01	3.64	0.21	12.54	0.31	12.59	0.07	34.86	0.10	26.80	85.00	8.16
	500 S	1	0.07	0.05	0.01	2.96	0.21	14.53	0.28	14.58	0.07	34.89	0.09	26.70	84.00	8.16
	500 D	74	0.07	0.05	0.01	2.59	0.19	13.69	0.26	13.75	0.07	35.07	0.23	25.50	90.00	8.15
OOMA 3	0 S	0.1	0.15	0.14	0.27	5.96	0.16	15.60	0.31	16.00	0.80	34.82	0.29	27.90	91.00	8.23
	5 S	1	0.09	0.11	0.15	5.80	0.25	14.34	0.33	14.60	0.16	34.81	0.27	26.50	92.00	8.17
	10 S	1	0.02	0.08	0.02	4.68	0.29	12.87	0.31	12.97	0.07	34.82	0.14	26.60	87.00	8.15
	10 D	7	0.03	0.05	BDL	3.85	0.20	12.81	0.23	12.85	0.03	34.85	0.12	26.60	83.00	8.14
	25 S	1	0.03	0.05	0.02	3.78	0.26	13.72	0.29	13.79	0.05	34.85	0.14	26.80	83.00	8.16
	25 D	10	0.03	0.05	0.01	3.33	0.23	13.59	0.26	13.65	0.13	34.87	0.12	26.70	87.00	8.17
	50 S	1	0.02	0.05	BDL	3.70	0.24	13.65	0.26	13.70	0.24	34.86	0.11	26.40	91.00	8.15
	50 D	25	0.01	0.02	BDL	3.02	0.25	12.16	0.26	12.18	0.04	34.87	0.12	26.80	91.00	8.11
	100 S	1	0.08	0.02	0.03	3.32	0.21	11.39	0.28	11.44	0.17	34.87	0.10	26.70	95.00	8.10
	100 D	55	0.07	0.02	BDL	2.50	0.19	12.53	0.26	12.55	0.07	35.14	0.25	25.10	97.00	8.14
	500 S	1	0.04	0.02	BDL	2.43	0.22	12.24	0.26	12.26	0.06	34.89	0.10	26.30	98.00	8.16
	500 D	82	0.09	0.33	BDL	2.80	0.15	11.70	0.23	12.03	0.04	35.24	0.14	22.90	66.00	8.11
O.O	S	1	0.07	0.05	0.14	2.94	0.20	14.10	0.26	14.30	0.07	34.89	0.12	26.90	97.00	8.12
	D	95	0.01	0.02	BDL	2.94	0.24	12.76	0.26	12.79	0.05	34.88	0.10	22.70	64.00	8.15
POND			1.85	42.45	3.40	589.65	2.30	34.90	4.15	80.75		12.28				

TABLE A4. Water chemistry measurements from ocean water off of the O'oma II Development on November 1, 2002. Also shown are result a sample taken from an anchialine pond near the southern boundary of the project site. Nutrient concentrations are expressed as micrograms per liter (µg/L). Abbreviations as follows: DFS=distance from shore; S=surface; D=deep; BDL=below detection limit; OO= open ocean.

TRANSECT SITE	STA. NO.	DFS (m)	PO_4^{3-} (µM)	NO_3^- (µM)	NH_4^+ (µM)	Si (µM)	TOP (µM)	TON (µM)	TP (µM)	TN (µM)	TURB (NTU)	SAL (ppt)	CHL a (µg/L)	TEMP (deg.C)	O2 (%sat)	pH
OOMA 1	0 S	0.1	4.13	4.32	3.54	280.00	7.66	217.13	11.79	224.98	0.28	34.77	0.45	27.40	100.00	8.28
	5 S	1	4.70	3.90	2.53	305.56	6.05	187.38	10.76	193.81	0.15	34.77	0.43	27.40	101.00	8.27
	10 S	1	1.26	18.33	BDL	408.37	10.79	194.97	12.05	213.30	0.06	34.48	0.18	26.60	97.00	8.16
	10 D	7	0.57	1.79	BDL	152.78	9.92	210.66	10.50	212.45	0.12	34.84	0.11	26.80	101.00	8.17
	25 S	1	0.57	8.16	BDL	268.39	9.02	208.62	9.59	216.79	0.09	34.66	0.13	26.70	94.00	8.16
	25 D	14	0.46	0.53	BDL	109.74	8.75	216.60	9.21	217.13	0.10	34.88	0.10	26.80	97.00	8.17
	50 S	1	0.46	6.06	BDL	246.57	9.52	191.07	9.98	197.13	0.07	34.70	0.12	26.80	98.00	8.16
	50 D	17	2.18	0.55	0.11	105.34	7.03	172.48	9.21	173.13	0.18	34.88	0.10	26.90	97.00	8.17
	100 S	1	0.57	5.22	BDL	250.46	8.89	175.44	9.46	180.66	0.17	34.69	0.13	26.80	98.00	8.17
	100 D	29	1.72	0.99	BDL	105.21	7.61	193.98	9.34	194.97	0.07	34.88	0.11	26.80	101.00	8.17
	500 S	1	2.06	0.57	BDL	92.36	8.69	213.10	10.76	213.67	0.09	34.89	0.10	26.70	98.00	8.09
	500 D	56	2.75	0.57	BDL	83.79	6.84	204.26	9.59	204.83	0.09	34.90	0.11	26.90	94.00	8.14
OOMA 2	0 S	0.1	1.95	1.01	2.62	124.16	6.87	196.77	8.82	200.39	0.26	34.85	0.16	27.70	99.00	8.19
	5 S	1	1.72	1.01	0.30	121.96	7.36	192.24	9.08	193.55	0.15	34.85	0.25	27.10	101.00	8.20
	10 S	1	1.95	1.44	0.38	121.88	6.61	188.08	8.56	189.91	0.21	34.84	0.11	26.60	89.00	8.08
	10 D	6	1.38	1.03	0.26	111.19	8.09	204.13	9.46	205.41	0.05	34.84	0.12	26.80	88.00	8.14
	25 S	1	2.75	3.15	2.59	164.10	6.84	199.56	9.59	205.31	0.04	34.78	0.12	26.70	88.00	8.14
	25 D	7	2.41	1.04	0.11	117.40	6.93	202.90	9.34	204.05	0.07	34.84	0.11	26.70	87.00	8.14
	50 S	1	2.52	1.47	0.25	125.79	7.85	197.89	10.37	199.61	0.05	34.83	0.13	26.30	86.00	8.16
	50 D	9	2.06	1.05	0.07	104.57	5.46	176.09	7.53	177.21	0.03	34.85	0.10	26.70	84.00	8.16
	100 S	1	2.29	0.64	BDL	110.84	7.04	162.16	9.34	162.79	0.35	34.85	0.11	26.60	87.00	8.17
	100 D	14	2.87	0.64	0.08	102.34	6.60	175.58	9.46	176.31	0.07	34.86	0.10	26.80	85.00	8.16
	500 S	1	2.06	0.65	0.12	83.31	6.49	203.41	8.56	204.18	0.07	34.89	0.09	26.70	84.00	8.16
	500 D	74	2.06	0.66	0.20	72.74	5.85	191.70	7.91	192.56	0.07	35.07	0.23	25.50	90.00	8.15
OOMA 3	0 S	0.1	4.70	1.94	3.73	167.35	5.02	218.35	9.72	224.02	0.80	34.82	0.29	27.90	91.00	8.23
	5 S	1	2.64	1.52	2.09	163.03	7.60	200.81	10.24	204.42	0.16	34.81	0.27	26.50	92.00	8.17
	10 S	1	0.57	1.10	0.35	131.42	8.89	180.17	9.46	181.62	0.07	34.82	0.14	26.60	87.00	8.15
	10 D	7	1.03	0.68	BDL	108.25	6.11	179.28	7.14	179.97	0.03	34.85	0.12	26.60	83.00	8.14
	25 S	1	0.92	0.69	0.26	106.09	8.03	192.13	8.95	193.08	0.05	34.85	0.14	26.80	83.00	8.16
	25 D	10	1.03	0.70	0.08	93.46	7.01	190.25	8.04	191.03	0.13	34.87	0.12	26.70	87.00	8.17
	50 S	1	0.57	0.70	BDL	103.87	7.47	191.07	8.04	191.78	0.24	34.86	0.11	26.40	91.00	8.15
	50 D	25	0.46	0.29	BDL	85.00	7.71	170.29	8.17	170.57	0.04	34.87	0.12	26.80	91.00	8.11
	100 S	1	2.41	0.29	0.38	93.30	6.41	159.47	8.82	160.15	0.17	34.87	0.10	26.70	95.00	8.10
	100 D	55	2.18	0.30	BDL	70.30	5.86	175.35	8.04	175.65	0.07	35.14	0.25	25.10	97.00	8.14
	500 S	1	1.38	0.31	BDL	68.19	6.80	171.30	8.17	171.61	0.06	34.89	0.10	26.30	98.00	8.16
	500 D	82	2.75	4.56	BDL	78.56	4.51	163.80	7.27	168.36	0.04	35.24	0.14	22.90	66.00	8.11
OO	S	1	2.06	0.75	2.03	82.68	6.11	197.45	8.17	200.23	0.07	34.89	0.12	26.90	97.00	8.12
	D	95	0.46	0.33	BDL	82.64	7.45	178.70	7.91	179.03	0.05	34.88	0.10	22.70	64.00	8.15
POND			57.35	594.30	47.60	16,569.17	71.30	488.60	128.65	1,130.50		12.28				

BOTANICAL SURVEY

Botanical Survey
TMKs 7-3-09:04 and 22
O`oma, North Kona, Island of Hawai‘i

By Ron Terry, Ph.D. and Patrick J. Hart, Ph.D.
Geometrician Associates, LLC

Prepared for PBR Hawaii
December 2006

Introduction

This report describes the results of a botanical survey of an approximately 300-acre property bordered by the sea, Queen Ka‘ahumanu Highway, Kohanaiki, and State property utilized by the Natural Energy Lab of Hawai‘i Authority (NELHA), just south of Kona International Airport on the Big Island of Hawai‘i (Fig. 1).

Purpose and Methodology

The objectives of the botanical survey were to 1) describe the vegetation; 2) list all species encountered; and 3) identify threatened or endangered plant species. The area was surveyed by Ron Terry and Patrick J. Hart in November 2006, with a repeat survey of the coastal area in December 2006 by Layne Yoshida and Graham Knopp. For purposes of survey and reporting, the area was divided into two regions: strand and upland. During the first survey, the botanists walked transects in upland areas spaced between 50 and 75 meters along GPS-guided UTM northings (i.e., east-west lines). Because of the very open and evenly sparse vegetation, plant visibility was excellent even over a range of 37.5 meters, but because each transect corridor was walked in a zigzag manner, coverage was actually much more intense than this spacing would indicate. In addition, botanists examined in detail rock outcrops, steep-sided depressions, lava tubes or other cave openings, and large fissures, where less common plants might be found.

As strand vegetation was much more dense, survey there consisted of near-100 percent coverage. Botanists walked along the beach road and ventured into patches of vegetation, walking or crawling under the canopy where necessary to examine ground herbs and grasses. In order to increase coverage, an additional survey was conducted on a separate day.

Species were identified in the field and, as necessary, collected and keyed out in the laboratory. Special attention was given to the possible presence of any federally (USFWS 2006) listed threatened or endangered plant species.

Limitations

No botanical survey of a large area can claim to have detected every species present. Some species are cryptic in juvenile or even mature stages of their life cycle. Dry conditions can render almost undetectable plants that extended rainfall may later invigorate and make obvious. Thick brush can obscure even large, healthy specimens. The findings of this survey must therefore be interpreted with proper caution; in particular, there is no warranty as to the absence of any particular species.

Vegetational Influences

The geologic substrate in this area is a 3-5,000-year old lava flow from Hualalai (Wolfe and Morris 1996). The surface is mainly *pahoehoe* (smooth or ropy lava) with scattered *'a'a* (clinkerly lava) inclusions. Elevation varies from sea level to about 120 feet above sea level. Annual rainfall in this area of Kona is about 20 inches. Almost no weathering has occurred on this substrate and little soil is present. The surface has been termed rough lava, 'a'a or pahoehoe in soil classifications (U.S. Soil Conservation Service 1973).

Based on the evidence of current rainfall, geology, and vegetation, the area probably supported a Coastal Dry Shrubland and Forest (per Gagne and Cuddihy 1990) prior to human disturbance. It was likely dominated in different places by naupaka (*Scaevola taccada*), ilima (*Sida fallax*) and pilo (*Capparis sandwichiana*), among other plants. Certain low-elevation areas of Kona that have avoided disturbance (often because of a rough 'a'a substrate) maintain semi-intact native vegetation. For example, a recent survey of relatively undisturbed land several miles north at somewhat higher elevations than the maximum found on this property (Hart 2003), found a *lama*-dominated forest with three endangered species: *halepepe* (*Pleomele hawaiiensis*), *uhiuhi* (*Caesalpinia kavaiensis*), and *'aiea* (*Nothocestrum breviflorum*), as well as several rare species: *'ohe makai* (*Reynoldsia sandwicensis*) and *maua* (*Xylosma hawaiiense*). Although elevation, rainfall and geology are not ideal for these on the subject property, some of these rare species may also have inhabited parts of it and were thus especially sought during the surveys.

This area seems to have avoided severe disturbance such as grading, although it has likely been intensely grazed by goats, and there is evidence of widespread small-scale trash dumping and some harvesting of rocks for rock walls. The margins of the property have been used for roads. The strand part of the property experiences intensive use for recreation, mainly picnicking.

Current Vegetation

There are two zones, strand and upland, neatly separated by the inland extent of wave-washed coral chunks and sand.

The vegetation of the upper portion has a simple and fairly uniform structure. The substrate is a mixture of pahoehoe and 'a'a, mostly the former. Vegetation cover varies from nearly continuous to sparse, and is most typically dominated by scattered bunch grasses, with low shrubs and herbs subdominant. There are a few very widely scattered trees. The most common grass is fountain grass (*Pennisetum setaceum*), with *pili* grass (*Heteropogon contortus*) locally abundant. Natal red-top grass (*Rhynchelytrum repens*) is also fairly common. The main herbs are *ilima* and *ʻuhaloa* (*Waltheria indica*), with various weedy composites, spurges, portulacas also common. The main shrub, surprisingly, is the regionally somewhat rare native *pilo*, with a fair amount of the aliens *noni* (*Morinda citrifolia*) and klu (*Acacia farnesiana*). The aliens *Pluchea symphitifolia* and *koa haole* (*Leucaena leucocephala*) are abundant in a few spots or widely scattered. The alien *Nephrolepis multiflora* fern is fairly common in cracks, with a native counterpart, *N. exaltata subsp. hawaiiensis* uncommon. Unusual natives scattered on the lava include the Polynesian-introduced herb *ʻauhuhu* (*Tephrosia purpurea*) and the native tree *naio* (*Myoporum sandwicense*). Cave underhangs support a few individuals of other natives species, including the fern *Doryopteris decora*, the fern ally *moa* (*Psilotum nudum*), and the herb *Plectranthus parviflorus*.

The strand area, enriched by sandy soil and groundwater, supports much higher species diversity and varies in cover from almost continuous blankets of herbs and grasses to low forests or parkland. It is dominated in biomass by the alien tree heliotrope (*Tournefortia argentea*), with the native *naupaka* and the aliens Christmas berry (*Schinus terebinthifolius*), *noni*, *kiawe* (*Prosopis pallida*), and *koa haole* also common. The herbs and shrubs mentioned in the upland description are also present below, but often more vigorous and common. There is also an abundance of other grasses, with Bermuda grass (*Cynodon dactylon*) very common. Coconuts (*Cocos nucifera*) and the native *kou* tree (*Cordia subcordata*) are also present. Vines include the natives *paʻu o hiʻiaka* (*Jacquemontia ovalifolia*) and *pohuehue* (*Ipoemoea pes-caprae*) as well as the alien ivy gourd vine (*Coccinea grandis)*. A large number of native and alien herbs typical of the strand, including heliotropes, chenopodes, and other types are present.

A full list of plant species found on the site is contained in Table 1, below. **No listed or proposed threatened or endangered plant species were found**. *Pilo* (*Capparis sandwichiana*), although common on the property, is considered a species of concern by the U.S. Fish and Wildlife Service and is often listed among rare plants in Hawaiʻi. Although this status does not provide official legal protection, USFWS and the Hawaiʻi Department of Land and Natural Resources are keenly interested in its protection.

Impacts and Mitigation Measures

Landscaping should avoid invasive species and employ native species to the greatest degree consistent with project goals. Reputable Kona nurseries will supply lists of, and sources for, suitable native species. With the understanding that the strand vegetation and some of the area behind this will be preserved, the impacts of clearing the property will generally not be severe. We recommend that consideration be given to preserving some areas with fairly dense concentrations of *pilo* (e.g, as part of archaeological preserves, if these are present), as this is a somewhat unusual and valuable vegetation type that is also important in traditional Hawaiian medicine.

Figure 1
USGS Map of Subject Property

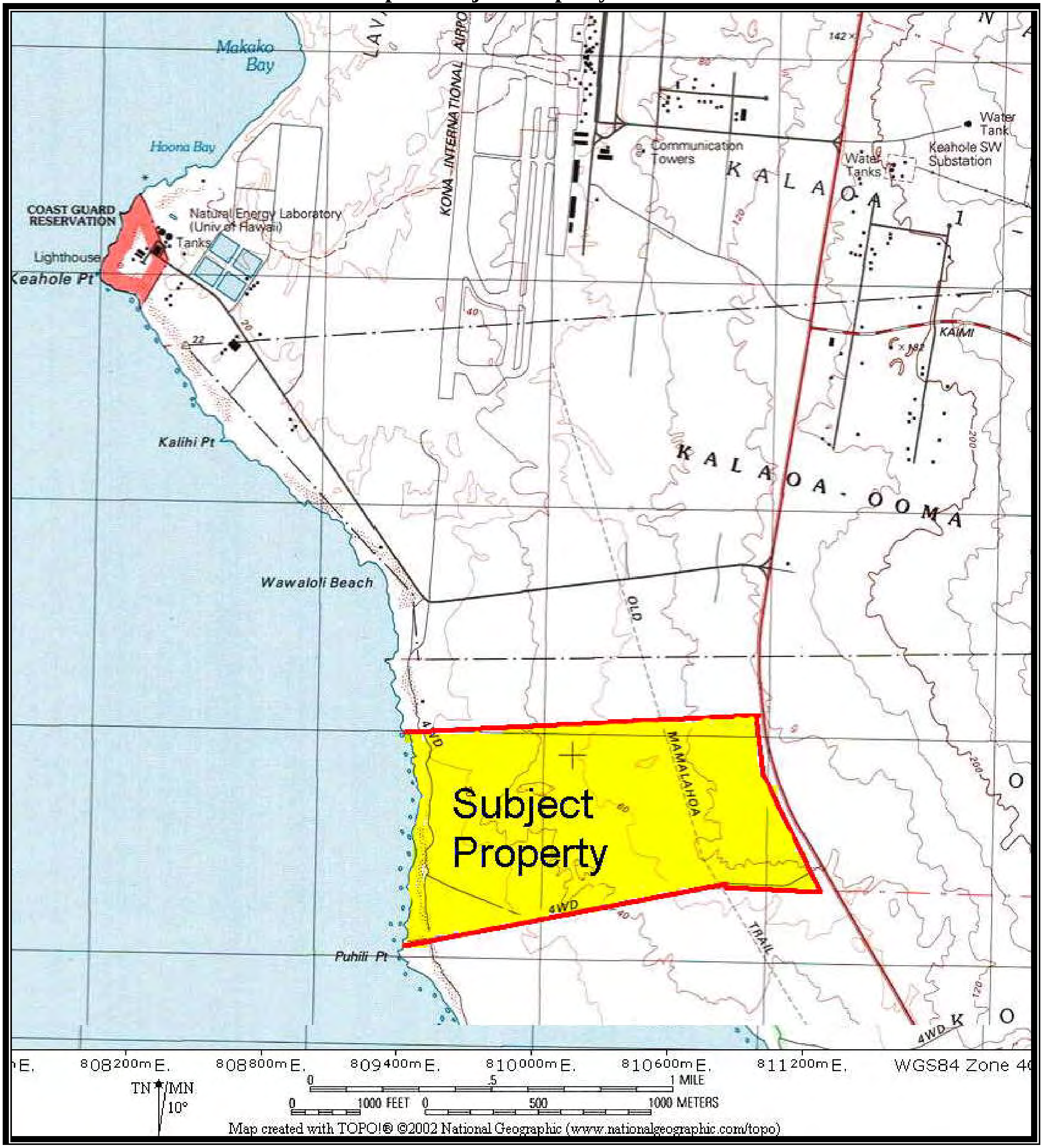

Table 1
Plants Observed on Property

Scientific Name	Family	Common Name	Life Form	Status*
Acacia farnesiana	Fabaceae	Klu	Shrub	A
Alternenthera pungens	Amaranthaceae	Khaki weed	Herb	A
Amaranthus sp.	Amaranthaceae	Amaranth	Herb	A
Argemone glauca	Papaveraceae	Pua kala	Herb	E
Bassia hyssopifolia	Chenopodaceae	None	Herb	A
Boerhavia coccinea	Nyctaginaceae	Boerhavia	Herb	A
Boerhavia acutifolia	Nyctaginaceae	Alena	Herb	I
Bougainvillea sp.	Nyctaginaceae	Bougainvillea	Shrub	A
Capparis sandwichiana	Capparaceae	Maiapilo	Shrub	E
Casuarina equisetifolia	Casuarinaceae	Ironwood	Tree	A
Catharanthus roseus	Apocynaceae	Madagascar periwinkle	Shrub	A
Chamaecrista nictitans	Fabaceae	Partridge Pea	Herb	A
Chamaesyce hirta	Euphorbiaceae	Garden Spruge	Herb	A
Chenopodium murale	Chenopodiaceae	‘Aheahea	Shrub	A
Chenopodium oahuense	Chenopodiaceae	‘Aheahea	Shrub	E
Coccinea grandis	Cucurbitaceae	Ivy gourd	Vine	A
Cocos nucifera	Arecaceae	Niu	Tree	A
Cordia subcordata	Boraginaceae	Kou	Tree	A
Cynodon dactylon	Poaceae	Bermuda grass	Grass	A
Dodonaea viscosa	Sapindaceae	‘A‘ali‘i	Shrub	I
Doryopteris decora	Pteridaceae	Doryopteris	Fern	E
Eleusine indica	Poaceae	Wire grass	Grass	A
Eragrotis variabilis	Poaceae	Lovegrass	Grass	E
Fimbristylis cymosa	Cyperaceae	Mau`u `aki`aki	Sedge	I
Fimbristylis hawaiiensis	Cyperaceae	Fimbristylis	Sedge	E
Heliotropium sp.	Boraginaceae	Heliotrope	Herb	I or A
Heliotropium curassavicum	Boraginaceae	Seaside Heliotrope	Vine	I
Heteropogon contortus	Poaceae	Pili grass	Grass	I
Indigofera suffruticosa	Fabaceae	Indigo	Shrub	A
Ipomoea pes-caprae	Convolvulaceae	Pohuehue	Vine	I
Jacquemontia ovalifolia	Convolvulaceae	Pa‘u o Hi‘iaka	Vine	I
Lantana camara	Verbenaceae	Lantana	Shrub	A
Leucaena leucocephala	Fabaceae	Haole koa	Tree	A
Morinda citrifolia	Rubiaceae	Noni	Shrub	A
Myoporum sandwicense	Myoporaceae	Naio	Tree	I
Nephrolepis exaltata subsp. hawaiiensis	Nephrolepidaceae	Ni‘ani‘au	Fern	E

Table 1, continued				
Scientific Name	**Family**	**Common Name**	**Life Form**	**Status***
Nephrolepis multiflora	Nephrolepidaceae	Sword Fern	Herb	A
Pennisetum setaceum	Poaceae	Fountain grass	Grass	A
Plectranthus parviflorus	Lamiaceae	‘Ala ‘ala wai nue	Herb	I
Pluchea symphytifolia	Asteraceae	Sourbush	Shrub	A
Portulaca oleracea	Portulacaceae	Pig weed	Herb	A
Portulaca pilosa	Portulacaceae	Portulaca	Herb	A
Prosopis pallida	Fabaceae	Kiawe	Tree	A
Psilotum nudum	Psilotaceae	Moa	Herb	I
Rhynchelytrum repens	Poaceae	Natal red-top	Grass	A
Scaevola taccada	Goodeniaceae	Naupaka	Shrub	I
Schinus terebinthifolius	Anacardiaceae	Christmas Berry	Shrub	A
Sesuvium portulacastrum	Aizoaceae	Akulikuli	Herb	I
Sida fallax	Malvaceae	‘Ilima	Shrub	I
Tephrosia purpurea	Fabaceae	‘Auhuhu	Shrub	A
Thespesia populnea	Malvaceae	Milo	Tree	I
Tournefourtia argentea	Boraginaceae	Tree heliotrope	Tree	A
Tribulus terrestris	Zygophyllaceae	Goat head	Herb	A
Tridax procumbens	Asteraceae	Coat buttons	Herb	A
Waltheria indica	Sterculiaceae	Uhaloa	Herb	I

A = alien, E = endemic, I = indigenous, End = Federal and State listed Endangered Species

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AVIFAUNAL & FERAL MAMMAL SURVEY/ TERRESTRIAL INVERTEBRATE RESOURCES SURVEY

AVIFAUNAL AND FERAL MAMMAL SURVEY FOR THE

PROPOSED O'OMA, SEASIDE VILLAGE, O'OMA, NORTH KONA, HAWAII

TMKs: (3) 7-3-9:004 and 22

Report Prepared for:

North Kona Village, LLC
c/o Midland Pacific Homes

Survey and Report by:

Phillip L. Bruner
Environmental Consultant
Faunal (Bird & Mammal) Surveys
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27 November 2006

INTRODUCTION

The purpose of this report is to provide the findings of a two day (18, 19 November 2006) field survey of an approximately 300 acre site (TMKs: (3)7-3-9:004 and 22) at Kona, Hawaii. The findings of an earlier survey (Bruner 2002) of a mauka portion of this site are also noted for comparison. The goals of the survey were:

1- To document the species of birds and mammals currently on the property.
2- To examine the entire site and nearby lands for the purpose of identifying important natural resources available to wildlife at this location.
3- To devote special attention to documenting the presence and possible use of this property by native and migratory species particularly those that are listed as threatened or endangered.

SITE DESCRIPTION

The mauka portions of the property were examined previously (Bruner 2002). The coastal habitat was the primary focus of this expanded and updated survey. The majority of the property is covered in grass with a few scattered bushes. The coastal strand is forested with native and alien (introduced) trees and brush. A very small, vegetation choked wetland occurs just mauka of the coastal forest. Human foot and vehicle traffic through the coastal section was constant and heavy during the period of this survey.

SURVEY PROTOCOL

The field survey was conducted on foot over two days to allow for early morning and late afternoon-evening observations. All birds seen or heard were noted. Observations of mammals were limited to visual sightings and evidence in the form of tracks. The evening of 18 November was used to search for the presence of the endangered Hoary Bat (*Lasiurus cinereus semotus*). A Pettersson Elektronik AB Ultrasound Detector D 100 was used to listen for echolocating bats at several locations on the property.

Weather during the survey was clear and relatively mild. The overall condition for detecting birds was excellent.

The scientific names used in this report follow Pyle (2002) and Honacki et al. (1982). These sources provide the current accepted names found in the scientific literature.

RESULTS AND DISCUSSION

Native Land Birds:

As on the earlier (Bruner 2002) survey no native land birds were recorded. The only possible native land birds that might on rare occasion forage in this area are the Hawaiian or Short-eared Owl (*Asio flammeus sandwichensis*), known as Pueo in Hawaiian and the Io or Hawaiian Hawk (*Buteo solitarius*). These species hunt in a variety of habitats including forests, agricultural lands and grasslands (Pratt et al. 1987, Hawaii Audubon Society 2005). Pueo are not listed as endangered or threatened on the Big Island, however, the State of Hawaii does list them as endangered on Oahu. The Io is an endangered species and is only found on the Big Island.

Seabirds:

No seabirds were seen on this 2006 survey. None would be expected to nest on this site due to the abundance of ground predators and human disturbance.

Migratory Birds:

All four of the common migratory shorebirds that breed in the arctic and "winter" in Hawaii were observed in the coastal portion of the property. The Pacific Golden-Plover or Kolea (*Pluvialis fulva*) were observed on the 2002 survey. Five Kolea were also tallied on this 2006 survey. This species has been extensively studied here in Hawaii and on its breeding grounds in western Alaska (Johnson et al. 1981, 1989, 1993, 2001a, 2001b). Four Wandering Tattler or Ulili (*Heteroscelus incanus*), three Ruddy Turnstone or Akekeke (*Arenaria interpres)* and one Sanderling or Hunakai (*Calidris alba*) were also tallied on this survey. These three species were not recorded on the 2002 survey which was in the mauka section of the site which does not contain suitable habitat for these migrants.

Alien (introduced) Birds:

Only one new alien species, the House Finch (*Carpodacus mexicanus*), was added to the list obtained in 2002 (Table 1). None of the alien birds are listed as threatened or endangered.

Mammals:

The Small Indian Mongoose (*Herpestes auropunctatus*) and feral cat (*Felis catus*) were the only mammals recorded. Seven Mongoose were observed along the coastal section. The tracks of cats were common along the coastal beach road. The endangered Hawaiian Hoary Bat (*Lasiurus cinereus semotus*) was not recorded on the evening search using the ultrasound detector. This species was likewise not found on the 2002 survey. My most recent sighting of the Hawaiian Hoary Bat was on mauka lands above this property (Bruner 2006). Feral Goats (*Capra hircus*) were reported to occur on occasion along the coastal portions of O'oma and Kohanaiki (R.S.K. Mitchell pers. comm..)

EXECUTIVE SUMMARY

The emphasis of this field survey was to document the birds and mammals on the makai, coastal portion and to update data from the mauka grassland section of the property. There were no native birds or mammals found on the 2002 or this current 2006 survey. The Hawaiian Owl or Pueo, Hawaiian Hawk or Io and the Hawaiian Hoary Bat could forage on occasion at this site. I know of no data on their frequency of occurance in this general area of west Hawaii. All four common migratory shorebird species were seen in the coastal portion. The Pacific Golden-Plover or Kolea was also seen flying over the mauka grasslands. The vegetation choked wetland is too small and overgrown to be of use to waterbirds or migratory shorebirds. The only mammals seen were alien cats and the Small Indian Mongoose. The alien birds recorded on the 2002, 2006 surveys are those typically found in this region.

TABLE ONE

Alien (introduced) species of birds found on a two day (18, 19 November 2006) field Survey of TMKs:(3) 7-3-9:004 and 22 in North Kona, Hawaii. Data from 2002 are also shown (X=present, O=absent).

Common Name	Scientific Name	2002	2006
Gray Francolin	*Francolinus pondicerianus*	X	X
Ring-necked Pheasant	*Phasianus colchicus*	X	O
Spotted Dove	*Streptopelia chinensis*	X	X
Zebra Dove	*Geopelia striata*	X	X
Japanese White-eye	*Zosterops japonicus*	X	X
Common Myna	*Acridotheres tristis*	X	X
Northern Cardinal	*Cardinalis cardinalis*	X	X
Yellow-billed Cardinal	*Paroaria capitata*	X	X
House Finch	*Carpodacus mexicanus*	O	X
African Silverbill	*Lonchura cantan*	X	O
Nutmeg Mannikin	*Lonchura punctulata*	X	O
Java Sparrow	*Padda oryzivora*	X	O

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Survey of Terrestrial Invertebrate Resources at ‘O’oma, North Kona, Hawai‘i Island

A yellow-faced bee collects pollen from ‘ilima at ‘O’oma

Prepared by:
Steven Lee Montgomery, Ph. D., Waipahu, Hawai’i

Submitted to:
PBR Hawaii & Associates, Inc

For:
‘O’oma Beachside Village, LLC

November 11, 2008

Table of Contents

Tables

Figures

SUMMARY

The 'O'oma Beachside Village project site sampled in this biological survey yielded native and adventive mollusks and arthropods. No invertebrate currently listed as endangered or threatened under either federal or state statutes was located within the survey area.

INTRODUCTION

This report summarizes the findings of an invertebrate[1] survey conducted in support of an environmental impact statement as part of a proposal to construct residential units, areas for retail and commercial use, and supporting infrastructure in North Kona, Hawai'i. 'O'oma Beachside Village, LLC, proposes to build on 302.38 acres of land, within portions of Tax Map Keys: (3) 7-3-009:004 and :022. This survey was conducted by Steven Lee Montgomery, Ph.D., for 'O'oma Beachside Village, LLC, as part of a team effort directed by PBR Hawaii & Associates, Inc, Honolulu.

Invertebrates are often the dominant fauna in natural Hawaiian environments. The primary emphasis of this survey was on terrestrial arthropods, particularly those that are endemic or indigenous species, especially those having legal status under either, or both federal and state endangered - threatened species statutes (DLNR 1996, USFWS 2005a, 2008).

Native Hawaiian plant, vertebrate, and invertebrate populations are interdependent. Certain insects are obligatorily attached to host plants and use only that plant as their food. The health of native Hawaiian invertebrate populations depends on habitat quality and absence or low levels of continental predators. Sufficient food sources, host plant availability, and the absence or low levels of introduced, continental predators and parasites comprise a classic native, healthy ecosystem. Consequently, where appropriate in the survey discussion, host plants and some introduced arthropods are also noted.

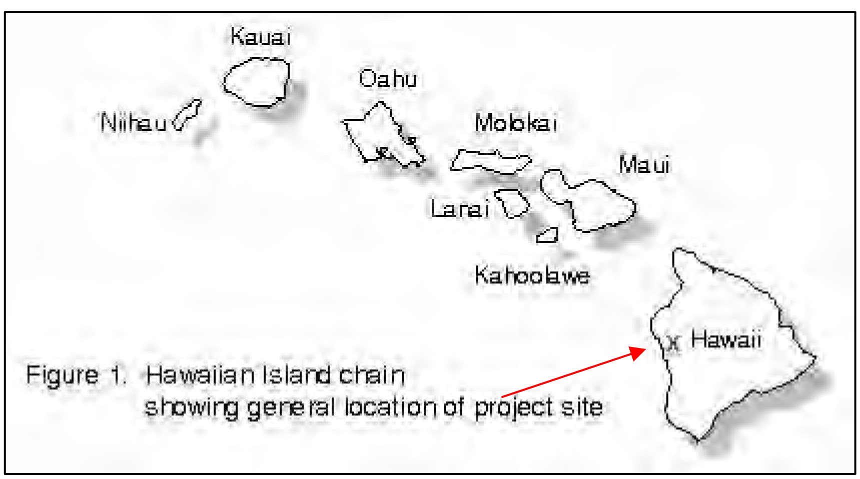

Figure 1. Hawaiian Island chain showing general location of project site

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[1] Animals without backbones: insects, shrimp, snails, spiders, etc.

GENERAL SITE DESCRIPTION

The project area is on the Kona coast of the Island of Hawai’i (Figure 1) in the ‘O’oma 2nd Ahupua’a. The property is south of the Kona International Airport and north of the Kaloko-Honokōhau National Park. The site is bounded by the Pacific Ocean, Queen Ka’ahumanu Highway, the Hawai’i Natural Energy Lab, and the “Shores at Kohanaiki” property (Figure 3). Elevation rises from sea level to 120 feet (ft).

The vegetation on the site has been through a variety of changes as first Polynesians adapted the area to their own needs. From early Hawaiian cultivation of crops and housing to grazing of domesticated and feral animals (Rechtman 2007), the native vegetation - and native invertebrate population - was increasingly displaced by a succession of introduced plants or chewed and grubbed out by introduced mammals (Terry & Hart 2006). Nevertheless, several native Hawaiian plants of interest as hosts or shelter for invertebrates are present. A strand vegetation community gives way to an inland plant community on mixed pāhoehoe and ‘a’ā lavas. An anchialine pond is located behind the sand dunes (Figure 2). Lava tubes are present throughout the area. The inland area is dominated by fountain grass (*Pennisetum setaceum*) overlaying an ‘ilima-pili grass community. In comparison to many other dryland, low elevation locations in the islands this site has not been altered by grading, but has been grazed by goats (Terry & Hart 2006).

Figure 2: The water level in the anchialine pond fluctuates with the tide

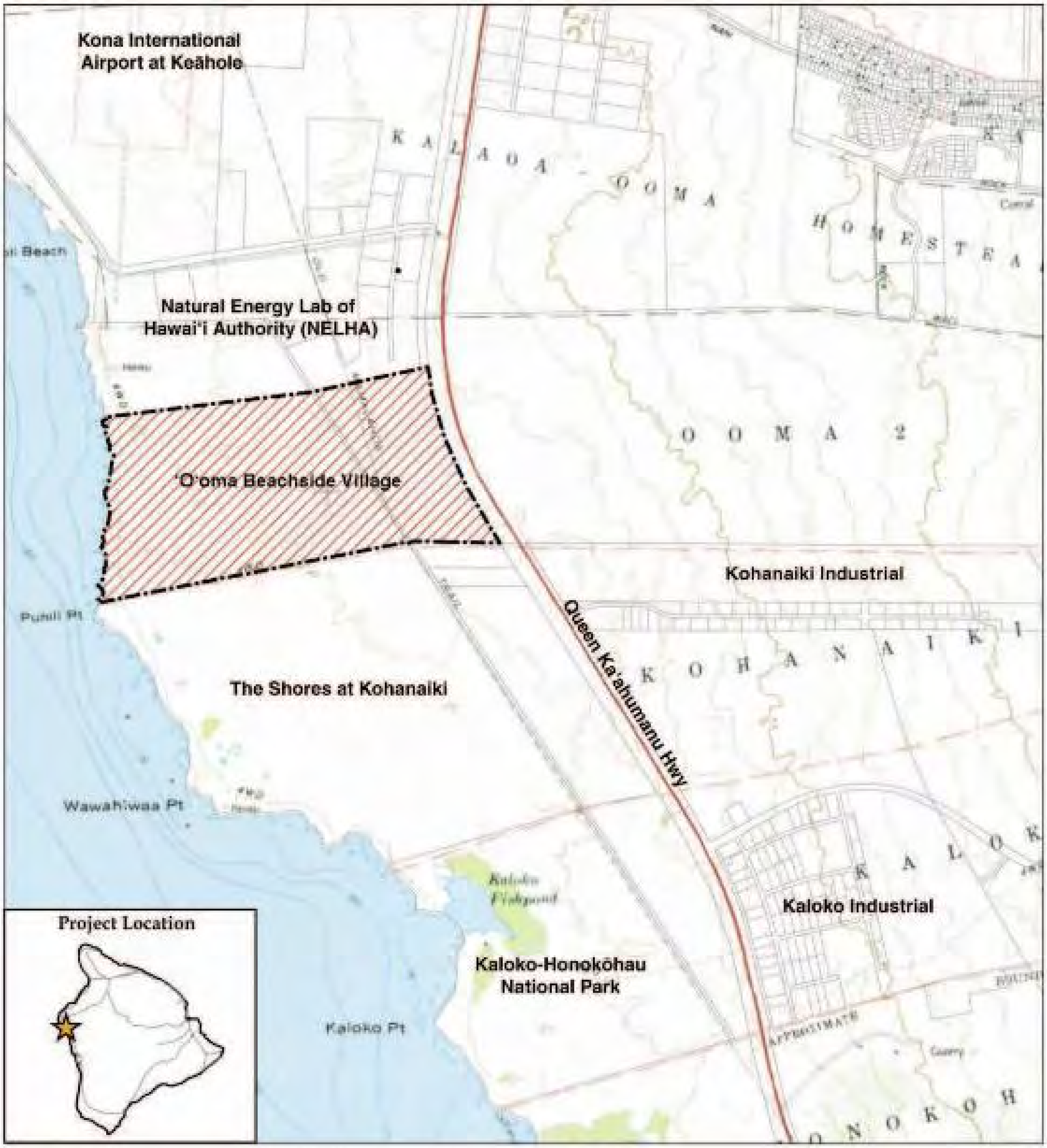

Figure 3. Map showing location of project site, North Kona, Hawai’i

[from PBR Hawaii 2008]

INVERTEBRATE SURVEY METHODS

Since 1970, I have taken part in field projects at other locations in the Kailua-Kona area and in other dryland locations throughout the island chain. Surveys of other dryland areas have created a sizeable body of information on native invertebrate and related botanical resources found in areas similar to ‘O’oma (Bridwell 1920, Swezey 1935). Those experiences and the results of those surveys provided the basis for my study design and my analysis of results.

Previous Surveys and Literature Search

Avian, mammalian, ocean resource, archaeological, and botanical surveys of the project area have been conducted since at least 1986. Previous Environmental Assessments and Environmental Impact Statements associated with this site (Bruner 2006, Helber et al. 1986, 1991a, 1991b; PBR 2007, 2008) were reviewed. While these were very helpful in preparing for this study, none showed reference to previous terrestrial invertebrate surveys or surveys of lava tubes for cave-adapted invertebrate species. Recent surveys did include a review of the anchialine pond (Marine Research Consultants 2008a, 2008b).

Searches were made in the Bishop Museum Library, University of Hawai’i Hamilton Library, and State’s Office of Environmental Quality Control web site (2008). Surveys done for other projects in the general area (Towill 1976, 1988) were reviewed. Only the planning for Kula Nei, a nearby but inland project, included a survey of lava tube invertebrates (SWCA 2006-7).

A search was made for independent studies of invertebrates associated with this site or with nearby sites. Access to the area was limited prior to construction of Queen Ka’ahumanu Highway. The area lacked the commercial agriculture which generated much of Hawaii’s formal entomological surveys in the 1900s. The combination of these factors makes it unremarkable that this review showed no previous invertebrate surveys of the area. Also searched were the online proprietary data bases of Biological Abstracts, Ingenta, and Zoological Record. Searches were made for publicly available articles mounted on the web and in regional and national databases which provide geographic access, such as the Pacific Basin Information Node and Hawaii Natural Heritage Program. Natural History Museum London’s HOSTS database of the Lepidopteran host plants was used to prepare for the survey using results of the previous botanical surveys. Data base searches were made in Bishop Museum’s Arthropod Checklist, and the University of Hawaii, Hamilton Library’s Hawaii-Pacific Journal Index.

Fieldwork

Field surveys were conducted in August and September, 2008. I conducted a general assessment of terrain and habitats at the start of the survey. Surveying efforts were conducted at various times of day and night, a technique which is vital for a thorough survey. Native botanical resources identified by Char (1986, 1990) and Terry & Hart (2006) were an important focus of my searches, as were lava tubes located by the archaeological survey (Rechtman 2007).

Fieldwork schedule:

August 12-13, 2008	Site examination, orientation, collecting; light survey
August 13-14, 2008	General collecting; light survey; lava tubes surveys
September 5, 2008	Lava tube orientation; general collecting; light survey
September 6-11, 2008	General collecting; light survey; lava tubes surveys

Daylight surveying was concentrated during the cooler early morning and late afternoon hours when temperatures are lower and invertebrates are more active.

See Figure 5 for light surveying locations within the survey area.

Collecting Methods

The following collecting methods for terrestrial invertebrates were used as appropriate to the terrain, botanical resources, and target species.

Baiting: Baits are used to attract insect species to specific tastes or smells. For example, some flies come to dead or dying plants with a specific odor. Baits can mimic that smell and taste and so attract those insects. Insects are enticed by the bait’s ‘advertisement.’ Baits are placed at likely locations or inserted in bottle traps and checked periodically. Any insects at the bait are then observed and collected if appropriate. This is much more efficient than roaming the research area seeking cryptic insects. Baiting is a recognized method of censusing lava tubes for cave adapted fauna.

Lava tubes were chosen for baiting after an orientation to the location of lava tubes previously located and from among tubes located in my own survey. Tubes were chosen for baiting based on the size of the dark zone, presence and amount of intruding roots, and dripping water which experience shows create a lava tube environment suitable for cave fauna. Traps used shrimp paste and blue cheese baits, both proven and durable attractants in other lava tube surveys. A baited live bottle trap was deployed at a sink hole on August 13 and retrieved on August 14, 2008. Baited traps were placed in 2 lava tubes September 5 and in 2 more tubes on September 8, 2008 All traps were retrieved on September 10, 2008.

Host plant searches: Potential host plants, both native and introduced, were searched for arthropods that feed or rest on plants. Wandering transects were followed throughout the inland area with emphasis on reaching native host plants.

Light sampling: A survey of insects active at night is vital to a complete record of the fauna. Many insects are only active at night to evade birds, avoid desiccation and high temperatures, or to use night food sources, such as night opening flowers. Light sampling uses a bright light source in front of a white cloth sheet (Figure 4). Night active insects seem to mistake the collecting light for the light of the moon, which they use to orient themselves. In attempting to navigate by the collecting light, confused insects are drawn toward the light and land on the cloth in confusion. This type of collecting is most successful during the dark phase of the moon or under clouds blocking starlight. Vegetation usually blocks light from being seen over long distances, and most moths and other night fliers are not capable of very distant flight. Consequently, light sampling does not call in many insects from outside the survey area.

Sampling was conducted for approximately 11 hours each on August 12-13 and 13-14, 2008, and on September 5-6, 6-7, and 7-8, 2008. The light source was a mercury vapor (MV) bulb powered by an electric generator. An additional, UV light source was used at all sites.

Competing light from housing, street lights and other artificial sources was not a factor in response success.

© Figure 4: A light census is important to understand the invertebrate fauna.

Locations were chosen based on experience, host plant proximity, and terrain. The botanical survey placed most of the native plants in the shoreside vegetated strip. As the interconnection of arthropods and host plants would predict, light sampling in that area was most successful. All light sample locations are marked on Figure 5.

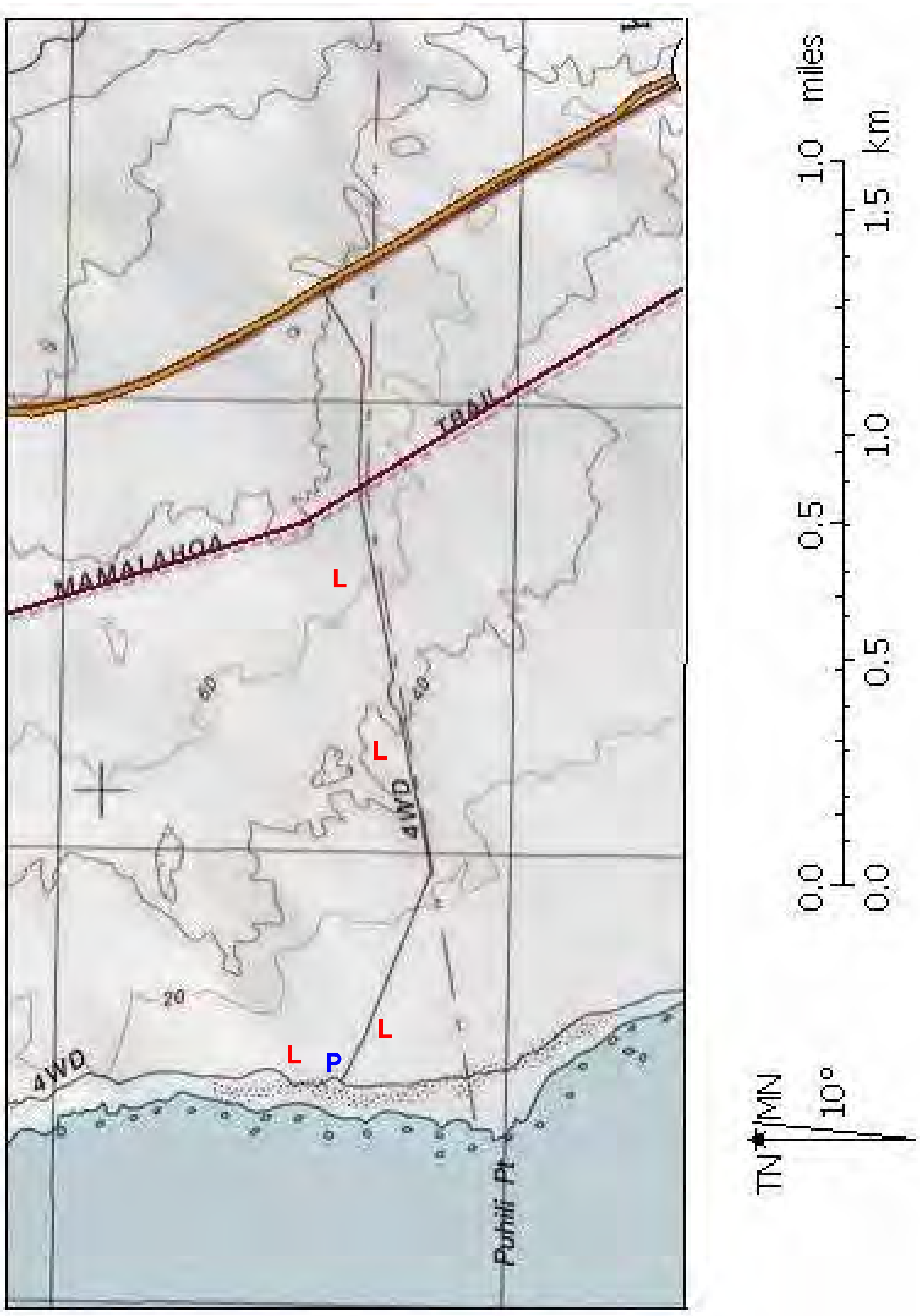

Figure 5: Map of ‘O’oma project area showing light monitoring sites, pond.

L = light monitoring **P** = pond

Sweep nets: This is the most common and general method of collecting most flying and perching insects. A fine mesh net was swept across plants, leaf litter, rocks, etc. to collect any flying, perching or crawling insects. Transfer from the net was either by aspiration, or by placing the net contents into a holding container.

Visual observation: At all times, I was vigilant for any visual evidence of arthropod presence or activity. Visual observations provide valuable evidence and are a cross check that extends the reach of sampling techniques. Visual observation also included turning over rocks, dead wood, and other debris.

Survey Limitations / Conditions

My ability to form advisory opinions is limited / influenced in the following ways:

Collecting conditions:

Weather: Weather was favorable for surveying during each field day.

Seasons: Monitoring at a different time of the year might produce a longer or different arthropod list. Weather and seasonal vegetation play an especially important role in any survey of invertebrates. Many arthropods time their emergence and breeding to overlap or follow seasonal weather or to coincide with growth spurts of an important plant food. Host plant presence/absence, and seasonal changes, especially plant growth after heavy rains, affect the species collected.

This survey was conducted without the benefit of winter rains and vegetation revitalization. If vegetation had developed after winter rains, a different insect list might have resulted. Nevertheless, the low level of native plants outside the coastal zone was a stronger factor in determining the invertebrates encountered than the season or condition of vegetation.

Moon: The moon presented some competition to the collecting light on the evenings of August 12-13-14, 2008: The moon rose between 4 and 5 p.m. each night[2] and set between 3 and 4 a.m. the following morning. The moon was described as "waning gibbous" with 85-90% of the Moon illuminated. (USNO) The complete lack of artificial light sources compensated to a degree for the competition.

The moon did not present important competition to light collecting efforts during most days of September surveying and should not have affected the number of

[2] Times given are for Kailua-Kona as closest city tracked by U. S. Naval Observatory

insects attracted to the light. At the start of fieldwork, the moon rose during daylight hours, set and then rose well after midnight each day, giving many hours of moon-free census time. The moon was described then as a “waxing crescent” in the first quarter. Toward the end of fieldwork the larger moon was rising later, but setting earlier also, again giving many moon-free hours. (USNO)

Limited duration: Surveying for a longer period of time might enlarge the list of species; however, given the size of the property, I believe the survey provides a fair review of the invertebrates present.

Selectivity: My survey was focused on finding any endemic and indigenous Hawaiian land invertebrates species. No attempt was made to collect or completely document the many common alien arthropod species present in the area.

A detailed survey was not made of the anchialine pond as that task was assigned to another surveyor. (See Marine Research Consultants 2008a, 2008b)

RESULTS:

In addition to the invertebrate results noted below, I noted the presence of the small Indian mongoose (*Herpestes auropunctatus*).

DISCUSSION

Native species of note are discussed. Also, information is provided on several adventive species often misidentified by the public, especially those confused with native species. Non-native species in conflict with native species or human beings are discussed.

INVERTEBRATE RESOURCES

ARTHROPODS

ARANEAE (spiders)

Salticidae: Unidentified species

One immature jumping spider was noted under stones on the inland lava flow. Identification of immatures from one sample is extremely difficult. There are 9 spiders of the family Salticidae reported from Hawai’i island, four endemics, all of the genus Sandalodes, and 5 adventive or introduced spiders. (HBS 2002a, Nishida 2002)

Table 1: List of Invertebrates:[3] ‘O’oma, North Kona, Hawai’i

Species	Common Name	Status	Abundance	Notes
MOLLUSCA				
GASTROPODA				
PULMONATA	snails and slugs			
Melania sp.		Ind	O	in anchialine pond
Assimineidae				
Assiminea sp.		Ind?	O	in anchialine pond
ARTHROPODA				
ARANEAE	spiders			
Heteropodidae				
Heteropoda venatoria	large brown spider or cane spider	Adv	U	leaf litter
Salticidae	jumping spider			
unidentified immature		?	U	under stones
ARACHNIDA				
SCHIZOMIDA				
Scorpiones	scorpions			
Isometrus maculatus (De Geer)	lesser brown scorpion	Adv	U	at light
CRUSTACEA				
DECAPODA				
Alpheidae				
Metabetaeus lohena Banner & Banner	native preying shrimp	End	R	in anchialine pond
Atyidae				
Halocaridina rubra Holthuis	'opae ula	End	U	in anchialine pond
INSECTA				
COLLEMBOLA	springtails			
Entomobryidae				
undetermined sp. 1		?	O	under stones
DIPTERA	flies			
Canacidae				
Canaceoides hawaiiensis		End	R	at light
Dolichopodidae	long-legged flies			
Dolichopus exsul Aldrich, 1922		Adv	R	UV light
Thambemyia acrosticalis (Parent), 1938		End	O	swept in wetland
Syntormon flexibile Becker, 1922		Adv	O	swept in wetland
Ephydridae	shore flies			
Clasiopella uncinata Hendel, 1914		Adv	A	at light; sweeping
Scatella sexnotata Cresson, 1926		Ind	U	at light

[3] Names authority: Hawaii Biological Survey 2002a; Nishida 2002; Zimmerman 1948-80; Zimmerman 2001

Table 1: continued

Species	Common name	Status	Abundance	Notes
HETEROPTERA	true bugs			
Lygaeidae	seed bugs			
Nysius nigriscutellatus Usinger		End	O	at light & swept
HOMOPTERA	planthoppers			
Cixiidae				
Oliarus inconstans Giffard, 1925		End	R	at light
HYMENOPTERA	wasps, bees, ants			
Anthophoridae				
Ceratina arizonensis Cockerell, 1898	small carpenter bee	Adv	C	swept over flowers
Apidae				
Ceratina smaragdula (Fabricius)	small carpenter bee	Adv	U	at *Sida*
Colletidae				
Hylaeus anthracinus (F. Smith)	yellow-faced bee	End	C	at *Sida*, *Capparis*, & *Tournefortia*
Hylaeus psammobius (Perkins)	yellow-faced bee	End	R	at *Sida*, *Capparis*, & *Tournefortia*
Formicidae	ants			
Camponotus variegatus	carpenter ant	Adv	C	to light
Monomorium pharaonis (Linnaeus, 1758)	pharaoh ant	Adv	A	pond margins
Vespidae	wasps			
Polistes exclamans Viereck, 1906	common paper wasp	Adv	C	at flowers
LEPIDOPTERA				
Cosmopterigidae	case bearers			
Hyposmocoma sp. 1	slender wedge case	End	R	under stones
Hyposmocoma sp. 2	broad case	End	U	under stones
Hyposmocoma sp. 3	black, pointed adult	End	A	at light
Crambidae	micro-moths			
Tamsica hyacinthina (Meyrick 1899)		End	A	at light
Noctuidae	miller moths			
Ascalapha odorata (Linnaeus, 1758)	black witch moth	Adv	O	at light
Sphingidae	hawk moths			
Agrius cingulata (Fabricius, 1775)	sweetpotato hornworm	Adv	U	at light

Table 1: continued

Species	Common name	Status	Abundance	Notes
ODONATA	dragonflies; damselflies			
Aeshnidae				
Anax junius (Drury, 1770)	common green darner	Adv	U	at pond
Libellulidae	skimmers			
Pantala flavescens (Fabricius, 1798)	globe skimmer	Ind	C	in flight
ORTHOPTERA	praying mantis, grasshoppers, crickets			
Gryllidae	crickets			
Caconemobius anahulu Otte,1994	lava cricket	End	U	surface near lava tube entrance; baited trap
Gryllodes sigillatus (Walker)1869	flightless field cricket	Adv	A	baited trap
CHILOPODA				
SCOLOPENDROMORPHA				
Scolopendridae	centipedes			
Scolopendra subspinipes Leach, 1815	large centipede	Adv	U	on soil

Status:
End endemic to Hawaiian Islands
Ind indigenous to Hawaiian Islands
Adv adventive
Pur purposefully introduced
? unknown

ABUNDANCE = occurrence ratings:
R Rare seen in only one or perhaps two locations.
U Uncommon- seen at most in several locations
O Occasional seen with some regularity
C Common observed numerous times during the survey
A Abundant found in large numbers
AA Very abundant abundant and dominant

CRUSTACEA
DECAPODA
Alpheidae: *Metabetaeus lohena* Banner & Banner
Atyidae: *Halocaridina rubra* Holthuis 'opae ula


Figure 6. *Metabetaeus lohena* at ‘O’oma

Halocaridina rubra was previously reported from the anchialine pond (Marine Research Consultants 2008).

Metabetaeus lohena (Figure 6), seen in this survey, also is reported in a 1991 record from this area (HNHP). *M. lohena* is listed by US Fish & Wildlife Service as a candidate species, however, in the 2007 review of status it was assigned a rating of 5 (1 most urgent, 12 least) as they appear to be relatively safe from destruction of habitat and introduction of fish to their ponds. Alien fish appear to be the biggest threat: “negative effects from the introduction of fish are extensive and happen quickly.” (USFWS 2007) The pond, seen by this survey at high tide, continues to be free of fish and mosquitoes, an important factor in the survival of these native invertebrate species.

INSECTA
HETEROPTERA (True bugs)
Lygaeidae: *Nysius* sp.
This native seed bug, commonly found in dryland locations, uses many alien and native host plants. It was found by sweeping of the ‘ilima (*Sida* sp.) plants.

HYMENOPTERA (Bees, wasps, and ants)
Colletidae: *Hylaeus* sp. yellow-faced bee


© Figure 7. *Hylaeus* male with yellow face spot

The yellow faced bee was found while searching ‘ilima (*Sida* sp.) plants. This native bee is widespread in island coastal zones. Yellow-faced bees comprise over 60 species of native pollinators important to the native flora. Several species are present at ‘O’oma. It is often seen pollinating ‘ilima flowers. The females of this native, ground nesting bee are larger than males and lack the yellow heartshaped face spot of males (Figure 7). Males and females live in individual tunnels in soft ground. The yellow-faced bee species were recently monographed by Daly & Magnacca (2003).

The yellow-faced bee population at ‘O’oma is very healthy. In my 30 + years field experience in Hawai’i this is easily the largest population I have seen. The large numbers of blooming ‘ilima (*Sida* sp.) and tree heliotrope (*Tournefortia argentea*) probably support the population. These bees are important native pollinators and may become more important in pollinating crops due to a reduction in honey bee populations. The parasitic Varroa mite, recently introduced to O’ahu from North America is now spreading through honey bee hives across the island chain. As the Varroa mite kills honey bee larvae, colonies die. In the future, the unaffected yellow-faced bee may fill some pollinating needs.

Yellow-faced bees do not sting and are not a danger to humans.

Figure 8. Yellow-faced bee collects pollen from ‘ilima at ‘O’oma

Formicidae**:** *Monomorium pharaonis* (Linnaeus, 1758) Pharaoh ant

This worldwide invasive species was present in great numbers. It is widespread in Hawaii and has been known in the Hawaiian Islands since 1910 - 1912 (Ehrhorn 1912, Gulick 1913). Today it commonly invades homes, being attracted to both sweet and protein food sources. This ant is a bad neighbor, as it both stings and bites. For a general discussion of control measures see Tenorio & Nishida 1995 and for more specifics see Harris, et al.

LEPIDOPTERA (butterflies and moths)

Cosmopterigidae: *Hyposmocoma* sp.

© Figure 9. *Hyposmocoma* sp.
Photo# starr-030724-0089
credit: "Forest & Kim Starr" (HEAR)

Adult *Hyposmocoma* or case bearer moths responded to the light survey. *Hyposmocoma* are called “case bearers” because after an early beginning inside a leaf curl or similar hiding place, the caterpillars create protection in an intricately constructed portable shell of their own silk. For camouflage, they add bits of their surroundings to the case using silk: snips of dry grass or leaves, flakes of bark, maybe a little dirt. The case is then easily mistaken by a predator as another part of the inedible landscape. These bunkers are fitted with a hinged lid (operculum), pulled shut by mandibles to defend them from enemies. Their relationship to the case is similar to that of a hermit crab to his shell. They are dependent on their case, and die if removed – even if protected from predators and given food. They don’t move far, but feed while partly emerged from the case, dragging along their protective armor by their six true legs. Cases are sometimes attached to rocks or tree trunks and foliage. (Manning/Montgomery in Liittschwager & Middleton 2001) With over 500 kinds, *Hyposmocoma* micromoths are the greatest assemblage of Hawaiian Island moths, showing astonishing diversity. After writing 630 pages on them, Dr. Elwood Zimmerman lamented the inadequacy of his study. He noted an enormous cluster of species with explosive speciation and diverging radiation (Zimmerman 1978). Much remains to be learned about the life ways of this interesting group of insects now under study by University of Hawaii’s Daniel Rubinoff and his graduate students (Rubinoff & Haines 2006).

Noctuidae: *Ascalapha odorata* Black witch moth

© Figure 10. Black witch moth resting on tree trunk

The black witch moth has been widely distributed in the island chain since the first sightings were noted at Honaunau in 1928 (Bryan 1929). This large moth is occasionally mistaken for a bat. It is most frequently seen at dawn or dusk. In cities it is seen resting under the eaves of roofs during the day. In rural areas it rests under foliage and against tree trunks.

© Figure 11. Sweetpotato hornworm showing pink markings

Sphingidae: *Agrius cingulata* Sweet potato hornworm

This large and easily seen moth is most easily confused by the public with the Blackburn's sphinx moth (*Manduca blackburni*) described below. The adult *A. cingulata* having PINK markings along both sides where *Manduca* has orange (Figure 15). When the moth is at rest with wings folded, these color markings are hidden. The caterpillars feed on all sweet potato, morning glory, and related plants. It is widely distributed around the Hawaiian Islands. (HBS 2002a, Nishida 2002)

ODONATA (Dragonflies and Damselflies)

Aeshnidae: *Anax junius* (Drury), 1770 Green Darner

This non-native species is widely distributed, being known in North and South America, Europe and parts of Asia. It is sometimes confused with native species. It was observed laying eggs in the anchialine pond.

Libellulidae: *Pantala flavescens* Globe skimmer

© Figure 12. Globe skimmers often use human created water sources

This indigenous dragonfly was observed on the property. Among the most easily observed native insects, they are large, easily approached by people, and graceful in flight. Any small amount of fresh water will attract them and they often colonized human maintained water sources such as golf-course water hazards and ponds. Globe skimmers are widely distributed throughout the Hawaiian Islands, from Kure to Hawai'i Island (HBS 2002a, Nishida 2002) and has even been found flying at sea (Howarth & Mull 1992).

ORTHOPTERA (Praying Mantis, Grasshoppers, Crickets)

Gryllidae

Caconemobius anahulu Otte, 1994 Lava cricket

The species was first discovered by Dr. D. Otte on barren lava 1 km from 'Anaeho'omalu Bay, Hawai'i Island. In his major revision of Hawaiian crickets Otte writes this species "may be widespread along the western slopes of Hawaii Island." (Otte 1994) Nevertheless, it is much less common than *Gryllodes sigillatus* (below) in these extremely barren lavas at 'O'oma.

Gryllodes sigillatus (Walker), 1869 Flightless field cricket

This world-wide traveler was first recorded in the Hawaiian Islands in 1895 (Zimmerman 1948). Over the years since, it has spread up and down the island chain.

Although superficially similar in appearance, *Gryllodes sigillatus* males can 'sing' by rubbing vestigial wings together, while *C. anahulu* is mute.

INVERTEBRATES NOT PRESENT

Alien predatory ants are a major cause of low numbers of native arthropods. The pharaoh ant (*Monomorium pharaonis*), and carpenter ant (*Camponotus variegatus*), which prey on other insects (Zimmerman 1948-80), are present on the property. Ants are well documented as a primary cause of low levels of native arthropods at elevations up to 2000 ft. (Perkins 1913). On all nights, during light censusing, ants quickly appeared and began attacking the resting moths and smaller insects at my light. Ant populations often do not overlap. Rather they have separate territories, effectively apportioning the hunting grounds between themselves, offering few ant-free zones to native arthropods.

Lava Tube Species

Figure 13. Lava tube without a dark zone

The lava tube survey did not yield native invertebrates despite the use of baits known to be attractive. Only one tube generated a response to my traps - an alien cockroach. Many of the lava tubes have many skylights and lack covering vegetation. Many ‘O’oma tubes have either a short dark zone, or none at all.

Figure 14. Lava tubes lack ecosystem supportive intrusive roots

Most tubes have no root systems reaching into the lava tubes, and insufficient moisture. Some tubes have a few grass roots, but the major food source (long roots) that is the basis of most lava tube arthropod communities is absent.

MOLLUSCA

Gastropoda (Snails) Pulmonata

No native snails were observed on the project property.

ARTHROPODA

Diptera: Drosophilidae*: Drosophila*

No native *Drosophila* were observed on the property. The location does not provide appropriate habitat for any of the 12 native *Drosophila* species recently listed as endangered or threatened. (USFWS 2006a, b).

Lepidoptera Sphingidae: *Manduca blackburni*

Blackburn's sphinx moth (*Manduca blackburni*), an endangered species (Fed Reg 1999-2000) which favors leeward slopes was not found in this survey. Neither the moth's solanaceous native host plant, 'aiea (*Nothocestrum* sp.), nor the best alien host, tree tobacco (*Nicotiana glauca*), was observed on the property in my own survey or prior botanical surveys (Terry & Hart 2006). No other solanaceous plants were found by the botanical survey. *Capparis sandwichiana*, (maiapilo or pilo[4]) reported to be a nectar plant for adult *Manduca* (USFWS 2005b), is known on the property. *Ipomea pes-caprae* subsp. *brasiliensis* (pōhuehue or beach morning glory) also grows on the site. Searches were made each day I was present on the property for adult *Manduca* feeding on the blooming flowers of either plant. *Manduca* was not observed.

© Figure 15. Blackburn's sphinx moth is distinguished from other hawk moths by orange markings.

Although the original *Recovery Plan* (USFWS 2005b) for this large sphinx moth proposed two small management areas in North Kona, Hawai'i, the *Final Rule* (USFWS 2003) designated habitat only at the inland location, Pu'uwa'awa'a. Nevertheless, preservation of the coastal habitat will ensure preservation of habitat suitable for adult *Manduca* feeding.

[4] The name *pilo* also is associated with the genus *Hedyotis*. *Hedyotis* is not associated with *Manudca* however.

Medically important species

The ‘O’oma Beachside Village project area includes classic habitat for centipedes, scorpions, and widow spiders. These medically important species may be present in the area. Common paper wasps (*Polistes exclamans*) (Figure 16) were seen repeatedly on the property. Employees should be alert for these species when working in the area. These species may pose a serious risk to some individuals, and supervisors should be aware of any special allergy by employees. Some individuals can experience anaphylactic reactions to venom.

© Figure 16. Paper wasp

Also note that the ant species reported present (see page 18) are known to bite people. When moving stones or piled brush, use of gloves and long sleeves will greatly reduce the risk of accidental contact and bites with all species noted here. Please see *What Bit Me?* (Nishida & Tenorio 1993) and *What’s Bugging Me?* (Tenorio & Nishida 1995).

POTENTIAL IMPACTS

Potential Impacts on Native, Rare, Federally or State Listed Species

No federally or state listed endangered or threatened species were noted in this survey (USFWS 2008). No anticipated actions related to the proposed project activity in the surveyed locations are expected to threaten an entire species.

RECOMMENDATIONS

Prevent habitat degradation

Fulfillment of the planned preservation of the shoreside environment should shield the pond sheltering *Metabetaeus lohena* and the most important habitat for the thriving colony of yellow-faced bees (*Hylaeus* sp.). Managers should consider removal of the Christmas berry (*Schinus terebinthifolius*) and Mesquite (*Prosopis pallida*) trees overhanging the anchialine pond. The trees block sunlight needed for algal production, which is the basis of the pond’s native food chain. The trees accelerate the filling of the pond with leaf litter.

A **Best Practices Management Plan** for construction should be written and implemented specifying methods and controls for the entire construction zone to prevent or minimize runoff and impact on the coastal habitats.

Establish construction staging areas and storage of materials well away from the proposed coastal preserve area.

Prevent establishment of new competitive or predatory alien species

Two factors influence establishment of alien species: access and regular food sources.

Inspect construction materials for hitchhiking seeds or animals.

Clean tools, boots, and equipment used at other sites to minimize the chance of transporting new pest plants or animals to the area. Soil packed in tires, on helicopter runners, or workers’ boots can transport seeds, and insect or snail eggs. Ants, snails and slugs, and many other invertebrates can hide in boxes or equipment resting at one location and later be carried to ‘O’oma.

When establishing plantings after construction, care should be taken to prevent alien plant or animal species from being introduced on the plantings or associated soil.

Remove trash regularly. Predatory species such as ants easily establish in areas where food trash is consistently available. Food trash during construction can increase mongoose (*Herpestes auropunctatus*) populations as well. Construction workers are socialized to simply drop food remains and food wrappers, bottles and containers. Change expectations: Provide trash cans, establish a culture of using them, and empty the cans frequently.

Enhance habitat for native species:

Fulfillment of the plan to preserve coastal, archaeological and some natural features, should preserve habitats for many native invertebrate species. Selective removal of alien plants in these areas can assist native plants in filling the available niches.

Landscape with native dryland plants for lower cost maintenance:

Given the Kona climate of the project area, it would be most appropriate to use dryland native plants in landscaping developed areas at ‘O’oma and in stabilizing areas around archaeological features. Landscaping with native leeward plants will serve to provide habitat for native arthropods, while creating an interesting recreation area for walking, cultural learning, and bird watching. ‘O’oma native plants already support a large colony of yellow-faced bees. Importantly, using dryland plants to landscape can lower long-term watering costs and water draws, following an initial establishment period. Native plants will remain green and thus more fire resistant throughout the summer. Most native plantings will have lower human maintenance costs as well (less hedge trimming, weed whacking, no fertilizer). Planted in a mix of ground cover, shrub, and tree heights native plants also help slow run off and retain moisture when rains do come. Native insects will find this refuge over time. The plantings will provide educational, visual, and aesthetic benefits to residents while conserving water at very low on-going cost.

Homeowners should be given guidance on xeriscaping with restrictions being considered as part of covenants or homeowner association rules. Plants that are adapted to dryland areas also will not require doses of fertilizer and pesticides and so reduce non-point pollution. Several southwestern U. S. continental cities have long enforced water / yard planting restrictions due to water concerns. Their experiences may prove helpful in planning.

Resources helpful in understanding Hawaiian plants in an urban setting include *Native Hawaiian Plants For Landscaping, Conservation, and Reforestation* (Bornhorst & Rauch 1994) and *Growing Native Hawaiian Plants* (Bornhorst 2005). By prior arrangement with growers, native Hawaiian plants can be as convenient to mass plant as the introduced plants commonly used to re-vegetate after new construction. Some suppliers of native plants are listed at

http://hbs.bishopmuseum.org/botany/riparian/pdf/propagators.pdf

Some plants have demonstrated their adaptation to the area by growing at the ‘O’oma site naturally [marked with asterisk (*) in the list below]. Dryland adapted plants suitable for landscaping, many with beautiful foliage or flowers, are listed below.

Ground cover:

‘ilima	*Sida* sp. (prone) (*)
maiapilo	*Capparis sandwichiana* (*)
nehe	*Melanthera integrifolia, Melanthera subcordata*
‘ohai	*Sesbania tomentosa*
pā’ūohi’iaka	*Jacquemontia ovalifolia* (*)
pili grass	*Heteropogon contortus* (*)

Shrub:

a’ali’i	*Dodonaea* sp.
‘ākia	*Wikstroemia* sp.
‘ilie’e	*Plumbago zeylanica*
‘ilima	*Sida* sp. (upright) (*)
naio	*Myoporum sandwicense* (*)
pōhinahina	*Vitex rotundifolia*

Tree:

kou	*Cordia subcordata*
milo	*Thespesia pupulnea*
‘ohe makai	*Reynoldsia sanwicensis*
wiliwili	*Erythrina sandwicensis*

A’ali’i / *Dodonaea* sp.

© Figure 17. A’ali’i *Dodonaea* sp. foliage and blossoms

A’ali’i grows at shrub height without hedge triming. It produces flowers and foliage useful in lei making and is host to several invertebrates. It stays green year round without watering.

‘Ilima / *Sida* sp.

Figure 18. ‘Ilima *Sida* sp.

‘Ilima is host to a large number of native invertebrates, maintains color and foliage during the dry months and needs little maintenance. It grows in a prone, ground cover form and an upright, shrub form. The plant will grow at seaside or inland locations. ‘O’oma already hosts a healthy population of these plants supporting a vigorous community of native bees.

Maiapilo / *Capparis sandwichiana*)

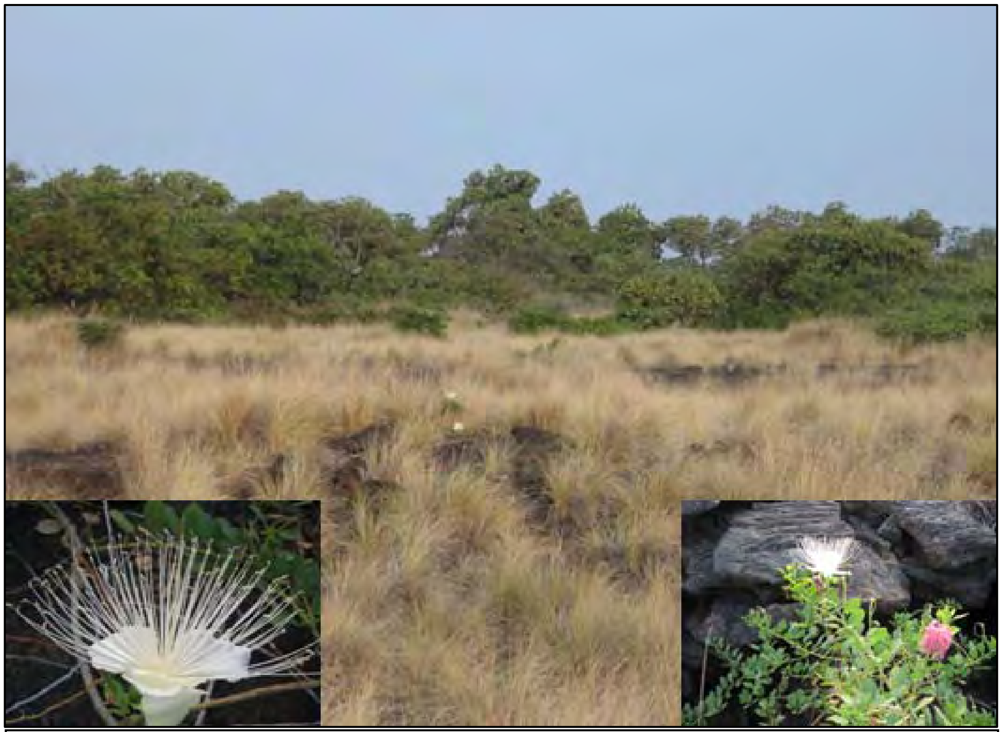

Figure 19. Maiapilo (*Capparis sandwichiana*) [center] blooming at 'O'oma amidst native pili and alien fountain grasses.

Maiapilo is well adapted to the 'O'oma site and host to several native arthropods. The plant bears numerous white flowers, which wilt to a beautiful pink as the day progresses. Already growing on site, maiapilo, planted as a ground cover, provides nectar, pollen, and keeps down weeds. Morning walkers and joggers would find them a special attraction.

'Ohai / *Sesbania tomentosa*

Once known from all major islands, 'Ohai now is rare outside planted areas. It has beautiful, moisture retaining, silvery leaves and dark orange, curved blossoms. It is a short shrub and stays 'green' all summer.

© Figure 20. 'Ohai *Sesbania tomentosa*

Pōhinahina / beach vitex / *Vitex rotundifolia*

Now considered a beach plant, this hardy, flowering creeper likes to cascade over rocky areas or down small slopes but will form hedges. It will easily grow in upland locations. It tolerates abuse associated with human co-habitation, and even responds to pruning. It would form a natural hedge along pathways, thus keeping people on pathways with grace, beauty, and low upkeep. Spicy smelling leaves, small blue flowers, and brown seed capsules create visual interest. No watering required after establishment. Foliage, flowers, and seed capsules are all good lei making materials.

© Figure 21. Pōhinahina seed capsules, foliage, and flower

wiliwili / *Erythrina sandwicensis*

© Figure 22. Wiliwili is dryland adapted and needs no watering

© Figure 23. Wiliwili receives solar energy through green bark when leaves are dropped.

Wiliwili has a proven track record as a dryland decorative, low maintenance planting, co-habiting with homes and parks. Seasonal flushes of flowers provide remarkable beauty. The seeds make beautiful lei.

Although currently wiliwili is under attack from a recently introduced alien gall wasp, a control agent of that pest is expected soon. Wiliwili is summer deciduous - dropping its leaves in summer and relying on minimal photosynthesis through green bark. Native wiliwili have suffered less from the wasp’s attacks than the alien *Erythrina* trees, in part because their green bark provides some nutrition during periods when leaves are reduced by the wasp’s effect.

Community Education:
The best defense the fragile coastal ecosystems can have is an informed public. Providing signage and partnering with community environmental groups to provide information and guidance about enjoying the preserved coastal, archaeological, and natural features, would make preservation more effective. Providing defined pathways would reduce trampling of plants and disturbance of wildlife.

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Steven Lee Montgomery conducted all collecting and is responsible for all conclusions. Anita Manning contributed to preparation of this report. Some images used in this report were not taken in the course of this project. These photos, marked by © symbol are not released for other uses. They were made by Anita Manning and/or S. L. Montgomery prior to this contract and were chosen because they best illustrate the subject.

STANDARD NOMENCLATURE

Bird names follow *Hawaii's Birds* (Hawaii Audubon Society 2005).
Invertebrate names follow
Freshwater & Terrestrial Mollusk Checklist (HBS 2002b)
Common Names of Insects & Related Organisms (HES 1990)
Hawaiian Terrestrial Arthropod Checklist (HBS2002a; Nishida 2002)
Mammal names follow *Mammals in Hawaii* (Tomich 1986).
Place name spelling follows *Place Names of Hawaii* (Pukui et al. 1976).
Plant names follow
Manual of the Flowering Plants of Hawaii (Wagner et al. 1999)
A Tropical Garden Flora (Staples and Herbst 2005)

ABBREVIATIONS

DLNR Department of Land and Natural Resources, State of Hawai'i
DOFAW Division of Forestry and Wildlife, State of Hawai'i
HBS Hawai'i Biological Survey
MV Mercury Vapor
n. new
sp. species
spp. more than one species
UH University of Hawai'i
USFWS United States Fish and Wildlife Service
UV Ultraviolet

GLOSSARY[5]

Adventive: organisms introduced to an area but not purposefully.

Alien: occurring in the locality it occupies ONLY with human assistance, accidental or purposeful; not native. Both Polynesian introductions (e.g., coconut) and post-1778 introductions (e.g., guava, goats, and sheep) are aliens.

Arthropod: insects and related invertebrates (e.g., spiders) having an external skeleton and jointed legs.

Aspiration: invertebrates are transferred from the original location (leaf, net, etc.) into a large vial. Two tubes are lodged in one stopper in the vial. Air drawn in on one tube, creates suction at the end of the second tube; the target insect is drawn into the vial by the pulling air.

5 Glossary based largely on definitions in *Biological Science: An Ecological Approach*, 7th ed., Kendall/Hunt Publishing Co., Dubuque, a high school text; on the glossary in *Manual of Flowering Plants of Hawai'i*, Vol.2, Wagner, et al., 1999, Bishop Museum Press, and other sources.

Glossary: cont.

Endemic: naturally occurring, without human transport, ONLY in the locality occupied. Hawaii has a high percentage of endemic plants and animals, some in very small microenvironments.

Gibbous: describes the Moon or a planet before and after it is full, when it has more than half its disk illuminated; swollen on one side.

Indigenous: naturally occurring without human assistance in the locality it occupies; may also occur elsewhere, including outside the Hawaiian Islands. (e.g., Naupaka kahakai (*Scaevola sericea*) is the same plant in Hawai'i and throughout the Pacific).

Insects: arthropods with six legs, and bodies in 3 sections

Invertebrates: animals without backbones (insects, spiders, snails / slugs, shrimp)

Larva / larval / larvae (plural): an immature stage of development in offspring of many types of animals.

Mollusk: invertebrates in the phylum Mollusca. Common representatives are snails, slugs, mussels, clams, oysters, squids, and octopuses.

Native: organism that originated in area where it lives without human assistance. May be indigenous or endemic.

Naturalized: an alien organism that, with time, yet without further human assisted releases or plantings, has become established in an area to which it is not native.

Nocturnal: active or most apparent at night.

Pupa: the stage between larva and adult in insects with complete metamorphosis, a non-feeding and inactive stage often inside a case

Purposefully introduced: an organism brought into an area for a specific purpose, for example, as a biological control agent.

Rare: threatened by extinction and low numbers.

Species: all individuals and populations of a particular type of organism, maintained by biological mechanisms that result in their breeding mostly with their kind.

Waning: describes a gradual decrease in the amount of the moon's disk that is visible; shrinking

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