
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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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.

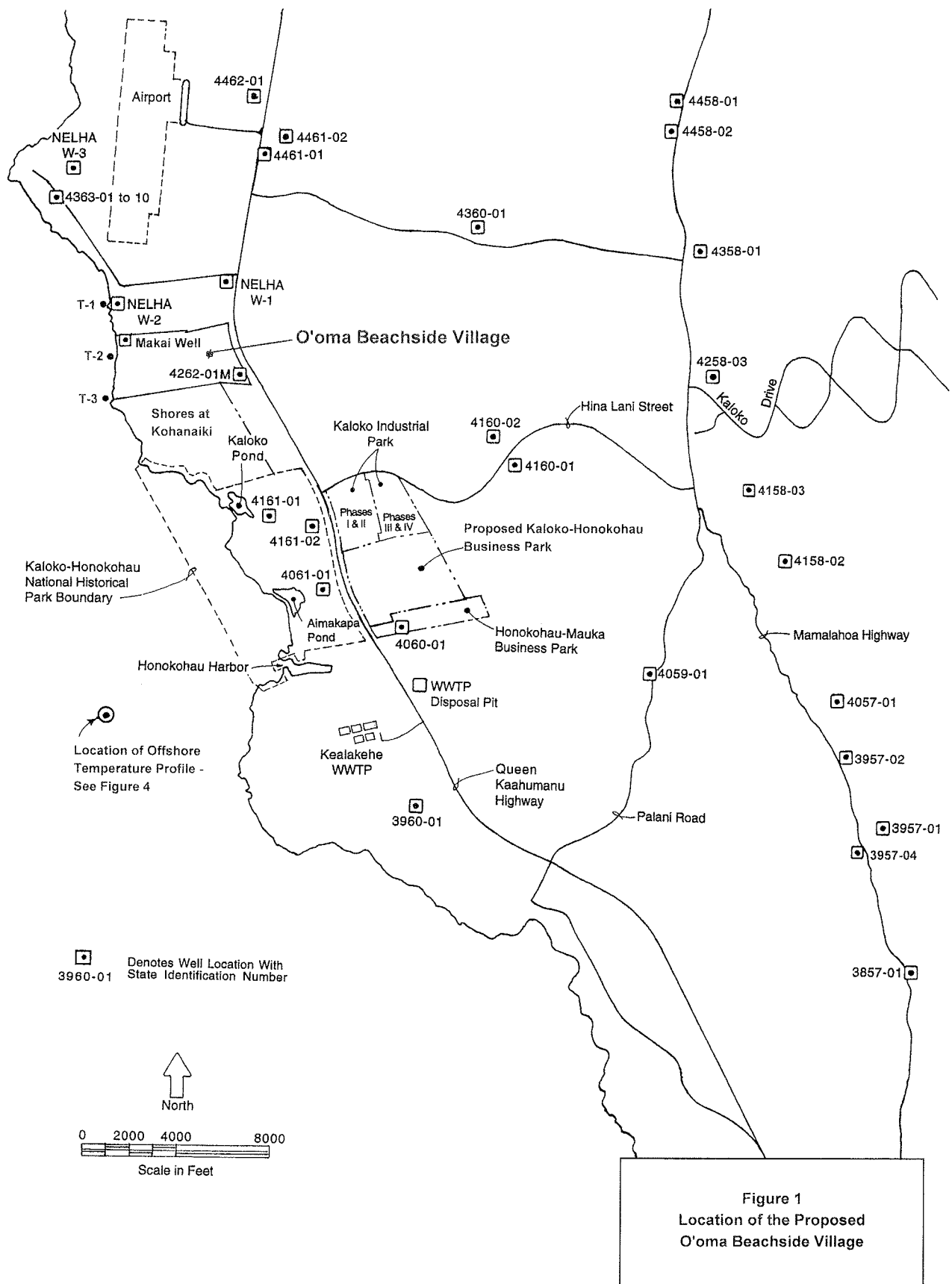
**Projected Average Water Use and Wastewater Generation
by the O'oma Beachside Village***

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.

Potable and Irrigation Water Supply. 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 the NELHA deep (cold) or shallow (warm) systems and onsite deepwells which would tap saline groundwater at depth beneath the brackish lens.

For the purposes of the analyses of the impact on water resources herein, it has been assumed that the second alternative, onsite reverse osmosis (RO) desalting, would be the source of potable and irrigation supply. For water from NELHA or onsite wells, the product recovery rate would be on the order of 40 to 45 percent of the feedwater supply. The remaining 55 to 60 percent would be a brine "concentrate" that would be disposed of in onsite deep wells.



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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.

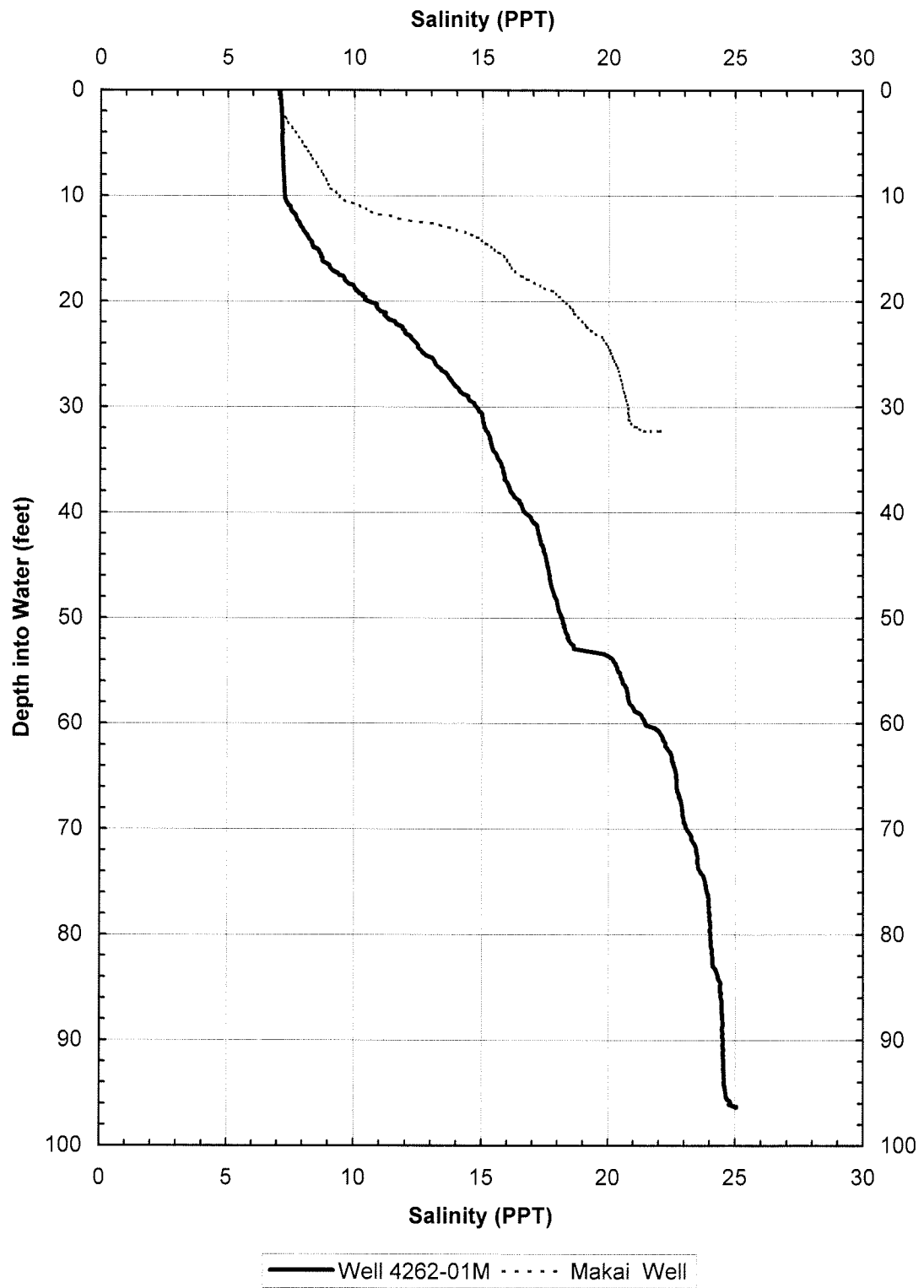
- The basal lens between the Old Kona Airport and Keahole Point is relatively saline, preventing it from being a significant source of irrigation supply unless it is extracted in small quantities from inland areas or it undergoes desalinization. There are two, small diameter monitor wells on the project 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

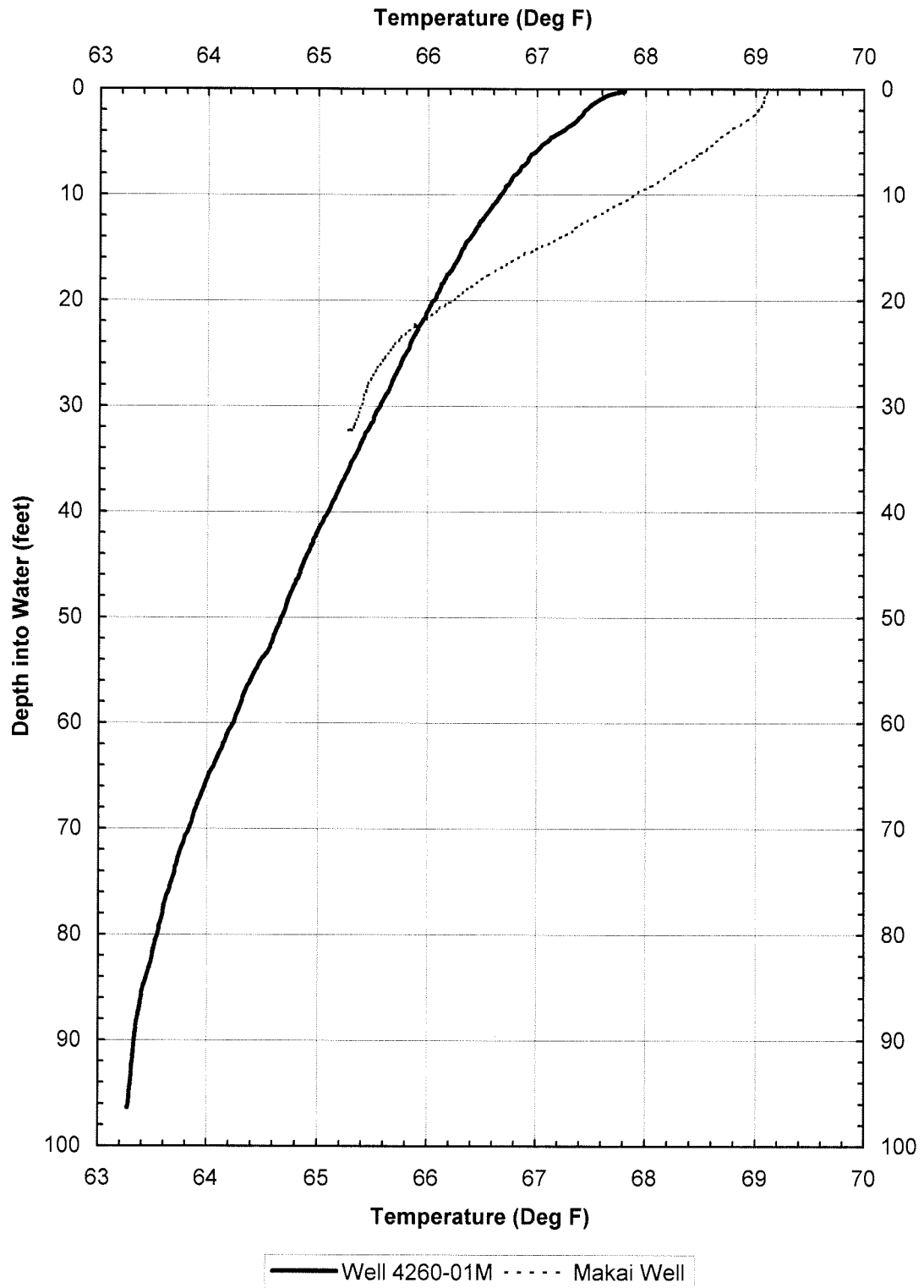


Figure 4
Comparative Ocean and Groundwater Temperature Profiles

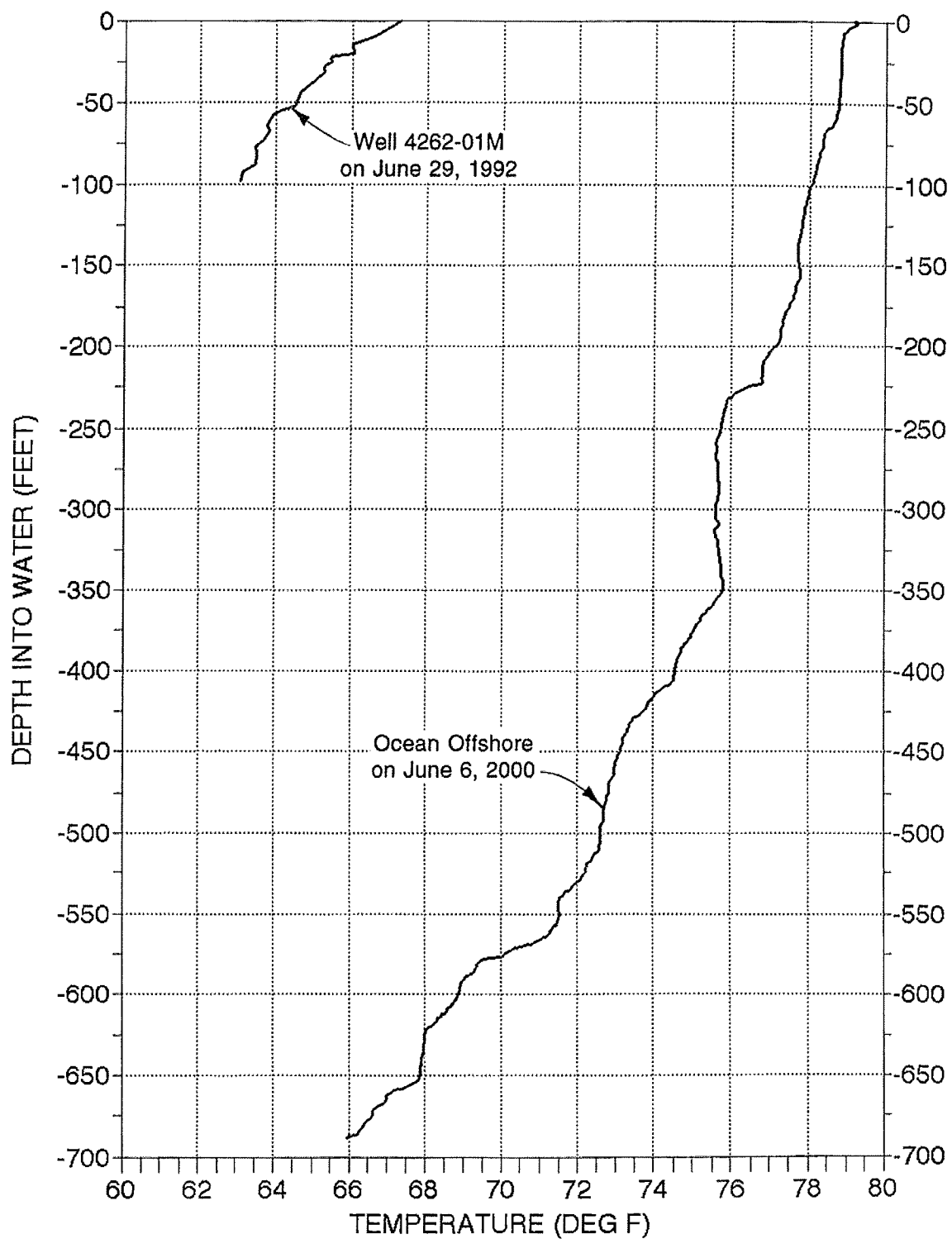


Figure 5. Tidal Variation in Groundwater Beneath the O'oma Beachside Village Site

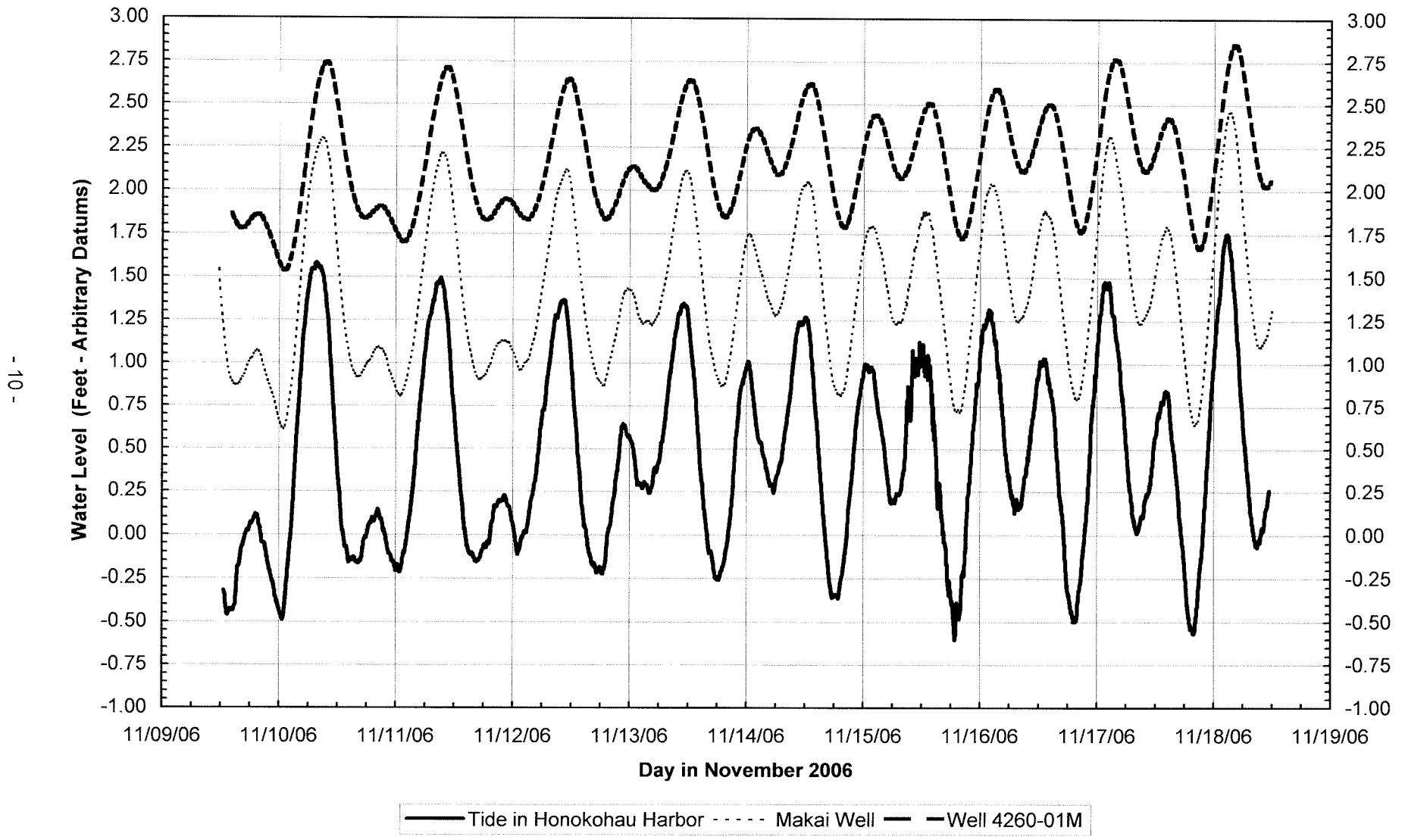


Table 2

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	
4158-02	7-20-01	0.079	776	85.1	0.0	35.1	120.2	3.83	3.16	6.99	
	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	
4258-03	11-03-06	0.149	804	76.4	6.9	6.1	88.4	2.64	0.80	3.44	
	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
4161-02 : 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
	4160-02 : 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	
4363-04	6-02-00	25.698	356	30.5	1.6	22.5	54.6	1.40	0.70	2.10	
	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

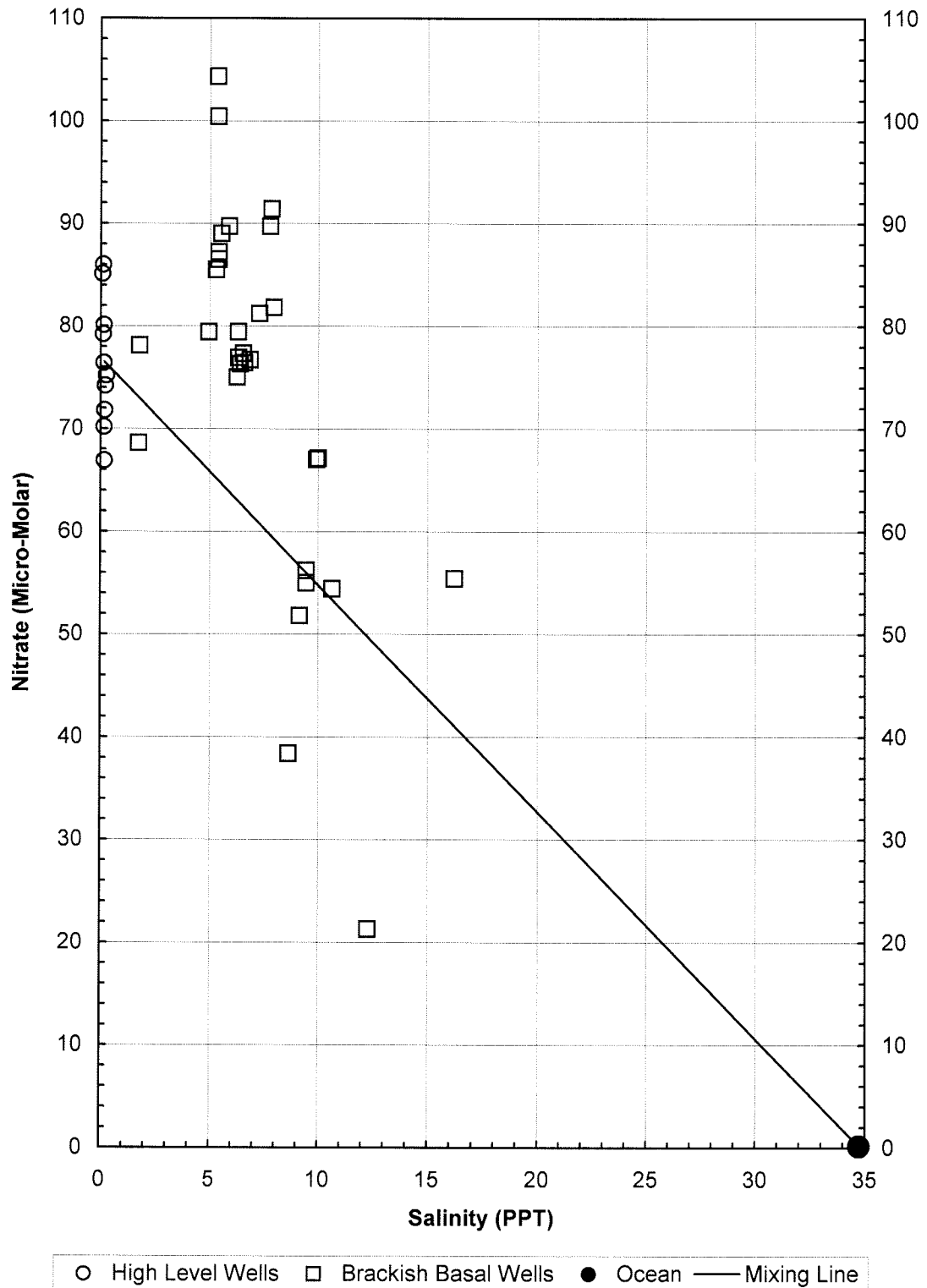


Table 3

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 saltwater from NELHA or onsite (deep) 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 onsite 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 across the project site 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 onsite 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 in 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 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**

I t e m	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

- Exhibit 1. Conceptual Plan
- Exhibit 2. Project Areas
- Exhibit 3. Summary of Ground Surface
- Exhibit 4. Potable and Non-Potable Water Consumption Estimate
- Exhibit 5. Water Demand Summary
- Exhibit 6. Wastewater Calculations
- Exhibit 7. Storm Drainage Calculations
- Exhibit 8. Drainage System Overview





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

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	2	35 - 60	1	-	-	400 GPD/DU	24,000	36,000
Oona 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	-	-	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	80,000	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	-	15,000	3,000 GPD/AC	27,000	40,500
Grocery Store	1	-	1	0	-	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. 5,000sf x .20 = 1,000 / 43,560 = 0.023 acre x 6,000 gpd = 159 gpd + 400 gpd = 559 say 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	-	-	-	-	-
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.

'O'OMA BEACHSIDE VILLAGE

Water Demand Summary

SUMMARY:	AVERAGE DAILY DEMAND			MAXIMUM DAILY DEMAND		
	POTABLE	NON-POTABLE	TOTAL	POTABLE	NON-POTABLE	TOTAL
	(gpd)	(gpd)	(gpd)	(gpd)	(gpd)	(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

'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

'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

$$I = 3.75 \text{ in/hr (from Plate 4)}$$

$$Q = 6 \text{ cfs (based on average capacity of 6' deep drywell)}$$

$$A = 2.67 \text{ acres / drywell}$$

'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	Length	Slope	Tc	I	C	Planimeter	Meas. Area	Q=CIA
ID	(ft)	(%)	(min)	(in/hr)		(si)	(acres)	(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



M&E Pacific, Inc.

METCALF & EDDY | AECOM

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Drainage System Overview

Infrastructure Report

O'one North Kona Villages

February 2008

DRAINAGE SYSTEM OVERVIEW
SCALE: NOT TO SCALE