

**STUDY OF UNACCOUNTED WATER LOSSES  
OF THE  
MOLOKAI PUBLIC UTILITIES, INC.  
KALUAKOI RESORT WATER SYSTEM**

**by**

**Tom Nance  
Belt Collins & Associates**

**for**

**Carlsmith, Wichman, Case Mukai & Ichiki  
Honolulu, Hawaii**

**September 1988**

**E**

## Contents

	<u>Page</u>
Introduction . . . . .	1
Overview of MPUI's Kaluakoi Resort Water System . . . . .	1
Organization of the System into Three Sections . . . . .	3
Available Records and Section-by-Section Accounting Of Uses and Losses . . . . .	8
Section of the System From the Source Well in Kualapuu to the Pump Station at Mahana. . . . .	8
Section of the System From the Mahana Pump Station to the Resort Entrance. . . . .	10
Section of the System Within the Resort. . . . .	10
Annual Summaries of Supply, Water Sales, Non-Revenue Uses, and Losses. . . . .	20
Recommendations. . . . .	25

**List of Figures**

<u>No.</u>		<u>Page</u>
1	MPUI Water System - Kaluakoi Resort, West Molokai . . . . .	2
2	Schematic of MPUI's System From Its Source Well In Kualapuu to the Pump Station at Mahana . . . . .	4
3	Schematic of MPUI's System From Mahana Through Puu Nana to the Resort's Entrance. . . . .	5
4	Schematic of MPUI's System Within the Resort. . . . .	7

**List of Tables**

<u>No.</u>		<u>Page</u>
1	Monthly Compilation of Supply by the Kualapuu Well and Withdrawal From the MIS at Mahana . . . . .	9
2	Monthly Compilation of Flows in the Section of the System From Mahana to the Resort Entrance for September to December 1985 . . . . .	11
3	Monthly Compilation of Flows in the Section of the System From Mahana to the Resort Entrance for 1986 . . . . .	12
4	Monthly Compilations of Flows in the Section of the System From Mahana to the Resort Entrance for 1987 . . . . .	13
5	Monthly Compilation of Flows in the Section of the System From Mahana to the Resort Entrance for January to July 1988. . . . .	14
6	Summary of Inflow, Outflow, Sales, and Losses Through the Mahana to Resort Entrance Section of the System, February to July 1988 . . . . .	15
7	Compilation of Flows Within the Resort for September to December 1985. . . . .	16
8	Compilation of Flows Within the Resort for 1986. . . . .	17
9	Compilation of Flows Within the Resort for 1987. . . . .	18
10	Compilation of Flows Within the Resort for January to July 1988 . . . . .	19
11	Summary of Supply, Sales, Non-Revenue Uses, and Losses for September through December 1985. . . . .	21
12	Summary of Supply, Sales, Non-Revenue Uses, and Losses for 1986 . . . . .	22
13	Summary of Supply, Sales, Non-Revenue Uses, and Losses for 1987 . . . . .	23
14	Summary of Supply, Sales, Non-Revenue Uses, and Losses From January Through June 1988. . . . .	24

## INTRODUCTION

Molokai Public Utilities, Inc. (MPUI) owns and operates the private water system which supplies Kaluakoi Resort on West Molokai. In December 1986, MPUI applied to the State Public Utilities Commission (PUC) for an increase in its water rates. In the PUC's Decision and Order No. 9695 of March 1988 granting this request, MPUI was ordered to submit a report on unaccounted water losses in its system.

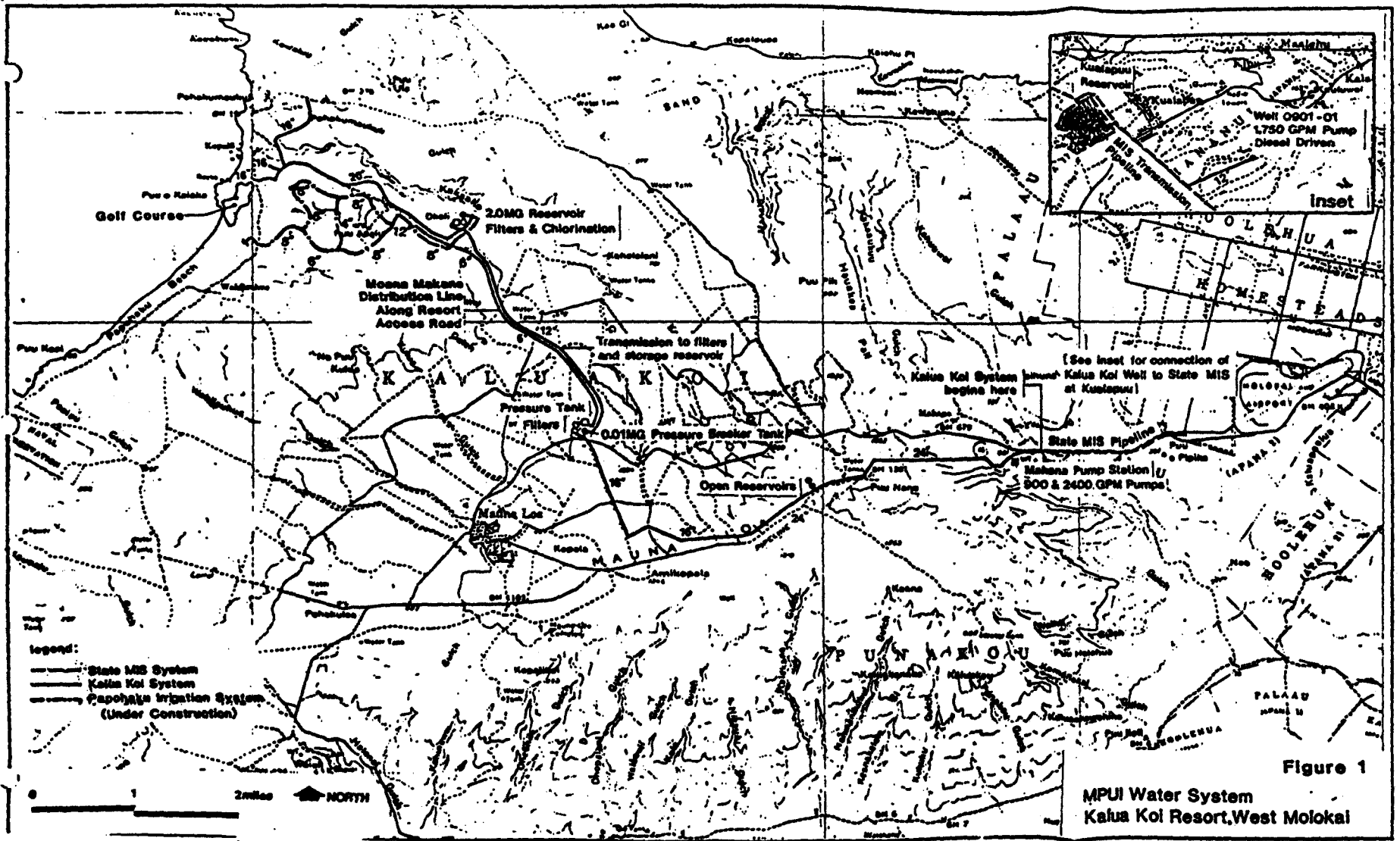
At the request of Carlsmith, Wichman, Case, Mukai & Ichiki, the law firm representing MPUI, Belt Collins & Associates proposed to study the unaccounted water losses in stages. The intent of the first stage was to assemble all available flow data in an interpretable form, to account for non-revenue uses such as filter backwashing, to provide estimates for identifiable losses such as reservoir evaporation, and using these results, to compute the amount of unaccounted losses. If these losses were unacceptably high, then subsequent stages of study would be conducted. This subsequent effort would primarily consist of leak detection in specific sections of the system.

The first stage of the study has been completed and is summarized in this report. The period studied is from September 1985 to July 1988. Although the total of non-revenue uses and losses in the system is relatively high (from 24 to 28 percent over the last two and one-half years), most of this can be accounted for in the surplus well pumpage required for transmission through the State's Molokai Irrigation System (MIS) and filter backwashing. Based on the figures available, unaccounted losses in the system are less than five percent. This loss rate is considered to be acceptably low. In our opinion, the subsequent leak detection stages of the study are not warranted.

It will be clear in reviewing the data in this report that better coordination of meter reading and more timely compilation of these records is needed so that the operators would have a current appraisal of the system's performance. These and other recommendations are presented at the end of the report.

## OVERVIEW OF MPUI'S KALUAKOI RESORT WATER SYSTEM

MPUI's water system extends from its source well in central Molokai to its distribution system within Kaluakoi Resort at the west end of Molokai (see Figure 1). Water is pumped from MPUI's 1070-foot deep well in Kualapuu into a nearby MIS transmission pipeline. The MIS serves as a transmission link across Hoolehua to Mahana. MPUI's pumps at Mahana lift the water up to two open reservoirs at Puu Nana. From there it flows by gravity to a pressure breaker tank at the Resort's entrance road, then on to filters and storage at Puu Okoli, and finally to customers within the Resort. Two important



aspects of the MIS transmission link should be noted. First, the contract with the State requires 10 percent more water to be pumped into the MIS than is drawn out at Mahana. Second, water drawn out at Mahana is a mixture of surface from MIS sources and ground water from MPUI's well. It requires filtration to make it potable.

### ORGANIZATION OF THE SYSTEM INTO THREE SECTIONS

For purposes of clarity in accounting for water uses and losses, the system has been divided into three sections: (1) from the Kualapuu Well to Mahana; (2) from Mahana to the Resort's entrance; and (3) within the Resort itself. The first section, which is depicted schematically on Figure 2, is the simplest. Water pumped from MPUI's Well 0901-01 is measured by an 8-inch Sparling meter just prior to its connection to the MIS 30-inch transmission main. Water withdrawn by MPUI at Mahana is measured by a 16-inch Sparling meter. The only accounting required for this section is a comparison of the readings of these two meters.

The second section of the system is illustrated schematically on Figure 3. It begins at the meter and pump station at Mahana. Water is pumped over the 2.6-mile distance and 770-foot increase in elevation to two open reservoirs at Puu Nana. For the 18-month period from October 1986 through April 1988, a supplementary, surface water supply purchased from Molokai Ranch was added at these reservoirs. This supply has been temporarily suspended due to some quality problems which have been attributed to it. From the Puu Nana Reservoirs, water flows by gravity through former pineapple irrigation mains now owned by MPUI to the Resort's entrance road. Along this route, there are two metered connections to Molokai Ranch. One is to a cattle trough. The other is back-up supply line for the town of Maunaloa. Beginning in February 1987 when Molokai Ranch began installation of a gravity filter system for Maunaloa, MPUI provided water to the town on a continuous basis. This supply is expected to resume its standby status soon.

At the end of this section of the system at the Resort's entrance, a small portion of the flow is diverted to the separate treatment, storage, and distribution system serving the 34-lot Moana Makani Subdivision. The remainder of the supply flows through a 10,000-gallon pressure breaker tank and main line meter. An accounting of supply, water sales, non-revenue uses, and losses for this section of the system can be summarized as follows:

#### Inflow to the Section

- Main source of flow measured by the 16-inch meter at Mahana
- Supplementary Molokai Ranch source measured by two 4-inch meters at Puu Nana

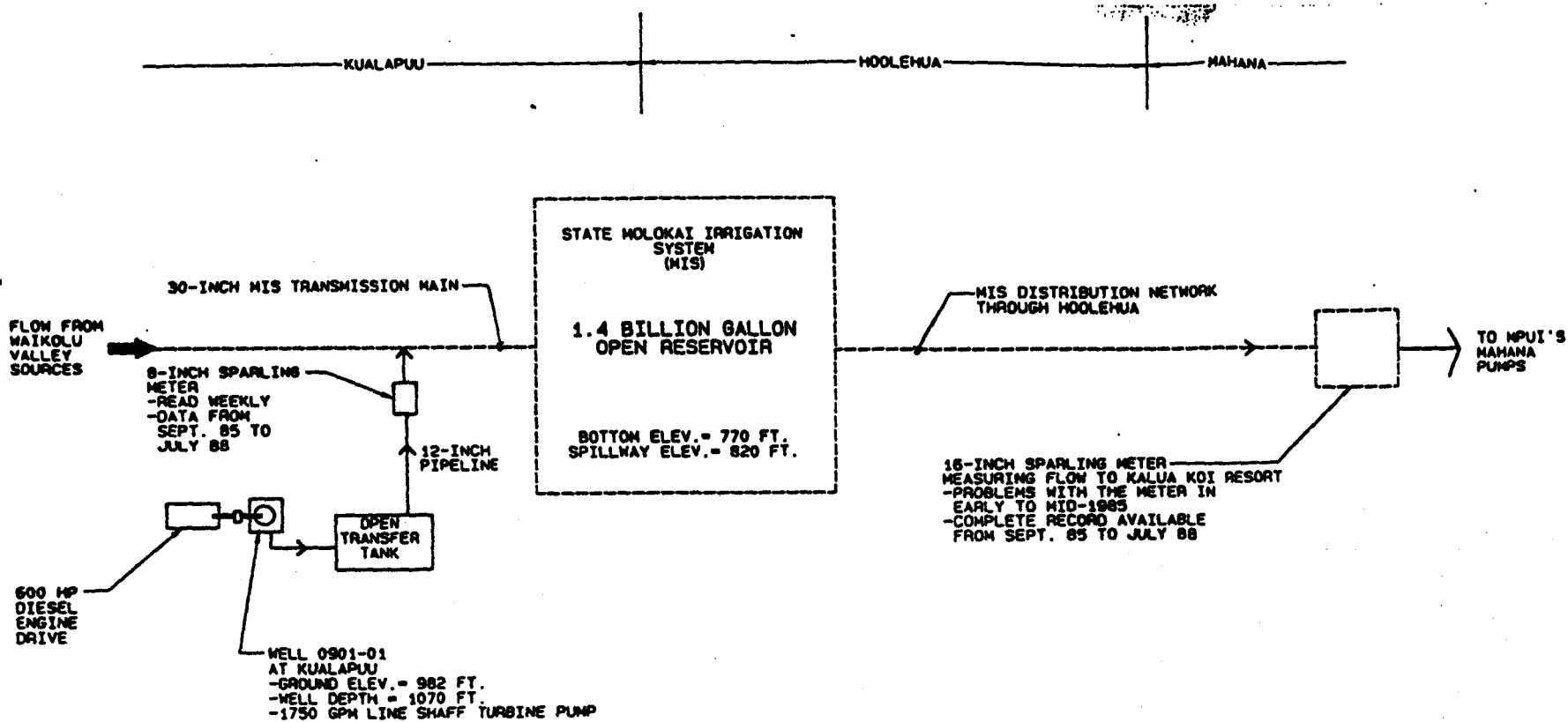


FIGURE 2

SCHEMATIC OF MPUI'S SYSTEM FROM ITS SOURCE WELL IN KUALAPUU TO THE PUMP STATION AT MAHANA

NOTE: THE STATE'S MOLOKAI IRRIGATION SYSTEM IS DELINEATED BY DASHED LINES.

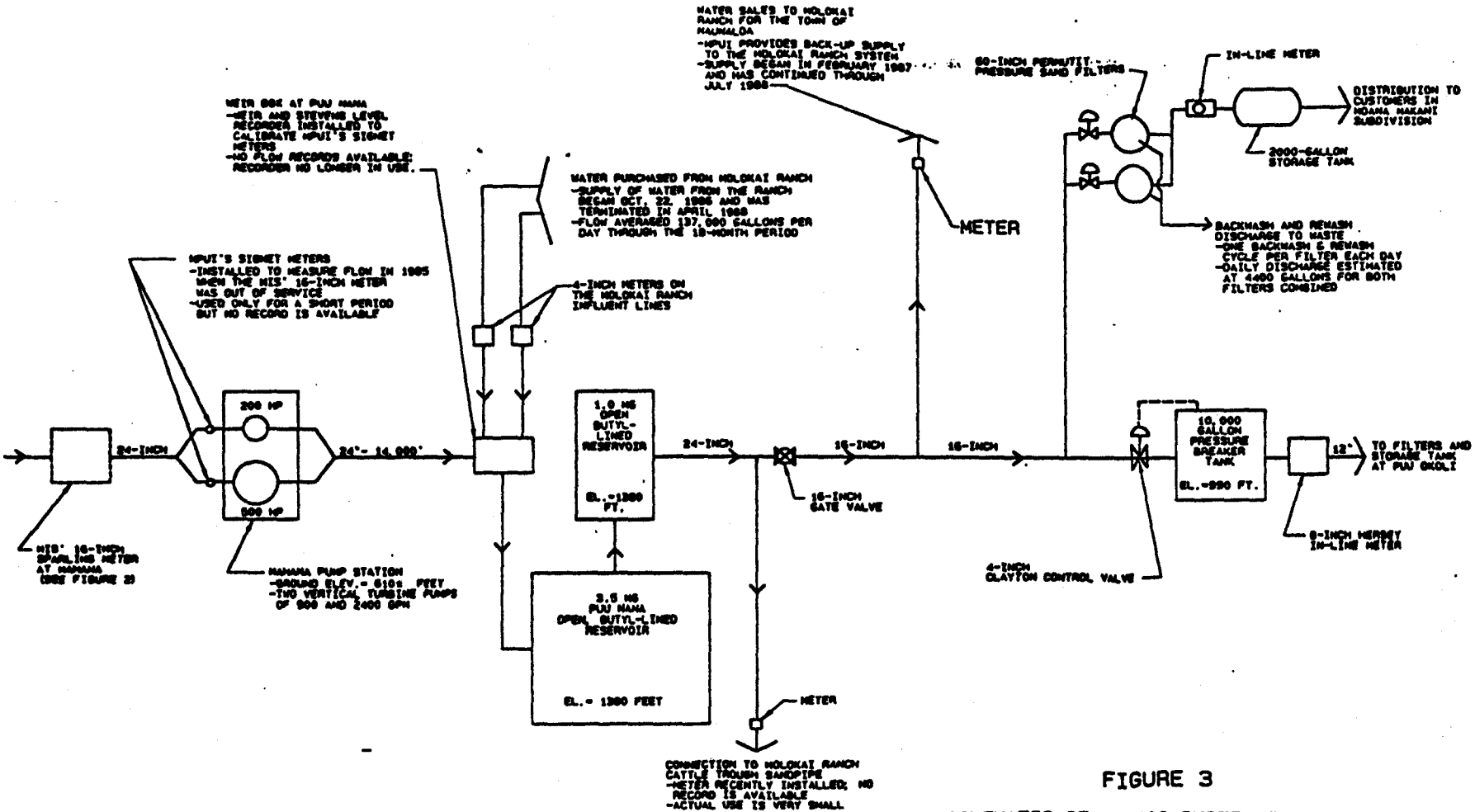


FIGURE 3

SCHMATIC OF MPUI'S SYSTEM FROM MAHANA THROUGH PUU NANA TO THE RESORT'S ENTRANCE



### Metered Water Sales

- Molokai Ranch for the town of Maunaloa
- Molokai Ranch cattle trough
- Customers within Moana Makani Subdivision

### Non-Revenue Uses

- Backwash and rewash at the two Moana Makani pressure filters. Each filter is automatically backwashed (for 10 minutes at an estimated 195 GPM) and rewash (for 4.5 minutes at an estimated 60 GPM) once a day; total discharge to waste by the two filters is approximately 4440 gallons per day.

### Accountable Losses

- Evaporation from the approximately 0.5 acres of open water surface of the Puu Nana Reservoirs; this loss is estimated as the difference between pan evaporation and rainfall and it varies from 800 to 4000 gallons per day.

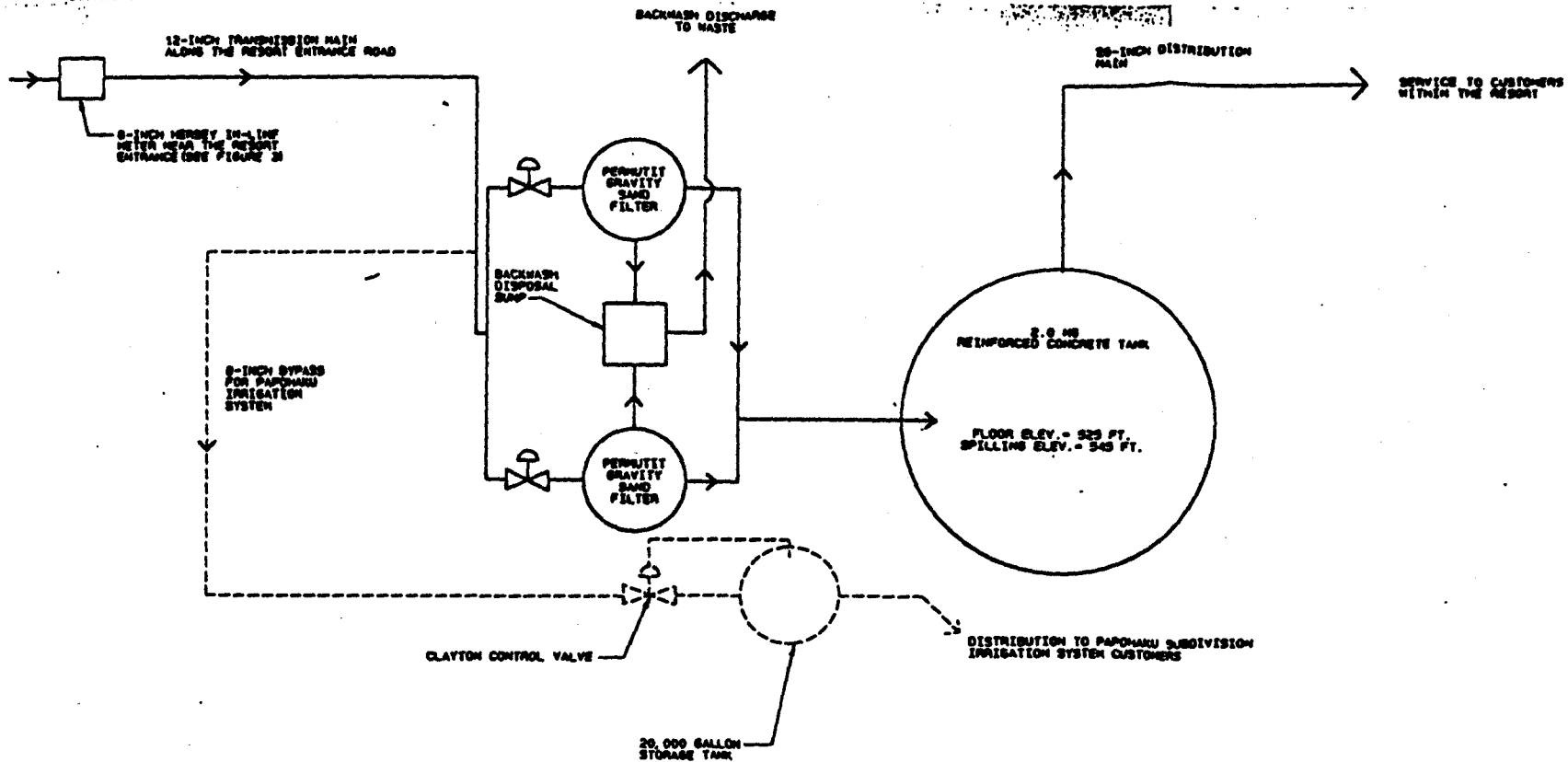
### Unaccounted Losses

- Reservoir seepage
- Possible unauthorized connections along the transmission line from the Puu Nana Reservoirs to the Resort Entrance.
- Line leakage

### Outflow From the Section

- Flow from the 10,000-gallon pressure breaker tank measured by the 8-inch Hersey meter.

The third section of the system is depicted schematically on Figure 4. From the 10,000-gallon pressure breaker tank, a 12-inch transmission pipeline carries water along the entrance road down to the two gravity filters and reinforced concrete storage tank at Puu Okoi. Each of the filters is a 20-foot diameter, automatic valveless gravity sand filter manufactured by Permutit. Filtered water is then stored in the 2.0-million gallon tank for on-demand distribution to customers within the Resort. In addition, a non-potable irrigation system for the Papohaku Subdivision within the Resort is presently under construction. When in service, the system will provide unfiltered water for irrigation within the subdivision. Supply, water sales, non-revenue water uses, and unaccounted losses within this section of the system consist of the following:



**FIGURE 4**  
**SCHEMATIC OF MPUI'S SYSTEM**  
**WITHIN THE RESORT**

### Influent Supply

- Measured by the 8-inch Hersey meter located just below the 10,000-gallon pressure breaker tank near the Resort's entrance.

### Water Sales

- The sum of meter readings of customers throughout the Resort. Golf course irrigation comprises about 50 percent of all water sales.

### Non-Revenue Water Use

- Automatic backwash of the two Permutit filters is a significant amount. Although hydraulic counters of each backwash event were installed in mid-1987, their record is only reliable from January 1988. Each backwash event uses approximately 25,000 gallons. This estimate is based on removal of the 8.7-foot deep, 20-foot diameter volume of water above the sand bed plus the flow through the sand bed itself during backwashing. The flow through the bed consists of an initial five minutes at about 200 GPM and a final four minutes at about 950 GPM. Although just an estimate, it is based on the manufacturer's written descriptions of the backwash cycle and is independently confirmed by calculations made by the Hawaii distributor and by Sid Kent of Pacific Electro-Mechanical, Inc.

### Unaccounted Losses

- Line leakage throughout the transmission and distribution pipeline network.

## AVAILABLE RECORDS AND SECTION-BY-SECTION ACCOUNTING OF USES AND LOSSES

Available records from September 1985 to July 1988 were assembled and analyzed for this study. Prior to September 1985, the records are too incomplete to reasonably derive figures for non-revenue water uses and unaccounted losses. In assembling this data, it was found that meter readings were not coordinated in time. To make the readings comparable over equivalent time intervals, it was necessary to prorate most of the readings. Other problems in meter reading and record keeping will be obvious in the presentation of this data.

### Section of the System From the Source Well in Kualapuu to the Pump Station at Mahana

Table 1 presents the available records (with our prorations) for well pumpage into the MIS at Kualapuu and withdrawal from the MIS at Mahana. Over this 2-year, 11-month period, well pumpage

Table 1. Monthly Comparison of Supply by the Sulphur Well and Withdrawal from the MSB at Nebraska

Month	1965				1966				1967				1968			
	Supply by Well No. 0901-01 (Gals)	Supply to Nebraska (Gals)	Difference Well and Nebraska (Gals)	Difference as a Percent of Nebraska Flourate (%)	Supply by Well No. 0901-01 (Gals)	Supply to Nebraska (Gals)	Difference Well and Nebraska (Gals)	Difference as a Percent of Nebraska Flourate (%)	Supply by Well No. 0901-01 (Gals)	Supply to Nebraska (Gals)	Difference Well and Nebraska (Gals)	Difference as a Percent of Nebraska Flourate (%)	Supply by Well No. 0901-01 (Gals)	Supply to Nebraska (Gals)	Difference Well and Nebraska (Gals)	Difference as a Percent of Nebraska Flourate (%)
Jan					35,734,786	24,546,143	11,190,643	45.59	26,013,386	13,973,857	12,039,529	46.13	22,160,857	18,053,857	4,107,000	22.75
Feb					17,501,857	14,107,143	3,394,714	8.66	17,859,571	12,497,714	5,361,857	42.90	20,330,714	19,400,386	932,328	4.24
Mar					20,674,571	19,007,714	1,666,857	50.86	25,760,143	18,062,000	7,698,143	34.57	25,322,815	23,200,571	2,114,244	9.11
Apr					24,445,429	17,022,143	7,423,286	55.48	21,097,643	20,435,477	662,166	5.15	22,939,900	25,052,572	(2,112,672)	-11.27
May					32,007,000	26,014,000	5,993,000	22.35	17,067,714	16,542,000	525,714	8.61	37,051,571	31,500,904	5,550,667	19.83
Jun					29,672,310	25,325,453	4,346,857	17.16	24,704,143	26,370,429	(1,666,286)	-6.35	38,035,000	39,293,394	(1,258,394)	-3.20
Jul					35,511,000	26,793,420	8,717,572	23.33	23,215,714	20,970,571	2,245,143	19.86	41,946,429	39,104,702	2,841,727	7.21
Aug					29,976,857	26,743,611	3,233,246	12.09	24,125,714	34,036,999	(9,911,285)	-33.03				
Sep	39,091,857	35,094,714	3,997,143	11.14	33,996,857	25,267,075	8,729,782	32.96	47,731,572	23,605,001	24,126,571	103.94				
Oct	34,500,000	24,530,000	10,000,000	30.34	34,521,429	30,431,571	4,089,858	19.23	24,757,386	24,005,000	752,386	2.79				
Nov	32,643,857	15,992,143	16,651,714	104.25	31,572,714	32,900,429	(1,327,715)	-4.00	34,000,142	27,241,000	6,759,142	32.45				
Dec	26,013,786	21,101,143	4,912,643	22.82	29,433,143	19,043,143	10,390,000	54.40	24,950,572	17,420,143	7,530,429	43.27				
Total	133,149,500	99,990,000	33,159,500	33.69	267,270,643	292,311,143	76,999,500	29.44	314,371,000	264,042,000	50,329,000	16.25	388,487,386	396,530,286	11,957,000	6.00

exceeded withdrawal by 19.8 percent. The excess is almost double the contract requirement of 10 percent. However, it is our understanding that the cost of well pumping above the required 10 percent is not included in MPUI's calculations of its rate base. The MIS has benefited from the excess but it was not at the expense of MPUI customers.

#### **Section of the System From the Mahana Pump Station to the Resort Entrance**

Tables 2 through 5 present monthly and annual figures of inflow, sales, outflow, and losses from the section of the system from Mahana through Puu Nana to the Resort entrance, including the separate system for the Moana Makani Subdivision. Gaps in the available record limit the interpretations that can be made. Records for the main line meter at the end of this section are only available since July 1987. Water sales to Maunaloa, which began in February 1987, are only available as a cumulative amount through January 1988. Monthly figures are only available since February 1988. The meter on the Molokai Ranch cattle trough, which was apparently installed by the Ranch rather than MPUI, has not yet been read. As a consequence of the available data, month-by-month and cumulative amounts of uses and losses for this section of the system can only be accounted for in the February through July of 1988 period (Table 5).

Nevertheless, there are several interesting results of this accounting. One is that the sum of customer sales in Moana Makani is substantially in excess of the measured flow passing into its storage tank (see Tables 4 and 5). Possible explanations are that the main line meter is inaccurate, or the customer meters are inaccurate, or that backflow of filtered water from the tank through the meter occurs during backwashing and/or rewashing. Another interesting result is identified in the simplified, February through July 1988 summary in Table 6. Total losses, including reservoir evaporation and Moana Makani backwash, amounted to just 1.1 percent of the flow through this section of the system. The unaccounted portion of these losses was just 0.4 percent and was actually computed to be an apparent gain in three of the six months.

#### **Section of the System Within the Resort**

Tables 7 through 10 present the 1985 through 1988 monthly and annual amounts of inflow, water sales, non-revenue uses, and losses for the section of the system within the Resort. As with the previous section, meaningful accounting can only be done for a portion of the 1985 to 1988 period. It begins in July 1987 when readings of the main line meter below the pressure breaker tank are first available (Table 9). Accounting for backwash begins in 1988. From January through April, backwashing as a cumulative amount can be estimated. Monthly backwashing figures are only available for May through June of 1988.

Table 2. Monthly Compilation of Flows in the Section of the System from Mahana to the Resort Entrance for September to December, 1985

Month	Reservoirs at Puu Mana				Mauna Mekaui System						Unaccounted Water, Mahana to Resort Entrance Road	
	Supply from Mahana (Gals)	Supply from Molekai Ranch System (Gals)	Total Inflow to Reservoirs (Gals)	Estimated Evaporation from Reservoirs (Gals)	Water Sales to Mauna Loa Comp (Gals)	Estimated Backwash & Rewash @ Pressure Filters (Gals)	In-Line Meter Below Filters (Gals)	Water Sales (Gals)	Apparent Loss (Gals)	Mainline Flow Below Pressure Breaker Tank (Gals)	Amount (Gals)	Percent of Mahana Flow (%)
Sep	35,894,714	0	35,894,714	99,443	0	133,200	NR	68,164	10	10	10	10
Oct	26,530,000	0	26,530,000	87,527	0	137,640	NR	50,000	10	10	10	10
Nov	15,992,143	0	15,992,143	47,742	0	133,200	NR	35,997	10	10	10	10
Dec	21,181,143	0	21,181,143	71,613	0	137,640	NR	21,476	10	10	10	10
Total	99,598,000	0	99,598,000	306,345	0	541,680	10	175,437	10	10	10	10

Notes:

1. "NR" means no record is available.
2. "10" means there is insufficient data to make the required calculation.

Table 3. Monthly Compilation of Flows in the Section of the System from Mahana to the Resort Entrance for 1986

Month	Reservoirs at Pua Kona			Mauna Nalani System						Unaccounted Water, Mahana to Resort Entrance Road		
	Supply from Mahana (Gals)	Supply from Holokai Ranch System (Gals)	Total Inflow to Reservoirs (Gals)	Estimated Evaporation from Reservoirs (Gals)	Water Sales to Mauna Loa Camp (Gals)	Estimated Backwash & Rinsing @ Pressure Filters (Gals)	In-Line Meter Below Filters (Gals)	Water Sales (Gals)	Apparent Loss (Gals)	Mainline Flow Below Pressure Breaker Tank (Gals)	Amount (Gals)	Percent of Mahana Flow (%)
Jan	24,546,143	0	24,546,143	62,330	0	137,640	NR	902,280	10	NR	10	10
Feb	16,107,143	0	16,107,143	22,545	0	124,320	NR	524,200	10	NR	10	10
Mar	19,007,714	0	19,007,714	61,004	0	137,640	NR	416,140	10	NR	10	10
Apr	17,022,143	0	17,022,143	124,640	0	133,200	NR	430,710	10	NR	10	10
May	26,814,690	0	26,814,690	102,115	0	137,640	NR	609,030	10	NR	10	10
Jun	25,325,453	0	25,325,453	122,007	0	133,200	NR	883,190	10	NR	10	10
Jul	28,793,428	0	28,793,428	115,377	0	137,640	NR	658,510	10	NR	10	10
Aug	26,743,411	0	26,743,411	125,986	0	137,640	NR	588,830	10	NR	10	10
Sep	25,267,875	0	25,267,875	102,115	0	133,200	NR	547,600	10	NR	10	10
Oct	30,631,571	0	30,631,571	115,377	0	137,640	NR	442,560	10	NR	10	10
Nov	32,988,429	5,199,515	38,187,944	102,115	0	133,200	NR	395,070	10	NR	10	10
Dec	19,063,143	7,683,743	26,746,886	78,244	0	137,640	NR	304,170	10	NR	10	10
Total	292,311,143	12,883,258	305,194,401	1,133,874	0	1,620,600	10	6,782,290	10	10	10	10

Notes:

1. "NR" means no record is available.
2. "10" means there is insufficient data to make the required calculation.

Table 4. Monthly Compilation of Flow in the Section of the System from Mahana to the Resort Entrance for 1987

Month	Reservoirs at Puu Hano			Mauna Makeni System						Unaccounted Water, Mahana to Resort Entrance Road		
	Supply from Mahana (Gals)	Supply from Maolokai Ranch System (Gals)	Total Inflow to Reservoirs (Gals)	Estimated Evaporation from Reservoirs (Gals)	Water Sales to Mauna Loa Camp (Gals)	Estimated Backwash & Remesh @ Pressure Filters (Gals)	In-Line Meter Below Filters (Gals)	Water Sales (Gals)	Apparent Loss (Gals)	Mainline Flow Below Pressure Breaker Tank (Gals)	Amount (Gals)	Percent of Mahana Flow (%)
Jan	13,975,837	9,490,071	23,465,928	79,370	0	137,640	NR	489,840	10	NR	10	10
Feb	12,497,714	5,757,701	18,255,415	10	*	124,320	NR	347,400	10	NR	10	10
Mar	18,842,000	4,444,628	23,286,628	103,441	*	137,640	NR	281,920	10	NR	10	10
Apr	20,635,477	1,927,043	22,562,520	82,222	*	133,200	NR	361,440	10	NR	10	10
May	14,542,809	7,305,514	21,848,323	92,832	*	137,640	NR	374,370	10	NR	10	10
Jun	26,378,429	2,052,843	28,431,272	133,943	*	133,200	NR	513,960	10	NR	10	10
Jul	28,970,571	2,942,636	31,913,207	137,921	*	137,640	NR	507,510	10	30,127,000	10	10
Aug	34,026,999	3,120,480	37,147,479	122,007	*	137,640	NR	490,730	10	30,052,500	10	10
Sep	25,405,001	972,441	26,377,442	122,007	*	133,200	699,943	836,470	(136,527)	25,618,286	10	10
Oct	24,086,000	1,849,629	25,935,629	124,640	*	137,640	428,326	427,430	896	25,785,253	10	10
Nov	27,241,000	2,397,585	29,638,585	95,484	*	133,200	280,588	592,680	(312,092)	17,263,890	10	10
Dec	17,420,143	5,761,257	23,181,400	39,678	*	137,640	NR	487,830	10	13,925,000	10	10
Total	264,042,000	50,261,828	316,303,828	1,153,766	*	1,420,600	1,408,857	5,711,580	(447,723)	142,749,929	10	10

Notes:

1. "NR" means no record is available.
2. "10" means there is insufficient data to make the required calculation.

\* Supply to Mauna Loa began in February 1987 but monthly totals are not available until February 1988. The cumulative amount from February 1987 to sometime in January 1988 is 21,264,000 Gallons (See Table 5).



Table 5. Monthly Compilation of Flows in the Section of the System from Mahana to the Resort Entrance for January to July 1988

Month	Reservoirs at Puu Mana				Mauna Mahani System					Unaccounted Water, Mahana to Resort Entrance Road		
	Supply from Mahana (Gals)	Supply from Molekai Ranch System (Gals)	Total Inflow to Reservoirs (Gals)	Estimated Evaporation from Reservoirs (Gals)	Water Sales to Mauna Loa Camp (Gals)	Estimated Sechinash & Reseach B Pressure Filters (Gals)	In-line Meter Below Filters (Gals)	Water Sales (Gals)	Apparent Loss (Gals)	Mainline Flow Below Pressure Breaker Tank (Gals)	Amount (Gals)	Percent of Mahana Flow (%)
Jan	18,053,857	1,255,306	19,309,163	74,268	21,264,100 *	137,640	78,400	182,300	(103,900)	11,853,571	10	10
Feb	19,408,286	6,443,632	26,071,938	71,613	5,598,300	128,760	147,229	266,670	(119,441)	16,789,000	3,217,595	16.58
Mar	23,208,571	2,268,614	25,457,185	83,549	3,826,900	137,640	231,357	454,220	(222,863)	21,747,857	(790,981)	-3.41
Apr	25,852,572	3,016,457	28,869,029	87,527	3,144,200	133,200	319,928	442,270	(142,342)	24,961,857	79,975	0.31
May	31,588,904	0	31,588,904	129,964	3,707,500	137,640	334,703	598,840	(264,137)	28,114,119	(1,099,159)	-3.48
Jun	39,293,394	0	39,293,394	139,268	3,854,000	133,200	451,133	635,960	(184,827)	34,497,647	(1,964,681)	-5.01
Jul	39,124,702	0	39,124,702	147,205	551,050	137,640	386,521	754,570	(368,049)	34,286,643	1,267,594	3.19
Total	196,530,286	13,184,029	209,714,315	733,371	10	945,720	1,949,271	3,354,830	(1,405,559)	176,250,714	10	10
Sub	for Feb to July 1988											
Sub	178,476,429	11,928,723	190,405,152	659,105	20,679,950	808,080	1,870,871	3,172,530	(1,301,659)	164,397,143	688,344	0.39

Notes:

1. "NR" means no record is available.
2. "10" means there is insufficient data to make the required calculation.

\* The amount represents a cumulative total for February 1987 through January 1988. Monthly amounts are available starting in February 1988.

**Table 6**

**Summary of Inflow, Outflow, Sales, and Losses Through the  
Mahana to Resort Entrance Section of the System,  
February to July 1988**

<b>Month</b>	<b>Total Inflow<sup>1</sup> (MG)</b>	<b>Water Sales<sup>2</sup> (MG)</b>	<b>Accountable Losses<sup>3</sup> (MG)</b>	<b>Total Outflow<sup>4</sup> (MG)</b>	<b>Unaccounted Losses<sup>5</sup> (MG)</b>
February	26.072	5.865	0.200	16.789	3.218
March	25.457	4.279	0.221	21.748	(0.791)
April	28.869	3.606	0.221	24.961	0.081
May	31.589	4.306	0.268	28.114	(1.099)
June	39.293	4.490	0.272	36.498	(1.967)
July	39.124	1.306	0.285	36.287	1.246
<b>Total</b>	<b>190.405</b>	<b>23.852</b>	<b>1.467</b>	<b>164.397</b>	<b>0.689</b>

<sup>1</sup>Sum of flow at Mahana and water purchased from Molokai Ranch.

<sup>2</sup>Sum of sales to Maunaloa and customers in Moana Makani Subdivision.

<sup>3</sup>Sum of reservoir evaporation and Moana Makani filter backwash.

<sup>4</sup>Readings of the main line meter below the pressure breaker tank.

<sup>5</sup>Calculated as inflow less the sum of sales, outflow, and accountable losses.

E

Table 7. Compilation of Flows within the  
Resort for September to December, 1985

Month	Mainline Flow Below Pressure Breaker Tank (Gals)	Water Sales (Gals)	Estimated Filter Backwash (Gals)	Unaccounted Losses	
				Amount (Gals)	Percent of Sales (%)
Sep	NR	21,939,000	NR	ID	ID
Oct	NR	17,553,000	NR	ID	ID
Nov	NR	11,012,630	NR	ID	ID
Dec	NR	12,563,950	NR	ID	ID
<b>Total</b>	ID	63,068,580	ID	ID	ID,

Notes:

1. "NR" means no record is available.
2. "ID" means there is insufficient data to make the required calculation.

Table 8. Compilation of Flows within the Resort for 1986

Month	Mainline Flow Below Pressure Breaker Tank (Gals)	Water Sales (Gals)	Estimated Filter Backwash (Gals)	Unaccounted Losses	
				Amount (Gals)	Percent of Sales (%)
Jan	NR	18,047,560	NR	ID	ID
Feb	NR	13,612,830	NR	ID	ID
Mar	NR	19,160,090	NR	ID	ID
Apr	NR	16,857,960	NR	ID	ID
May	NR	23,318,160	NR	ID	ID
Jun	NR	22,842,190	NR	ID	ID
Jul	NR	23,104,837	NR	ID	ID
Aug	NR	22,048,970	NR	ID	ID
Sep	NR	22,691,190	NR	ID	ID
Oct	NR	23,489,940	NR	ID	ID
Nov	NR	20,204,940	NR	ID	ID
Dec	NR	19,611,810	NR	ID	ID
<b>Total</b>	NR	<b>244,990,477</b>	ID	ID	ID

Notes:

1. "NR" means no record is available.
2. "ID" means there is insufficient data to make the required calculation.

**Table 9. Compilation of Flows within the  
Resort for 1987**

Month	Mainline Flow Below Pressure Breaker Tank (Gals)	Water Sales (Gals)	Estimated Filter Backwash and Losses (Gals)	Unaccounted Losses	
				Amount (Gals)	Percent of Sales (%)
Jan	NR	17,023,290	NR	ID	ID
Feb	NR	18,190,650	NR	ID	ID
Mar	NR	14,203,110	NR	ID	ID
Apr	NR	16,816,230	NR	ID	ID
May	NR	15,983,230	NR	ID	ID
Jun	NR	22,895,800	NR	ID	ID
Jul	30,127,000	26,293,200	NR	ID	ID
Aug	30,052,500	22,964,290	NR	ID	ID
Sep	25,618,286	23,629,180	NR	ID	ID
Oct	25,785,253	17,448,990	NR	ID	ID
Nov	17,263,890	18,198,900	NR	ID	ID
Dec	13,923,000	11,425,720	NR	ID	ID
<b>Total</b>	<b>ID</b>	<b>225,072,590</b>	<b>ID</b>	<b>ID</b>	<b>ID</b>
<b>Subtotal for July to Dec 1987</b>					
<b>Sub</b>	<b>142,769,929</b>	<b>119,960,280</b>	<b>22,809,649</b>	<b>ID</b>	<b>19.0</b>

**Notes:**

1. "NR" means no record is available.
2. "ID" means there is insufficient data to make the required calculation.

E

Table 10. Compilation of Flows within the Resort for January to July, 1988

Month	Flow from Pressure Breaker Tank (Gals)	Filter Backwash		Water Sales (Gals)	Unaccounted Losses	
		Count	Estimated Amount (Gals)		Amount (Gals)	Percent of Sales (%)
Jan	11,853,571	*	ID	9,134,950	ID	ID
Feb	16,789,000	*	ID	13,973,500	ID	ID
Mar	21,747,857	*	ID	19,646,260	ID	ID
Apr	24,961,857	*	ID	16,858,080	ID	ID
Jan-Apr Subtotal	75,352,285	591 *	14,775,000	59,612,790	964,495	1.62
May	28,114,119	194	4,850,000	22,407,480	856,639	3.82
Jun	36,497,667	181	4,525,000	28,257,410	3,715,257	13.15
Jan-Jun Subtotal	139,964,071	966	24,150,000	110,277,680	5,536,391	5.02
Jul	36,286,643	NR	NR	28,214,920	ID	ID
Jan-Jul Total	316,214,785	ID	ID	248,770,280	ID	ID

Notes:

1. "NR" means no record is available.
2. "ID" means there is insufficient data to make the required calculation.

\* Although monthly backwash counts are not available for January through April, a cumulative 4 - month total is available.

For this section of the system, the difference between supply at the entrance road and water sales within the Resort is significant. However, most of this can be attributed to backwashing at the two Permutit filters. For January through June 1988 when the backwashing events have been tallied and an amount of this use can be estimated, influent supply can be accounted for in the following breakdown: water sales, 78.8%; backwashing, 17.3%; and unaccounted losses, 3.9%.

#### ANNUAL SUMMARIES OF SUPPLY, WATER SALES, NON-REVENUE USES, AND LOSSES

The foregoing, section-by-section monthly accounting of supply, sales, non-revenue uses, and losses are presented in simplified annual summaries in Tables 11 through 14. The last four months of 1985 had an unusually high total for non-revenue uses and losses, an occurrence for which no explanation has been found. However, in the two and one half years since the end of 1985, the total of non-revenue uses and losses have been in the range of 24 to 28 percent of the total water supply. Relative amounts of the non-revenue uses and losses were generally as tabulated below. Unaccounted losses, at under four percent, are low enough to be of little concern. On the other hand, it is clear that transmission through the MIS has significant cost consequences. In addition to the rental fee for transmission through that system, there are costs to pump an excess supply of 10 percent from the well and the costs of filtering the water because it has passed through the non-potable MIS. Avoiding these costs would require construction of a transmission pipeline to replace the link through the MIS and the addition of a second, back-up supply well. An economic analysis of this cost and the operating savings it would achieve is beyond the scope of this study.

	Generalized Percent of Total Supply <u>(%)</u>
<b>Non-Revenue Uses</b>	
Surplus Supply to the MIS	7.6
Filter Backwashing	<u>14.0</u>
<b>Total Non-Revenue Uses</b>	<u>21.6</u>
<b>Losses</b>	
Puu Nana Reservoir Evaporation	0.3
Unaccounted Losses	<u>3.8</u>
<b>Total Losses</b>	<u>4.1</u>
<b>Total Non-Revenue Uses and Losses</b>	25.7

E

Table 11

Summary of Supply, Sales, Non-Revenue Uses, and Losses for  
September Through December 1985

I t e m	Amount (MG)	Percent of Supply ( % )
Supply by Kualapuu Well	<u>109.558*</u>	100.0
Water Sales		
Moana Makani Subdivision	0.176	0.2
Distribution Within the Resort	<u>63.069</u>	<u>57.6</u>
Total Water Sales	<u>63.245</u>	57.7
Non-Revenue Uses and Losses		
10% Transmission Surplus Through the MIS	9.960	9.1
Puu Nana Reservoir Evaporation (est.)	0.306	0.3
Moana Makani Backwash (est.)	0.542	0.5
Unaccounted Uses and Losses	<u>35.505</u>	<u>32.4</u>
Total Non-Revenue Uses and Losses	<u>46.313</u>	42.3

\* Amount is the supply taken from the MIS at Mahana plus 10 percent. Actual well pumpage exceeded this figure.



Table 12

Summary of Supply, Sales, Non-Revenue Uses, and Losses for 1986

I t e m	Amount (MG)	Percent of Supply ( % )
<b>Supply</b>		
Kualapuu Well	321.542*	96.1
Molokai Ranch	<u>12.883</u>	<u>3.9</u>
Total Supply	<u>334.425*</u>	100.0
<b>Water Sales</b>		
Moana Makani Subdivision	6.782	2.0
Distribution Within the Resort	<u>244.990</u>	<u>73.3</u>
Total Water Sales	<u>251.772</u>	75.3
<b>Non-Revenue Uses and Losses</b>		
10% Transmission Surplus Through the MIS	29.231	8.7
Puu Nana Reservoir Evaporation (est.)	1.134	0.3
Moana Makani Backwash (est.)	1.621	0.5
Unaccounted Uses and Losses	<u>50.667</u>	<u>15.2</u>
Total Non-Revenue Uses and Losses	<u>82.653</u>	24.7

\* Amount is the supply taken from the MIS at Mahana plus 10 percent. Actual well pumpage exceeded this figure.

Table 13

Summary of Supply, Sales, Non-Revenue Uses, and Losses for 1987

I t e m	Amount (MG)	Percent of Supply ( % )
<b>Supply</b>		
Kualapuu Well	292.646 <sup>1</sup>	85.3
Molokai Ranch	<u>50.242</u>	<u>14.7</u>
Total Supply	<u>342.888</u>	100.0
<b>Water Sales</b>		
Maunaloa Town (est.)	17.264 <sup>2</sup>	5.0
Moana Makani Subdivision	5.712	1.7
Distribution Within the Resort	<u>225.073</u>	<u>65.6</u>
Total Water Sales	<u>248.049</u>	72.3
<b>Non-Revenue Uses and Losses</b>		
10% Transmission Surplus Through the MIS	26.604	7.8
Puu Nana Reservoir Evaporation (est.)	1.154	0.3
Moana Makani Backwash (est.)	1.621	0.5
Unaccounted Uses and Losses	<u>65.460</u>	<u>19.1</u>
Total Non-Revenue Uses and Losses	<u>94.839</u>	27.7

<sup>1</sup> Amount is the supply taken from the MIS at Mahana plus 10 percent. Actual well pumpage exceeded this figure.

<sup>2</sup> Prorated amount of the 21.264 million gallons sold to Maunaloa from February 1987 through January 1988.

E

Table 14

Summary of Supply, Sales, Non-Revenue Uses, and Losses For  
January Through June 1988

Item	Amount (MG)	Percent of Supply (%)
<b>Supply</b>		
Kualapuu Well	166.541*	92.7
Molokai Ranch	<u>13.184</u>	<u>7.3</u>
Total Supply	<u>179.725</u>	100.0
<b>Water Sales</b>		
Maunaloa Town (est.)	24.129	13.4
Moana Makani Subdivision	2.600	1.4
Distribution Within the Resort	<u>110.278</u>	<u>61.4</u>
Total Water Sales	<u>137.007</u>	76.2
<b>Non-Revenue Uses and Losses</b>		
Transmission Surplus Through the MIS	9.135	5.1
Puu Nana Reservoir Evaporation (est.)	0.586	0.3
Moana Makani Backwash (est.)	0.808	0.4
Permutit Gravity Filters Backwash (est.)	24.216	13.5
Unaccounted Losses	<u>7.973</u>	<u>4.4</u>
Total Non-Revenue Uses and Losses	<u>42.718</u>	23.8

\* Amount is the actual well pumpage; the well pumpage from January through June was less than the withdrawal from the MIS at Mahana plus 10 percent.

E

## RECOMMENDATIONS

The difficulties encountered in assembling the section-by-section data, as well as the incomplete results of this accounting, suggest that the following changes and additions should be made:

1. The timing of the meter readings should be coordinated so that direct comparisons over equivalent periods can be made.
2. Meter reading data should be compiled in a form that will enable significant uses and losses to be monitored. The data presentations in Tables 1 through 10 are examples of the appropriate form of the compilations.
3. The discrepancy between supply and sales within the Moana Makani Subdivision system should be investigated. This should include calibration of the meter between the filters and 2000-gallon storage tank and observation of the meter's behavior during backwashing. Also, consideration should be given to relocating the meter upstream of the filters so that the backwash flow can also be measured.
4. The cost consequences of the MIS as a transmission link should be further investigated. In addition to the annual rental charge, about 20 percent of the system's total supply is attributable to the obligation to pump an excess into the MIS and the requirement to filter water withdrawn from the MIS at Mahana. The contract with the MIS expires in 1995 and may not be renewed. At that time, a new transmission pipeline and standby well will be needed to replace use of the MIS.
  - a. It would be appropriate to undertake an analysis of the initial costs, operational savings, and rate base consequences of bringing the new pipeline and well into service prior to expiration of the MIS contract.
  - b. If the analysis indicates that the MIS contract should be continued, two possibilities concerning the backwash water from the two, 20-foot diameter Permutit filters should be evaluated:
    - (i) Route the golf course irrigation supply through the Papohaku Subdivision irrigation system. Removing this supply from the potable system would reduce backwashing by about 50 percent.

- (ii) Recover discharged backwash water for non-potable reuse or to be recycled through the potable system's filters. The latter option would require installation of a holding tank, pump and flocculator.

# Kukui Molokai, Inc. Pumpage

## Well #17 (Well No. 0901-01)

