ASSESSMENT AND IMPROVEMENT RECOMMENDATIONS FOR THE MOLOKAI IRRIGATION SYSTEM

Lance T. Santo
Hawaii Agriculture Research Center
99-193 Aiea Heights Drive, Suite 300,
Aiea, Hawaii 96701-3911
Telephone: (808) 486-5355

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EXECUTIVE SUMMARY

In August 2001, the Hawaii Agriculture Research Center initiated a review of the Molokai Irrigation System (MIS) to recommend changes to mitigate the current water shortage problem. The system in Waikolu valley (dams, wells and tunnel), Kualapuu (transmission pipeline and reservoir) and Hoolehua (distribution pipeline and users) was visited on August 15, 2001. Past reports, memoranda, meeting minutes and data relative to this task were reviewed at the State of Hawaii, Department of Agriculture (DOA), Agricultural Resource Management Division office in Honolulu. Relevant data were digitized for analysis. Weather, tunnel flows, pumping, reservoir depth and customer use data were obtained and utilized. Various individuals from the DOA, MIS Users Advisory Board, University of Hawaii Cooperative Extension agents, and interested community members were contacted to document the issues and concerns of the Molokai community.

The current water shortage is primarily the result of the most severe drought since the inception of the MIS. The drought started in 1998 and is continuing through 2001. Rainfall total of 7.97 inches in 1998 was a record low compared to the average of 22.68 inches since 1970 at the Kualapuu reservoir in central Molokai. The rainfall in 1999 and 2000 were the second and sixth lowest totals at 9.22 and 11.84 inches. The dry weather has decreased water collection in Waikolu valley and increased water demand in central Molokai resulting in the Kualapuu reservoir depth dropping to 4 ft, the lowest level on record.

The findings indicate that improving the water collection in Waikolu valley, reducing system losses and developing new sources could result in obtaining additional water. New sources being considered are stream diversions of Waihanau, Kawela, Kaunakakai, Manawainui and use of some brackish wells. The additional water may be sufficient to increase the customer base from the current 2,931 acres to about 6,000 acres with a total of about 12 mgd. This assumes that more than 6 mgd can be gained by system improvements and from new sources. The 12 mgd is still not enough to support the 9,960 acres in the current service area of Hoolehua. Therefore, expansion of the MIS to Kalamaula homestead is not feasible unless more water can be obtained from the

northeastern Molokai such as Pelekunu stream with an average flow of 17.2 mgd. Any development in the northeastern mountains will be costly and likely met with environmental and cultural oppositions. The Kalamaula area could be served directly by diverting the water flow of 0.5 mgd from Waihanau stream to irrigate about 125 cultivated acres.

Recommendations for the development of new water sources are long-term courses of action. Environmental and cultural issues of the impact of water removal on the ecosystem, other water sources, the Public Trust Doctrine and Hawaiian rights require studies before any new water project can proceed. Four new sources are proposed: stream diversions on Kawela, Kaunakakai, Manawainui and development of brackish wells near the current MIS system.

Short-term actions are more feasible, and these emphasize the improvement of the efficiency of the water collection, transport, storage, distribution and customer use. These recommendations are divided into system and management improvements. It is roughly estimated that up to 20% more water can be gained by minimizing known system losses. Water use as measured by MIS customers' meters has never exceeded the west portal tunnel flow, the water collected in Waikolu. The west portal flow provides the best estimate of the total water available before transmission, storage and distribution losses. Evaporation loss alone is about 300 million gallons annually or about 15% of the total available water. Seepage loss from the reservoir could be higher than evaporation loss, but was not measured. The storage of water in Kualapuu reservoir is expected to be the difference of the west portal flow and the flows adjusted for evaporation loss and customer use. From 1990 through 1999, the expected cumulative water storage is expected be 2.540 billion gallons, which is more than the capacity of the 1.4 billion-gallon reservoir. Since the reservoir depths have steadily decreased instead of increasing, it strongly suggests there are other major losses in addition to evaporation such as errors in the measurement of the west portal flow and the customer water usage. Twenty-seven of thirty recommendations are short-term actions to minimize losses, improve irrigation efficiencies and better manage the MIS.

INTRODUCTION

The Molokai Irrigation System (MIS) is operated and managed by the State of Hawaii, Department of Agriculture (DOA) since July 1, 1989. As of August 1, 2001, the MIS serves 239 agricultural customers with 2,931 acres in central Molokai. The MIS was designed to collect and pump water from the Waikolu valley, transport, store and distribute the water in central Molokai. Three consecutive years (1998 to 2001) of sparse rainfall of less than half of normal has resulted in very low water level of less than 5 ft deep in the Kualapuu reservoir, which has a maximum storage depth of 54 ft. This present drought prompted the DOA to encourage a 30% voluntary water use reduction by all MIS customers. The water shortage is reaching a critical point, where the Molokai farmers cannot apply sufficient irrigation to maintain normal yields.

This document is for the Agribusiness Development Corporation (ADC) to provide information to respond to Senate Resolution 34, SD 1 of the 21st Legislature of the State of Hawaii (Appendix A). The information and data provided in this document as specified in Hawaii Agriculture Research Center contract with ADC include the following:

- Original and present design and objective of the MIS
- Physical capacity, operational requirements and maintenance of the MIS
- Current and new sources of water and their limitations
- Current water use patterns relative to optimal crop requirements
- Rights of the Department of Hawaiian Home Lands (DHHL)
- Community concerns and issues as expressed by representatives of ADC, DOA, DHHL, Natural Resources Conservation Service and the MIS Water Users Advisory Board

Based on the above findings, courses of actions are recommended to ADC.

DESIGN

Intended Collection System

The original design of the MIS called for four stages of implementation of which only the first stage was completed. Parsons, Brinckerhoff-Hirota Associates (1969) describes the plan in a report to the State of Hawaii, Department of Land and Natural Resources (DLNR). Stage I included the construction of the water collection system in Waikolu valley consisting of four diversion dams (Dams 1, 2, 3 and 4), six wells (Wells 22, 23, 24, 4, 5 and 6), Waikolu tunnel, transmission system (concrete flume and pipeline), Kualapuu reservoir, and the distribution system to the users. Well 4 have no pump and used only to monitor the groundwater level. Wells 5 and 6 were not operational until after 1996. Photographs of some of the completed structures are shown in Appendix B.

Stages II, III and IV were not undertaken because of funding problems. Stage II proposed the construction of a collection system in Pelekunu valley with a tunnel connecting Waikolu to Pelekunu valley. The average total surface flow (including dike groundwater overflow) at the 1,000 ft elevation in Pelekunu was measured at 17.16 mgd compared to 6.56 mgd for Waikolu at the same elevation. The average base flows (estimate of sustainable groundwater) for Waikolu and Pelekunu were 2.52 and 6.09 mgd at the 1,000 ft elevation, respectively. Stage III would consist of installing additional transmission pipelines. Stage IV proposed three diversion structures each on Pilipililau and Lanipuni streams above the 1,000 ft elevation in Pelekunu valley. The intended cumulative amounts of water delivered by MIS in Stages I, II, III and IV were predicted at 3.8, 9.0, 11.0 and 19.3 mgd, respectively. The total cost of all four stages was estimated at $12,568,000 (Parsons, Brinckerhoff-Hirota Associates, 1969). With only Stage I completed, the MIS was intended to have an average annual flow of 3.8 mgd.

Current System

In times of normal rainfall, 54% of the MIS water comes from four surface water diversion dams in the Waikolu valley, 28% from groundwater intercepted by the Waikolu tunnel and 18% pumped from wells (Water Resource Associates, 1999). For the period from April 12, 1996 to November 30, 1997, the rainfall total in Waikolu valley was 176.52 inches (above normal) and pumping averaged 0.746 mgd. More recent rainfall data from the DOA Waikolu weather station are in Appendix C (weekly reports by the MIS manager). The flows and distribution by water sources for this period were as follows: Waikolu valley surface runoff (diverted stream flow), tunnel groundwater (tunnel interception only), and groundwater (well source) flows were 2.98, 1.60, and 0.746 mgd or 50.3, 33.3, and 16.4% relative to the total of 5.33 mgd, respectively. The collected surface water and pumped groundwater were transported by gravity through a 5.1 mile-long tunnel, 0.3 mile-long concrete flume and a 3.85 mile-long pipeline connecting to the 1.4 billion-gallon Kualapuu reservoir.

Waikolu Stream Watershed

Parsons, Brinckerhoff-Hirota Associates (1969) describes the watershed as follows:

> *"Waikolu valley consists of a main stream that follows the axis of the valley nearly to its headwater boundary. Its main tributaries flow from swamps on andesite on the small plateau between Waikolu and Pelekunu. No appreciable drainage comes from the west side of the valley in its upper portion. The main stream serves as a drainage channel for dike water except in the lower part of the valley where the old alluvium acts as a semi-impermeable cap. The dikes are about 20 to 25 degrees off the perpendicular at intersections with the stream. In the upper part of the valley, including the portion above elevation 1,000 feet, water in the stream derives from overland flow from the andesite interfluve, direct runoff within the valley, and dike water that drains directly into the stream. In the lower part of the valley, the old alluvium forces water to overflow from dike compartments to a maximum elevation of about 600 feet, and direct runoff originates from the valley proper."*

The estimated amounts of groundwater and total surface water available in the Waikolu valley at different elevations are shown in Table 1.

Table 1. Estimates of available water in Waikolu valley at three elevations (ft) with MIS collection structures. The flows are in million gallons per day (mgd).

Elevation	Avg. Base Flow	Avg. Direct Surface Flow	Total Avg. Surface Flow
1,000	2.52	4.04	6.56
900	2.66	4.27	6.93
750	3.02	4.86	7.88

Source: Parsons, Brinckerhoff-Hirota Associates (1969)

The average base flow estimates the amount of groundwater that can be pumped from the ground without significantly lowering the level of the dike-confined water or referred to as the sustainable groundwater yield (Parsons, Brinckerhoff-Hirota Associates, 1969). The average direct surface flow is the average amount of water that can be diverted by dams without dike overflow from the Waikolu stream. The average total available water at the 750 ft elevation is about 7.88 mgd. The dams, wells and tunnel location in Waikolu valley are shown below in Figure 1 where the lowest dam (Dam 4) is at the 730 ft elevation.

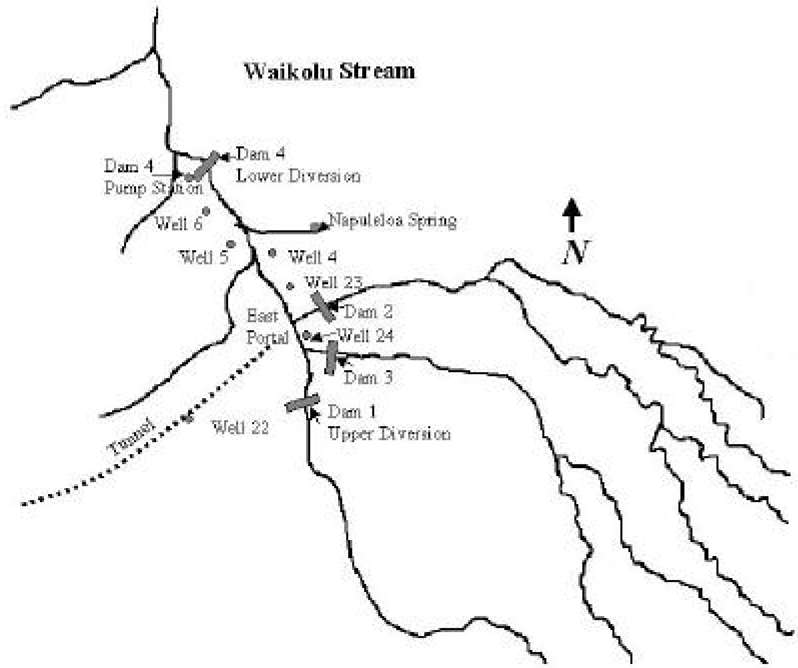

Figure 1. Diversions of Waikolu stream and wells in Waikolu valley. Circles and rectangles depict pumps and dams, respectively.

The Waikolu valley surface and groundwater resources were estimated at a maximum average yield of about 7.88 mgd but were not intended to service all the current acres in central Molokai without system upgrades planned in Stages II, III and IV. The Waikolu valley was intended to yield only 3.8 mgd or about half of the average flow available in Waikolu valley. The highest average monthly flow measured at the tunnel's west portal was 10.24 mgd in February 1990 for the period from 1989 to 2000 (Table 2). The west portal flow represents the total amount of water collected from Waikolu valley and available to the MIS before any delivery or storage losses. The monthly averages for all years in the aforementioned period ranged from a low of 4.60 mgd in September to a high of 6.85 mgd in December with an overall annual average of 5.80 mgd. Average daily pumping from January 1988 to May 2001 was 0.88 mgd (Table 3). October 1995 had the highest pumping at 4 mgd. However, annual average diverted stream flow was only 3.12 mgd for the period from 1989 to 2000 (Table 4), which was less than the expected average direct surface flow of 4.86 mgd at the 750 ft elevation in Waikolu valley. Therefore, the average obtainable flow is about 7.4 mgd assuming diverted stream flow, pumping and tunnel ground water of 3.1, 2.5 and 1.8 mgd. A maximum of 0.744 mgd of pumping in Waikolu valley was allowed until the well permit was amended to 0.853 mgd on October 17, 2001.

Table 2. East and west portals daily average tunnel flows (mgd) from 1989 through 2000 measured by USGS. West portal average for the period was 5.8 mgd.

	Jan		Feb		Mar		Apr		May		Jun	
Year	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**
1989	6.45	4.62	7.11	5.24	7.11	4.89	9.24	6.98	6.44	3.68	5.87	3.22
1990	6.98	4.95	10.28	8.08	8.73	6.46	4.98	2.75	8.02	5.75	6.98	4.78
1991	5.32	3.61	6.06	4.38	9.18	7.05	4.98	3.24	4.98	3.17	4.65	2.84
1992	3.46	1.99	4.53	2.86	3.98	2.28	3.07	0.96	4.99	3.41	4.47	2.93
1993	5.42	3.93	4.57	2.48	6.22	4.56	7.24	5.46	6.79	5.04	5.84	3.91
1994	7.11	5.26	7.30	5.53	8.66	6.53	8.02	6.19	6.01	4.55	6.85	4.71
1995	5.99	3.39	5.39	3.08	5.85	4.08	6.21	4.38	4.66	2.80	5.79	3.68
1996	4.06	3.12	5.80	4.62	4.74	3.59	4.70	3.68	3.57	2.67	4.01	3.32
1997	6.53	4.80	4.27	2.81	7.24	5.38	4.69	2.73	5.29	3.57	5.36	3.65
1998	4.96	3.13	5.48	3.85	5.51	3.99	7.76	5.91	6.25	4.54	8.27	6.13
1999	6.30	4.74	7.24	5.70	7.69	6.02	6.59	5.11	4.41	3.05	5.11	3.70
2000	7.76	5.87	3.65	2.33	5.15	3.85	7.50	5.86	4.97	3.56	4.18	2.85
Avg	**5.86**	**4.12**	**5.97**	**4.25**	**6.67**	**4.89**	**6.25**	**4.44**	**5.53**	**3.82**	**5.62**	**3.81**

	Jul		Aug		Sep		Oct		Nov		Dec	
Year	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**	**West**	**East**
1989	7.50	4.88	5.53	3.23	4.48	2.23	4.27	2.04	3.69	2.05	5.40	3.45
1990	4.98	3.02	4.54	2.53	4.82	2.70	5.03	3.35	7.76	5.97	8.92	6.85
1991	4.81	2.85	4.73	2.88	3.24	1.64	3.38	1.62	2.93	1.20	4.52	2.97
1992	5.49	3.32	3.75	2.44	4.80	3.30	4.46	2.99	7.37	5.62	6.53	5.08
1993	7.82	5.86	5.22	3.56	4.52	2.74	5.26	3.57	6.98	5.24	5.66	4.02
1994	6.26	4.29	4.42	3.47	5.51	3.76	4.64	2.49	8.47	4.63	8.14	4.87
1995	4.15	2.75	4.38	2.89	4.49	2.62	6.85	5.20	5.79	4.51	5.16	4.17
1996	4.16	3.51	3.41	2.85	4.24	2.77	4.36	2.68	7.69	5.92	8.73	6.98
1997	6.53	4.03	4.29	2.34	4.82	2.73	4.45	2.50	7.82	5.86	6.85	4.98
1998	6.44	3.91	4.81	2.89	4.97	2.61	5.48	3.19	9.05	6.00	7.76	5.85
1999	6.20	4.80	5.22	3.78	4.65	3.26	5.54	4.21	6.20	4.88	7.69	6.22
2000	4.98	3.66	4.93	3.58	4.68	3.35	na	na	na	na	na	na
Avg	**5.78**	**3.91**	**4.60**	**3.04**	**4.60**	**2.81**	**4.88**	**3.08**	**6.71**	**4.72**	**6.85**	**5.04**

Table 3. Average daily pumping (mgd) of Wells 22, 23 and 24 in Waikolu valley from January 1988 through April 2001.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1988	0.77	0.72	0.96	0.96	0.96	1.44	0.96	0.96	1.44	1.44	1.20	0.96	**1.06**
1989	1.44	1.20	0.96	0.96	1.20	0.96	0.96	0.96	0.96	0.96	1.20	0.00	**0.98**
1990	0.00	0.00	0.00	0.00	0.00	0.96	0.96	0.96	0.96	0.96	0.96	0.96	**0.56**
1991	2.11	1.34	1.34	1.34	1.34	1.35	0.65	0.00	0.00	0.00	0.00	0.00	**0.79**
1992	0.00	0.00	0.00	0.01	0.01	1.38	2.35	1.10	0.33	0.71	1.41	0.00	**0.61**
1993	0.00	0.74	1.12	1.11	1.24	1.72	1.79	0.92	0.82	1.05	0.00	0.75	**0.94**
1994	0.60	0.48	0.34	0.59	0.79	0.79	0.49	0.68	0.84	0.81	0.59	0.60	**0.63**
1995	0.74	0.70	0.66	0.61	0.59	0.81	0.73	0.55	1.76	3.99	3.53	3.09	**1.48**
1996	1.34	1.64	1.01	0.80	1.15	1.01	0.34	0.85	2.64	3.41	3.19	1.30	**1.55**
1997	1.14	0.65	0.25	0.11	0.15	0.15	0.36	0.42	0.43	0.88	0.94	0.00	**0.46**
1998	0.00	0.00	0.14	0.32	0.34	0.35	0.35	0.35	0.35	0.34	0.11	0.03	**0.23**
1999	1.45	1.17	0.62	0.55	0.69	0.98	1.08	0.98	0.00	2.47	2.74	1.35	**1.17**
2000	0.97	0.29	1.20	1.30	0.13	1.25	1.30	1.30	1.30	1.30	0.87	1.30	**1.04**
2001	1.43	0.44	0.60	0.58									**0.77**
Avg	**0.86**	**0.67**	**0.66**	**0.66**	**0.66**	**1.01**	**0.95**	**0.77**	**0.91**	**1.41**	**1.29**	**0.80**	**0.88**

Table 4. Average diverted stream flow (mgd) collected from the diversion dams in Waikolu valley from January 1989 through September 2000.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1989	3.18	4.04	3.93	6.02	2.48	2.26	3.92	2.27	1.27	1.08	0.85	3.45	**2.90**
1990	4.95	8.08	6.46	2.75	5.75	3.82	2.06	1.57	1.74	2.39	5.01	5.89	**4.21**
1991	1.50	3.04	5.70	1.89	1.82	1.49	2.20	2.88	1.64	1.62	1.20	2.97	**2.33**
1992	1.99	2.86	2.28	0.95	3.39	1.56	0.96	1.34	2.97	2.29	4.21	5.08	**2.49**
1993	3.93	1.74	3.43	4.35	3.81	2.19	4.08	2.64	1.93	2.52	5.24	3.27	**3.26**
1994	4.65	5.05	6.18	5.61	3.76	3.93	3.80	2.79	2.91	1.68	4.04	4.27	**4.06**
1995	2.65	2.38	3.42	3.77	2.21	2.88	2.01	2.34	0.86	1.21	0.98	1.08	**2.15**
1996	1.78	2.98	2.58	2.88	1.52	2.32	3.17	2.00	0.13	-0.73	2.74	5.68	**2.25**
1997	3.67	2.16	5.13	2.62	3.42	3.50	3.67	1.92	2.31	1.62	4.93	4.98	**3.33**
1998	3.13	3.85	3.85	5.59	4.20	5.78	3.56	2.54	2.25	2.84	5.89	5.82	**4.11**
1999	3.29	4.54	5.40	4.57	2.36	2.72	3.72	2.80	3.26	1.74	2.14	4.87	**3.45**
2000	4.90	2.04	2.65	4.57	3.43	1.60	2.36	2.29	2.05				**2.87**
Avg	**3.30**	**3.56**	**4.25**	**3.80**	**3.18**	**2.84**	**2.96**	**2.28**	**1.94**	**1.66**	**3.38**	**4.31**	**3.12**

Surface Water Collection

The Waikolu tunnel begins at the east portal (21^o 8’ 37” north latitude and 156^o 55’ 16” west longitude) of the Waikolu valley at an elevation of 990 ft and exits in the west at Kaunakakai gulch (21^o 7’ 24” north latitude and 156^o 59’ 44” west longitude) at an elevation of 970 ft. Dams 1, 2 and 3 diverted waters flow by gravity to the tunnel, while water from Dam 4 requires pumping to the tunnel. The elevations for Dams 1, 2, and 4 are 1005, 997, and 730 ft, respectively. The elevation of Dam 3 was not found in the records, but it is higher than Dam 1. Dam 3 is located northeast of Dam 1 and diverts water from a tributary to Dam 1. Dam 1 is the southernmost dam and the primary diversion of the Waikolu stream. Water diverted from Dam 1 is transported via a 20-inch diameter pipe with a capacity of 15.5 mgd to the tunnel. Dam 2 diverts water from another tributary north of Dam 3. The gravity flow capacity is 4.3 mgd from Dam 2 to the tunnel. Above Dam 2 are three waterfalls. In times of high flow, the lower waterfall can pass over Dam 2, but Dam 4 on the lower section of the Waikolu stream captures this flow. Dam 4 is north of the other dams and 260 ft below the tunnel entrance; hence, the additional cost of pumping is required to capture this surface water. Dam 4 also captures the flow from Napuleloa spring, which is located between and across from Wells 5 and 6. The pump station at Dam 4 consists of three pumps (two 700 gpm and one 1,400 gpm pumps) that are activated by the water level switches.

The amount of water diverted from the Waikolu stream was calculated from the total tunnel's west portal flow by subtracting the water pumped from wells and groundwater intercepted by tunnel. From January 1989 to September 2000, the average diverted stream flow was 3.12 mgd with the months of December through April having higher than average flows (Table 4). The stream flows for 1990, 1994 and 1998 were above the historical average prior to dam construction measured by USGS gauge 4080 of about 4 mgd (Table 1), but the flows for all the other nine years were lower.

Wells and Groundwater Sources

The wells in Waikolu valley consist of Wells 4, 5, 6, 22, 23 and 24. The well pumping capacities, ranging from 800 to 1,250 gpm, are shown below.

Well	**Pumping Capacity (gpm)**	**MGD**
5	800	1.152
6	1,000	1.440
22	800	1.152
23	1,000	1.440
24	1,250	1.800
Total	4,850	6.984

Well 4 is only used to monitor the groundwater depth in the valley. The original 100 h.p. motor of Well 24 was replaced with a 125 h.p. motor to increase the original capacity of

1,000 gpm to 1,250 gpm. By order of descending elevation, Well 22 is in the tunnel at about 992 ft elevation, 400 ft deep and with the inlet suction at 703 ft elevation (287 ft head relative to the tunnel's east portal). Well 24 is located at 970 ft elevation (between the tributaries diverted by Dams 2 and 3 and next to the main Waikolu stream), 300 ft deep and with the suction inlet at 675 ft elevation (315 ft head). Well 23 is at 875 ft elevation (below Dam 2, below the tunnel and above Well 4), 300 ft deep and with the suction inlet at 614 ft elevation (376 ft head). Well 5 is at 795 ft elevation (south or above the Napuleloa tributary), 285 ft deep and with the suction inlet at 694 ft elevation (294 ft head). Well 6 is at 766 ft elevation (north of Well 5 and below the Napuleloa tributary), 205 ft deep, and with the suction inlet at 675 ft elevation (315 ft head).

The total capacity of the current pumps is about 7 mgd, which exceeds the estimated average available groundwater of about 2.5 mgd (Table 1) and the allowable pumping of 0.853 mgd. Therefore, all pumps cannot be operated more than 30% of capacity, otherwise the groundwater levels will decrease significantly when rainfall is insufficient to recharge the dikes. However, the pumping permit will only allow operation up to 12% of full capacity. Analysis of Wells 4, 23 and 24 data (Water Resource Associates, 1999) for the period April 12, 1996 to November 30, 1997, shows that recharge occurred rapidly on the day after a rainfall and with additional recharging 5 days after the rainfall (Appendix D). The change in water depth (D) in Well 4 was significantly correlated to pumping (P) of Wells 22 and 23 and rainfall (R_1) at Waikolu for the 0.05 level of variable entry and rejection using stepwise regression. At the 0.10 rejection level, rainfall 5 days after its occurrence (R_5) was included in the regression model but not for variables of 2, 3, 4, 6 or 7 days after the rainfall event. The resulting regression equation was

$$D = 2.698\ R_1 + 0.8376\ R_5 - 9.31\ P - 33.16$$

where D is depth in ft, R_1 and R_5 are rainfall in inch, and P is pumping in mgd. The correlation coefficient (r^2) was 0.33 and significant at the 0.01 level.

Pumping output from January 1988 to April 2001 averaged 0.88 mgd (Table 3). The pumping per month ranged from 0 to 4 mgd. The period of high pumping was from September through November with an average of 1.2 mgd, while pumping was low in from January through May. Months with no pumping occurred because of electrical failure, inoperable pumps or when diverted stream flows were adequate to meet current demand.

Tunnel

The transmission system begins from the east portal with a 5.1 mile-long tunnel. The tunnel is 8 ft x 8 ft horseshoe-shaped with a concrete base and 1.5 ft high walls. The remainder surface area of the tunnel is unlined and can intercept and collect groundwater. This occurs mainly in the first 0.9 mile from the east portal. The tunnel slopes down from east to west. The first 0.9 mile is sloped 0.1% then 0.065% slope for 4.2 miles to the west portal. The tunnel is the only route to travel by car to Waikolu valley for equipment and facility maintenance. The flows entering the east portal (USGS station no. 16405100) and exiting the west portal (USGS station no. 16405300) are measured with USGS flow meters. The west portal flow measures the total flow from Waikolu available to central Molokai. DOA has flowmeters, but notes in the DOA files indicated that the data were unreliable. The average flow leaving the west portal from 1989 to 2000 was 5.8 mgd with a low of 4.6 mgd and a high of 6.8 mgd (Table 4). The consistency of the total flow was due to balancing the low stream flow with additional pumping by the MIS manager.

The difference between the west and east portal flow measurements, when Well 22 is not running, is the amount of groundwater intercepted by the tunnel. The average amount of tunnel groundwater was 1.78 mgd for 1989 to 2000 (Table 5). No significant relationship of flow relative to month was observed in this data in contrast to the diverted stream flow and time relationship. The tunnel groundwater flows appear to be lower in 1999 and 2000 than in previous years.

Table 5. Estimate of the average daily groundwater flow (mgd) contributed by tunnel sources from 1989 through 2000.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1989	1.83	1.87	2.22	2.26	2.76	2.65	2.62	2.30	2.25	2.22	1.64	1.95
1990	2.04	2.20	2.26	2.22	2.27	2.20	1.96	2.00	2.13	1.67	1.78	2.07
1991	1.71	1.68	2.13	1.75	1.81	1.81	1.96	1.84	1.60	1.76	1.73	1.56
1992	1.47	1.67	1.70	2.11	1.58	1.54	2.18	1.31	1.50	1.47	1.75	1.45
1993	1.49	2.09	1.67	1.78	1.75	1.93	1.96	1.67	1.78	1.69	1.74	1.64
1994	1.86	1.77	2.13	1.82	1.45	2.14	1.97	0.95	1.75	2.15	3.84	3.27
1995	2.59	2.31	1.77	1.84	1.86	2.10	1.40	1.49	1.87	1.65	1.29	0.99
1996	0.94	1.18	1.14	1.02	0.90	0.69	0.65	0.56	1.47	1.68	1.77	1.75
1997	1.73	1.46	1.86	1.97	1.72	1.71	2.50	1.95	2.09	1.95	1.96	1.87
1998	1.83	1.62	1.51	1.85	1.71	2.14	2.53	1.92	2.37	2.29	3.05	1.91
1999	1.56	1.54	1.67	1.48	1.36	1.41	1.40	1.44	1.39	1.33	1.32	1.47
2000	1.89	1.33	1.30	1.64	1.42	1.33	1.32	1.34	1.33	na	na	na
Avg	**1.74**	**1.73**	**1.78**	**1.81**	**1.72**	**1.80**	**1.87**	**1.56**	**1.79**	**1.81**	**1.99**	**1.81**

Operation of Well 22 pump, which is in the tunnel, was observed by the MIS manager to reduce the amount of groundwater intercepted by the tunnel. No measurements were found to verify this observation. It is recommended that the DOA take measurements to determine the optimum amount of pumping that can occur without significantly decreasing tunnel-intercepted water. The current pumping schedule is based on the experience of the MIS manager to maximize tunnel groundwater while minimizing the cost of pumping. The study by Water Resource Associates (1999) indicated that pumping water from Well 22 had no effect on the groundwater depth of the monitoring Well 4 and should probably not affect the yields of the other wells in Waikolu valley.

Transmission System

From the tunnel's west portal, the water travels by gravity 1,600 ft in a covered concrete flume. The purpose of the flume instead of a pipe was said to insure that the water be used for agricultural purposes and not for drinking. The water thereafter travels by pipeline to the Kualapuu reservoir. The flume is connected to 4,400 ft of 26-inch diameter steel pipe, 950 ft of 48-inch diameter C.I. 25 X-S RCPP pipe, 8,400 ft of 30-inch diameter C.I. 50 and C.I. 150 RCPP pipes, and 6,600 ft of concrete pipe (Kahane, 1987). A six-inch diameter pipe from the Molokai Ranch mountain system provides a connection to the MIS to allow injection of surplus water at the junction where the two systems cross. About 0.2 to 0.3 mgd of Molokai Ranch water is metered and added to the

MIS. The Kaluakoi Well 17 injects up to 2.37 mgd of water in the MIS transmission pipeline prior to the Kualapuu reservoir.

Kaluakoi Resort rents the right to use the MIS pipeline. Water is injected into the MIS at Well 17 and removed in central Molokai. The maximum allowable amount of water that can be removed by Kaluakoi is 2 mgd by contractual agreement. Kaluakoi was required to install accurate flowmeters to measure the inlet and outlet flows. In addition, frequent water quality analysis was required. The amount of water pumped into the MIS by Well 17 is required to be 110% of the amount removed by Kaluakoi in central Molokai. Kaluakoi uses some of the water for drinking, but the MIS water was intended for agricultural use only. This agreement with the State of Hawaii was intended to be temporary until Kaluakoi could install a separate pipeline. However, the construction of the pipeline met community objections; hence, it was never built. Records of daily and weekly reports from the MIS manager indicate regular replacement of water by Kaluakoi into the MIS (Appendix C). The daily reports from March 6, 2001 to September 9, 2001 show that Well 17 operated every day except two days injecting water into the MIS. The records of the amount of water removed by Kaluakoi was incomplete in the DOA records for this period but show daily removal of water from July 16, 2001 to September 4, 2001 at about 0.57 to 4.70 mgd where the amount exceeded the allowable maximum of 2 mgd on 7 days or 22% of the period. The weekly reports from December 25, 1999 to March 5, 2001 also show that Well 17 ran every week but record of Kaluakoi removing MIS water was not available in the DOA files at Honolulu.

The water from the transmission pipeline is fairly clean, is protected from evaporation, and leakage losses are minimal. It then enters the Kualapuu reservoir, which has high evaporation losses, possible seepage losses and water quality problems related to sediments, algae, animals (fish and snail) and organic matter. A bypass valve exists near the Kualapuu reservoir inlet to allow direct flow of water into the distribution system to the customers. This valve is not normally used because of excessive pressure that can damage low-pressure irrigation systems, and the MIS lacks a pressure-regulating valve. The static head difference from the west portal to the bottom of the reservoir is estimated to be about 200 ft or 88 psi, which might be feasible for generation of hydroelectricity.

This was previously studied. The generators would need to be located near the reservoir inlet where the spent water can flow by gravity into the reservoir and with the reservoir height providing enough water pressure for the customers. The water usually flows into the Kualapuu reservoir before being delivered to the customers. Clean water is imperative to enable the use of efficient drip irrigation systems. Sprinkler irrigation systems will result in high evaporation losses and distorted distribution patterns due to windy conditions at Hoolehua and Kualapuu in central Molokai.

<u>Kualapuu Reservoir</u>

The Kualapuu reservoir (inlet at 21° 9' 19" north latitude and 157° 2' 44" west longitude) is a 2,000 ft by 2,000 ft by 54 ft deep earthen-embankment reservoir lined with a 1/32 inch thick, nylon reinforced and butyl rubber sheets. Construction was completed in 1969. The inlet elevation is at 821 ft, and the outlet at 770 ft. It has a surface area of about 130 acres when full and can hold about 1.4 billion gallons of water. When full, it can supply most of the annual water consumed, which ranged from 1.2 to 1.9 billion gallons during 1990 to 2000 (Figure 2).

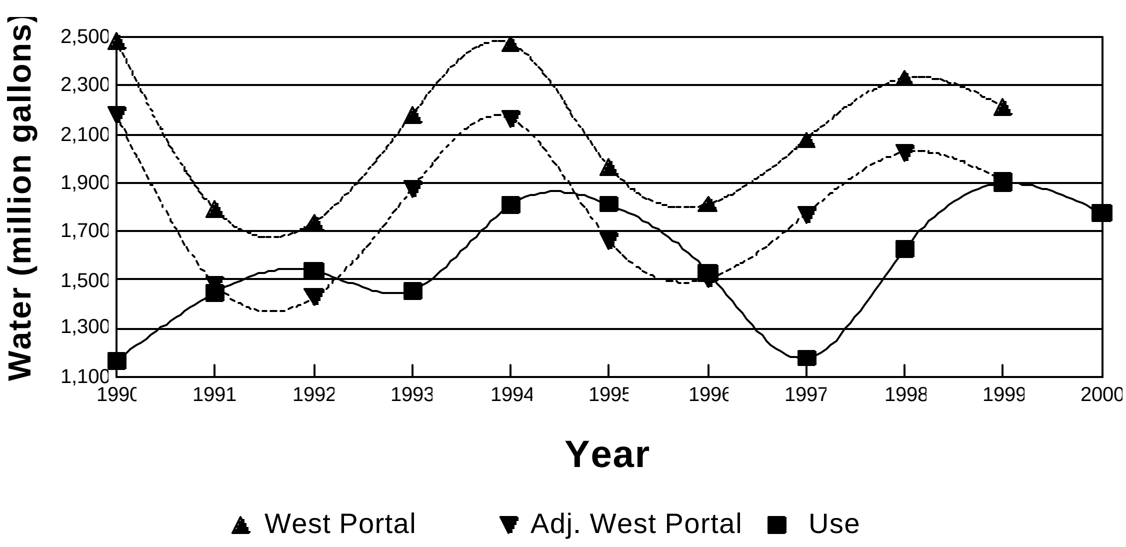

Figure 2. Annual total water from the tunnel's west portal from Table 2, the west portal amount adjusted for evaporation loss of 0.31 7inch per day, and water use (million gallons) from 1990 through 2000. No storage in the Kualapuu reservoir when the use exceeds the adjusted west portal amount.

Observations on August 15, 2001 found the rubber lining to be damaged beyond repair above the 8-ft water level. The condition of the lining underwater was not known. The amount of water seepage loss from the reservoir is thought to be low, but hasn't been measured. A rough estimate of the expected water storage from 1990 through 1999 suggested significant losses due to seepage or other causes. Assuming storage is equal to the difference between the west portal flow, evaporation losses (at 0.31 inch per day) and customer use, the cumulative storage is estimated at 2.5 billion gallons of water. The calculated cumulative storage suggest that the reservoir should be full instead of nearly empty. Seepage should be measured to determine whether relining or resealing of the reservoir is necessary. Hawaii soils are usually difficult to seal because of their normal stable and porous structure, hence significant seepage is expected if the lining is damaged. Seepage losses may exceed 3 mgd if the lining on the bottom is damaged.

Most reports suggest that most of the water loss from the reservoir is due to evaporation from the large 100-acre surface area, with warm temperatures (annual maximum temperature of 85 ^{o}F from 1991 through 2000 in Table 6) and high winds (data not found at the reservoir). At the Molokai Airport, a very high wind velocity of 16 to 31 mph (DLNR, 1966) was recorded 58% of the time. Pan evaporation measurements were made from May 1970 to June 1989 at the reservoir until the gauge was stolen on June 22, 1989 (Table 7). From 1977 to 1984, the highest and lowest monthly average daily pan evaporation readings were 0.47 inch per day for July 1981 and 0.18 inch per day for January 1983. The annual daily average for 1977 to 1984 was a very high 0.31 inch per day. Most irrigated agricultural areas in Hawaii have annual pan evaporation averages of about 0.22 to 0.25 inch per day (the average at Kunia, Oahu is 0.22 inch per day). The calculated losses due to evaporation of 0.47 and 0.18 inch per day from 100 acres of water are 1.276 and 0.489 mgd. The expected loss by evaporation is 307 million gallons of water per year based on the annual average evaporation rate of 0.31 inch per day. Bypassing the reservoir and injecting transmission pipeline water directly into the distribution system has the potential of saving 1.276 mgd of water or 22% of the average daily flow of 5.8 mgd from the west portal. At $0.255 per 1,000 gallons, this water saving will increase DOA revenues by $325.38 per day or $9,760 per month assuming all of the extra water is used by the customers. This additional revenue can offset some of the cost of electricity to pump water in Waikolu, which is about $10,000 to $25,000 per month.

The benefit to the farmer in times of drought will be several times more significant than that for DOA.

Another idea by Paul Matsuo of the DOA is to divide the large reservoir into smaller compartments that can be covered to reduce evaporation. This study is recommended to determine the cost and how it can be accomplished without significantly reducing the total storage capacity of the reservoir.

Table 6. Minimum and maximum temperatures (^{o}F) at Kualapuu reservoir from May 1991 to May 2001.

	Jan		Feb		Mar		Apr		May		Jun	
Year	**min**	**max**	**min**	**max**	**min**	**Max**	**min**	**max**	**min**	**max**	**min**	**max**
1991	na	na	na	na	na	Na	na	na	60	90	na	na
1992	na	na	58	78	58	70	62	84	64	94	64	86
1993	52	76	56	78	62	80	64	80	62	82	68	88
1994	52	88	58	85	58	88	58	82	61	88	61	82
1995	54	88	na	na	na	Na	na	na	61	87	64	89
1996	58	89	53	89	na	Na	na	na	na	na	na	na
1997	49	80	51	86	51	82	52	83	54	78	61	76
1998	47	82	47	80	50	82	53	78	54	75	na	na
1999	49	82	47	82	50	84	51	82	54	82	54	82
2000	53	82	50	82	50	82	51	75	53	87	56	89
2001	50	82	50	83	51	85	53	82				
Avg	**52**	**83**	**52**	**83**	**54**	**82**	**56**	**81**	**58**	**85**	**61**	**85**

	Jul		Aug		Sep		Oct		Nov		Dec		Annual	
Year	**min**	**max**	**min**	**max**	**min**	**Max**	**min**	**max**	**min**	**max**	**min**	**max**	**Min**	**max**
1991	66	84	na	na	na	Na	62	86	62	84	62	84	62.4	85.6
1992	66	88	68	82	66	90	64	86	64	84	60	88	63.1	84.5
1993	62	90	61	88	64	92	62	92	61	88	58	88	61.0	85.2
1994	64	85	71	88	64	95	64	92	63	88	58	85	61.0	87.2
1995	66	88	67	88	61	94	64	94	63	92	57	90	61.9	90.0
1996	na	na	61	na	na	Na	na	na	53	88	49	84	54.8	87.5
1997	58	87	57	85	58	87	58	89	54	87	51	82	54.5	83.5
1998	57	82	57	86	59	79	56	85	54	86	50	82	53.1	81.5
1999	55	82	58	82	60	84	54	82	55	82	53	82	53.3	82.3
2000	57	85	57	85	54	90	57	89	51	84	50	82	53.3	84.3
2001													51.0	83.0
Avg	**61**	**86**	**62**	**86**	**61**	**89**	**60**	**88**	**58**	**86**	**55**	**85**	**57.2**	**85.0**

Shrub (haole koa) and tall grass (California grass) weeds were recently cut to clear the banks and reduce a source of water loss. Frequent maintenance of the interior banks will be required especially to keep haole koa under control. Cutting alone will suffice in drought conditions, but herbicides, such as triclopyr (Garlon) and glyphosate

(Rodeo), may be necessary under normal rainfall conditions. This could be done using a cut-surface or spot-bark treatment on haole koa to minimize potential contamination of the reservoir water. Rodeo will be effective on grass weeds but not on haole koa. Herbicides can be used if the MIS water is not used for drinking by Kaluakoi.

The interior banks of the reservoir were highly eroded when observed on August 15, 2001. Efforts were made to stop the erosion by spray coating protective materials on the banks and planting bermudagrass. Most of the bermudagrass did not survive the drought. Bermudagrass is inexpensive but will require valuable irrigation water to maintain. Other methods to reduce bank erosion should be investigated. The erosion suggests that the bottom of the reservoir may have mud, which is expected to reduce the amount of water storage capacity, but more importantly it will adversely affect the water quality. The sediment layer may be less than 4 ft thick from the observation of the MIS manager when the reservoir depth readings were less than 5 ft. In letters to DOA, some users indicated that their irrigation systems were perhaps fouled by mud.

Table 7. Pan evaporation (inch) at Kualapuu reservoir from January 1977 through March 1984. The raw data sheets in the DOA files had many errors but were amended by an unknown person in colored pencil. The corrected data were used. Some months had more than 31 days, which suggests that data from an adjacent month was included in that total. Pan readings were found from April 1984 to June 1989, but the raw gauge readings were not summarized, hence the data were not used.

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yr
1984	Total	8.914	na	11.803	na	na	na	na	na	na	na	na	na	
	Days	31	na	30	na	na	na	na	na	na	na	na	na	
	PE/day	0.29	na	0.39	na	na	na	na	na	na	na	na	na	na
1983	Total	5.510	6.446	9.174	11.373	11.720	13.886	na	13.520	11.533	na	7.582	na	
	Days	31	28	31	29	31	30	na	31	30	na	30	na	
	PE/day	0.18	0.23	0.30	0.39	0.38	0.46	na	0.44	0.38	na	0.25	na	**0.33**
1982	Total	na	3.410	6.760	9.120	9.550	9.990	11.388	11.712	10.250	6.126	5.696	na	
	Days	na	18	26	29	28	32	30	30	29	22	25	na	
	PE/day	na	0.19	0.26	0.31	0.34	0.31	0.38	0.39	0.35	0.28	0.23	na	**0.31**
1981	Total	5.930	7.640	9.120	8.360	10.310	8.630	14.580	12.590	11.870	8.590	9.100	4.670	
	Days	27	27	29	27	30	24	31	30	30	26	32	19	
	PE/day	0.22	0.28	0.31	0.31	0.34	0.36	0.47	0.42	0.40	0.33	0.28	0.25	**0.34**
1980	Total	6.560	5.450	5.416	6.960	8.930	10.592	7.494	8.730	4.680	6.230	7.190	6.100	
	Days	31	27	19	27	30	28	22	26	16	20	29	29	
	PE/day	0.21	0.20	0.29	0.26	0.30	0.38	0.34	0.34	0.29	0.31	0.25	0.21	**0.28**
1979	Total	5.915	3.768	7.966	na	8.040	9.320	8.720	9.210	5.622	3.786	5.980	5.780	
	Days	24	16	27	na	27	22	22	24	16	13	22	27	
	PE/day	0.25	0.24	0.30	na	0.30	0.42	0.40	0.38	0.35	0.29	0.27	0.21	**0.31**
1978	Total	6.076	5.476	7.962	10.221	11.658	10.648	10.120	8.506	9.004	9.324	7.126	6.673	
	Days	24	24	28	28	31	27	28	27	28	29	28	28	
	PE/day	0.25	0.23	0.28	0.37	0.38	0.39	0.36	0.32	0.32	0.32	0.25	0.24	**0.31**
1977	Total	5.280	7.666	9.348	8.906	12.750	9.214	9.860	8.730	8.600	6.650	6.270	6.630	
	Days	22	30	27	27	33	26	28	25	29	24	28	32	
	PE/day	0.24	0.26	0.35	0.33	0.39	0.35	0.35	0.35	0.30	0.28	0.22	0.21	**0.30**
Avg	**PE/day**	**0.23**	**0.23**	**0.31**	**0.33**	**0.35**	**0.38**	**0.38**	**0.38**	**0.34**	**0.30**	**0.25**	**0.22**	**0.31**

The water quality problem was in part due to the location of the Kualapuu reservoir outlet to the distribution system. The outlet was located on the bottom of reservoir with a screen covering the opening, but was modified to extend off the bottom and has improved the water quality to the users. A floating outlet would be desirable to allow sediments to settle on the bottom and to skim the cleanest water at the surface. Y-strainer type screen filters were found next to the reservoir but were not being used, probably because of their high maintenance requirement for frequent back flushing. Back flushing also wasted a significant amount of water. Other water quality problems are associated with tilapia and snails living in the reservoir. Dredging the reservoir will be costly and probably not necessary unless to reseal the bottom and banks of the reservoir. Feasible alternatives may be chemical treatment to eliminate the fish and snails and a floating intake to avoid the sediments on the bottom. Chemical additives would make the water non-potable, however. Four feet of sediment will not significantly affect the storage capacity since the maximum height is 54 ft, and the deepest water depth since January 1975 was only 45.2 ft. The average water depth has been less than 23 ft since 1992 and less than 18 ft from 1996 to 2001. From the outlet, the water is distributed via 22 miles of pipeline to the customers. The distribution system after the reservoir was not evaluated in this study.

The reservoir depths from 1982 through 1985 and 1992 through 2001 were found in the DOA files. Data from December 25, 1999 through September 4, 2001 are shown in Appendix C. The lowest levels were recorded in November 1996, October 1999 and March 2001 with a minimum depth of 4 ft. Rainfall totals in 1996 were very low from May through October with only 2.1 inches, but November 1996 had the most rainfall of any month at the Kualapuu weather station. Rainfall annual totals at the reservoir for 1998, 1999 and 2000 were significantly lower at 7.97, 9.22 and 11.84 inches, respectively, than the 31-year average of 22.68 inches (Table 8a). The annual total for 1998 was the lowest ever recorded by this weather station, 1999 the second lowest and 2000 the sixth lowest. The frequency of rainfall events appears normal during the present drought from 1998 to present, but the amount per event was very small (Table 8b).

Table 8a. Monthly rainfall (inch) at Kualapuu reservoir from January 1970 through April 2001.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1970	0.00	1.35	0.13	0.83	0.00	0.04	1.37	0.24	0.19	0.14	6.24	0.83	**11.36**
1971	9.87	2.41	2.72	1.32	0.01	0.98	0.02	1.00	1.13	0.29	1.39	0.09	**21.23**
1972	2.56	6.53	4.89	0.66	0.10	0.89	0.16	1.22	0.21	2.44	0.89	3.09	**23.64**
1973	1.10	1.21	0.00	0.54	0.79	0.16	0.17	0.19	0.75	0.50	1.48	9.66	**16.55**
1974	6.58	1.49	5.16	0.65	1.37	0.45	0.76	0.30	0.67	0.48	3.41	0.62	**21.94**
1975	2.57	4.99	2.65	0.17	0.00	0.24	0.44	0.15	0.09	0.13	1.26	0.07	**12.76**
1976	0.19	5.81	4.54	1.45	0.07	0.50	0.44	0.69	1.54	0.21	1.96	0.29	**17.69**
1977	1.21	1.00	2.19	5.27	3.02	0.43	0.42	0.16	0.11	0.14	0.32	1.97	**16.24**
1978	0.80	0.68	2.36	1.36	4.66	0.83	0.14	0.14	0.23	2.83	4.03	1.52	**19.58**
1979	5.40	11.34	0.20	0.70	0.27	1.06	0.21	0.51	0.36	0.41	0.93	11.24	**32.63**
1980	11.94	3.77	1.85	1.75	1.53	2.21	0.31	1.04	0.36	0.65	0.06	6.52	**31.99**
1981	1.42	2.63	0.52	1.36	1.20	0.46	0.17	0.64	0.24	0.72	2.36	3.30	**15.02**
1982	13.46	3.69	3.13	3.68	0.00	0.63	0.70	0.50	1.01	5.76	1.77	6.34	**40.67**
1983	1.60	1.59	0.65	0.37	0.34	0.18	0.60	0.21	0.25	0.86	0.45	4.35	**11.45**
1984	1.98	1.30	1.53	0.78	0.44	0.00	0.06	0.54	0.26	0.03	1.37	1.93	**10.22**
1985	3.77	2.81	0.97	0.47	0.67	0.24	0.57	0.15	2.75	6.85	4.47	1.89	**25.61**
1986	2.00	3.45	2.84	0.72	0.34	0.55	1.09	0.11	1.14	1.75	1.13	10.95	**26.07**
1987	2.60	5.64	1.12	5.92	4.46	0.07	0.26	0.43	1.12	0.03	3.17	11.03	**35.85**
1988	5.66	1.24	1.15	0.37	0.22	0.44	0.16	0.23	0.69	0.28	3.42	7.66	**21.52**
1989	0.95	5.65	3.60	12.15	0.49	0.93	0.34	2.86	0.35	6.14	1.21	4.33	**39.00**
1990	5.46	10.11	4.13	0.45	2.16	0.86	1.09	0.44	0.67	0.90	7.76	9.32	**43.35**
1991	2.91	1.85	4.47	2.46	0.53	0.74	1.27	1.37	1.14	1.95	0.64	3.37	**22.70**
1992	3.11	1.01	3.68	0.47	7.17	0.75	3.29	1.26	2.09	3.88	8.37	4.17	**39.25**
1993	2.22	2.02	2.05	2.92	0.99	0.76	2.15	2.44	3.19	4.90	2.34	0.40	**26.38**
1994	1.46	5.82	2.67	0.75	0.06	0.38	0.44	0.06	0.91	0.01	0.14	0.35	**13.05**
1995	0.58	4.76	4.72	0.98	0.36	0.05	0.06	0.33	0.55	0.81	0.83	0.98	**15.01**
1996	6.30	2.97	1.97	1.45	0.55	1.31	0.00	0.10	0.14	0.00	11.98	5.91	**32.68**
1997	10.33	1.29	5.24	1.82	1.61	0.55	0.29	0.00	0.86	0.75	4.88	2.90	**30.52**
1998	1.73	0.61	0.78	1.77	0.40	0.00	0.14	0.09	0.26	0.06	1.99	0.14	**7.97**
1999	2.12	0.62	0.54	1.38	0.77	0.22	0.28	0.02	0.30	0.27	0.35	2.35	**9.22**
2000	0.93	0.10	1.11	2.19	0.13	0.13	0.35	2.06	1.18	0.29	3.17	0.20	**11.84**
2001	1.49	0.46	0.62	0.30									-
Avg	**3.57**	**3.13**	**2.32**	**1.80**	**1.12**	**0.55**	**0.57**	**0.63**	**0.80**	**1.43**	**2.70**	**3.80**	**22.68**

Table 8b. Rainfall events per month at Kualapuu reservoir from May 1991 to April 2001. Only weekday events were recorded.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1991	Na	na	na	na	4	na	9	na	na	7	2	8	**-**
1992	8	9	10	2	9	7	7	4	12	10	9	8	**95**
1993	11	8	11	12	6	7	10	9	10	9	10	4	**107**
1994	7	10	6	8	2	2	2	3	4	1	2	6	**53**
1995	3	8	11	11	3	2	4	8	1	4	5	4	**64**
1996	10	7	4	10	6	4	na	3	2	na	13	12	**71**
1997	16	5	10	8	6	6	4	0	4	7	15	14	**95**
1998	16	5	12	20	4	na	2	2	4	3	14	6	**88**
1999	4	6	6	7	6	5	7	1	1	2	na	11	**56**
2000	4	3	2	11	3	5	5	7	4	7	8	3	**62**
2001	6	7	8	4									**-**
Avg	**8.5**	**6.8**	**8.0**	**9.3**	**4.9**	**4.8**	**5.6**	**4.1**	**4.7**	**5.6**	**8.7**	**7.6**	

MIS OBJECTIVE AND SERVICE AREA

The four phases of the MIS project were designed for the irrigation of 8,900 acres of pineapple and 1,060 acres of diversified crops in Hoolehua and 7,500 acres of pineapple in Mauna Loa for a total of 17,460 acres in central Molokai (Parsons, Brinckerhoff-Hirota Associates, 1969). Even though the area in Mauna Loa was never connected to the MIS and there is no acreage in pineapple, the current acreage on the system is water-short because only Stage I of the MIS project was completed. The shortage is primarily due to an increase in diversified crop production in central Molokai and partially because of misassumptions used in estimating the water use for diversified crops in the original design. The water use design criterion was based on annual averages of 1,400 and 4,000 gallons per acre (gpa) per day for pineapple and diversified crops, respectively (M&E Pacific, 1991). The amount for pineapple was based on experimental data while that for diversified crops was estimated using the modified Hargreaves method (DLNR, 1966). The Hargreaves method is expected to underestimate the evapotranspiration because wind speed is not included in the model, and the calculation is based on only temperature and solar radiation data. Wind speed is a significant component affecting evapotranspiration, especially in central Molokai. I-Pai Wu (University of Hawaii) and R. Meinzer (Hawaii Agriculture Research Center) measured the consumptive uses of 0.7 ratio of pan evaporation (panfactor) for both lettuce and coffee, respectively (personal communications). The 4,000-gallon amount for diversified crops is adequate where the annual average pan evaporation is about 0.21 inch per day, as for most agricultural areas in Hawaii. But this is low for central Molokai with an annual average pan evaporation of 0.31 inch per day. The optimum is closer to 5,900 gpa per day in central Molokai. Another assumption was that only half of the available area would be in crop production at any given time. That may be true for vegetable and grain crops but not for perennial crops such as banana and coffee.

Water requirement is estimated at 27.2 mgd for 17,460 acres and 13.6 mgd for 8,730 acres under cultivation with the assumptions of 16,400 acres of pineapple at 1,400 gpa per day and 1,060 acres in diversified crop at 4,000 gpa per day. Excluding the 7,500 acres in pineapple at Mauna Loa, the expected amounts of water are still high at 16.7 mgd for 9,960 acres (8.35 mgd for half the area). Without the area in Mauna Loa and the Hoolehua area all in diversified crops, the 9,960 acres at 4,000 gpa per day will require 39.8 mgd (19.9 mgd for half the area). At 5,900 gpa per day, water needs are 58.8 mgd for the total area (29.4 mgd for half of the area). These amounts will be reduced if there is creased rainfall and in the cooler winter periods.

The current area, as of August 1, 2001, under the MIS is 2,931 acres. The majority of this is potential diversified crop acres. The actual acres under cultivation are not known. A maximum of 11.7 mgd is required for 2,931 acres at 4,000 gallons per day. Only 1,450 acres can be supported with 5.8 mgd (the annual average daily west portal flow), and 1,850 acres with 7.4 mgd (the maximum average flow possible from Waikolu). For central Molokai, the consumptive use of 0.7 panfactor is equivalent to about 0.217 inches per day or about 5,900 gpa per day assuming an annual average of 0.31 inch per day of pan evaporation. The 0.7 panfactor will increase the amount of water required for 2,931 cultivated acres from 11.7 to 17.3 mgd or support only about 983 and 1,254 cultivated acres with 5.8 and 7.4 mgd. It is clear that the MIS cannot provide sufficient water all the time to all customers in the current service area of 2,931 acres. It could service 49% of the acres when west portal flow is 5.8 mgd, assuming an average consumptive use of 4,000 gpa per day. Servicing more than 1,450 cultivated acres will require a reduction in water loss, water conservation, more pumping in Waikolu valley and the addition of new water sources to MIS. Additional pumping to a maximum of 2.5 mgd may provide sufficient water to meet current water use needs. However, additional pumping may not be sustainable if the present prolonged drought (starting in 1998) continues and reduces groundwater in Waikolu valley.

ADDITIONAL WATER FROM THE EXISTING SYSTEM

A three-fold approach should be considered to increase the usable water from the existing system: (1) increase pumping in Waikolu valley up to the sustainable yield of about 2.5 mgd, (2) reduce system losses, and (3) have farmers use water more efficiently.

Pumping

The records indicate that there are three primary wells in the system: 22, 23 and 24. However, Well 22 has not operated since August 23, 1997. Thereafter, pumping was primarily from Wells 23 and 24. No records were found for Wells 5 and 6. From November 26, 1995 to April 1, 2001 the downtimes due to mechanical and electrical failures for Well 22, 23 and 24 were estimated from weekly reports to be 1,557, 438 and 409 days, respectively or 46, 13 and 12% (Table 9). Scheduling preventative maintenance to reduce downtime is important to be able to rotate pumps (as intended by DOA) to allow wells to recharge for maximum output.

Table 9. Pump failures for Wells 22, 23 and 24 from December 1991 to April 2001 for a total of 3,409 days. Out of order = out. Despite problems, pumping was adequate to deliver 0.88 mgd or more than the allowable amount of 0.744 mgd.

Period		Well 22	Days	Well 23	Days	Well 24	Days	Comment
11/26/95	12/20/95	out	24					
1/5/96	3/9/96	out	64					
5/27/96	8/24/96	out	89					
3/17/96	5/14/96	out	58					
3/17/96	9/10/96			out	177			
12/8/96	12/13/96	out	5	out	5			
8/23/97	4/1/01	out	1,317					8/23/97 last day Well 22 on
8/24/97	9/13/97	-		out	20	out	20	No power, telemetry failure
11/30/97	3/18/98	-		out	108	out	108	No power, telemetry failure
12/22/99	2/21/00	-		out	61			
2/22/00	3/13/00	-		out	20	out	20	
3/20/00	11/22/00	-				out	247	
10/30/00	12/2/00	-		out	33			
2/26/01	3/5/01	-		out	7	out	7	No power
3/5/01	3/12/01	-		out	7	out	7	No power
Total day out			1,557		438		409	
% Not operating			46		13		12	

The well permits must be amended to allow pumping in excess of a moving average of 0.853 mgd. The average sustainable yield is estimated at 2.5 mgd. Pumping records and the water depth in Well 4 should be monitored and studied on a timely basis to prevent using too much of the groundwater. The effect of reduced downstream flow on the aquatic macrofauna as a result of over use must also be considered. The Water Resource Associates (1999) found that pumping of 1.55 and .46 mgd in 1996 and 1997, respectively, did not adversely impact the habitat of the Waikolu stream above Dam 1 and below the Napuleloa tributary. The study period from July through October of 1996 was the driest period to date in Waikolu valley and at Kualapuu reservoir. It is recommended that pumping in Waikolu valley not exceed 1.55 mgd to avoid the need for an additional environmental impact study.

It is highly desirable to download the pump operation, flowmeter and weather electronic data from Waikolu valley to a database or spreadsheet for easy data analysis. In addition, the dataset should include electrical use, reservoir depth, weather data at Kualapuu, and customer use to monitor compliance with the pumping permits, the Kaluakoi Resort contract and the DHHL two-thirds preference law. The digitized data also need to be archived for trend analyses. Currently, the data in the file cabinets are very difficult to use for making timely management decisions or for long-range planning.

In times of high rainfall and sufficient diverted stream flow in Waikolu valley, the pumps were set to shutoff automatically to minimize pumping cost. Instead, pumping should be maximized during the wet season. There would then be no danger of over-pumping the groundwater or adversely affecting stream flows as there is with pumping during the dry season. It will be essential that water storage losses be minimized so adequate water will be available in the reservoir for the dry season. The water not pumped in Waikolu valley is expected to overflow the dikes and presumably be lost downstream below Dam 4, the lowest stream diversion.

Besides the pumping permit, another limiting factor to more pumping is the high electricity cost. The cost for DOA to generate electricity should be investigated and compared to purchasing power from the utility company. Several farmers in the State find it more cost-effective to generate electricity rather than to purchase power from the utility. Another possibility is to find more energy efficient pumps, although electric pumps are usually very efficient and allow simpler remote control. The least acceptable alternative is to pass the cost on to the consumer. However, this may be preferable to no crop production in times of drought and for high value crops. One user pays $1.45 per 1,000 gallons for potable DHHL water for irrigation when MIS water at $0.25 per 1,000 gallons is insufficient.

System Losses

System losses can occur from diversion blockage, dam and pipeline leakage, reservoir seepage, faulty meter readings, inadequate maintenance and evaporation. Reduction of losses is probably the most cost-effective method for increasing the quantity of available water. The prerequisite is more water intensive management and maintenance of the entire system. Sufficiently trained personnel will be required to accomplish this goal. The current DOA staff on Molokai of a manager and two maintenance persons maintains the MIS, reads meters and services customers but are not trained as technicians. Budget cuts reduced the staff from five to three in 2000. The optimum MIS staff needs to be balanced with maximizing the amount of water from the entire system. One task considered urgent by the current staff and some customers is checking and replacing defective flowmeters.

Considerable losses can occur with obstruction by debris of the dam's collection grates. It is important to clean the grates prior to and during periods of expected high rainfall and runoff. Detection of blockage may be possible with the installation of accurate flowmeters on the pipes from the dams to the tunnel or with cameras at the dams linked electronically by the telemetry system to the MIS office. The current flow measurement in Waikolu valley is only taken at the east portal near the tunnel entrance. The large weir in use is not intended to detect small changes in flow, which can result in significant amount of undetected water lost over extended periods. The current manual detection requires frequent visits to Waikolu valley. Each visit takes about 90 minutes (travel-time and dam inspection of 60 and 30 minutes, respectively). Two staff members are usually required for safety reasons on a visit to the isolated Waikolu valley. The cost of electronic detection should be weighed against the value of the additional collected water and the labor cost of three worker-hours per visit.

Dams 1 and 4 were observed to have leaks on August 15, 2001. The magnitude and significance of these leaks in the diversion dams need to be evaluated. In addition, the lower waterfall is said to fall beyond Dam 2 during high runoff flow. Although Dam 4 captures this water downstream, it needs to be pumped to the tunnel. Water can be captured more efficiently and transported without pumping at Dam 2 if the angle of the falling water could be altered to fall before and not over Dam 2. Perhaps this can be accomplished by reshaping the rock-face of the lower waterfall with explosives. Another more expensive option is to modify Dam 2. Reshaping or reconstruction costs need to be weighed against pumping cost at Dam 4.

System leaks in the tunnel and transmission pipeline were not observed nor were any records of such losses found. One possible source of leakage is from cracks in the tunnel cement lining that bear the weight of the Jeep used to travel to Waikolu valley. It is recommended that this lining be visually inspected regularly. Seepage losses could occur through the concrete lining in the transmission tunnel and Kualapuu reservoir. Elsewhere in the system, water is contained in nonporous flumes or in pipes. The tunnel lining has a surface area of about five acres where a 0.1 inch per hour seepage loss is equivalent to about 326,000 gallons per day. The water permeability of the 35-year old concrete is not known and should be measured to determine if a sealant is necessary.

The most probable leakage losses would be in the distribution system after the reservoir. There is an unresolved incidence of 0.4 mgd of water unaccounted for by Kaluakoi. Pipeline leaks could not be found (discussed at the MIS Advisory Board on August 15, 2001). Accurate flowmeters are necessary to detect these losses. Under Chapter 4-152 of the Hawaii Administrative Rules (DOA, 1989), the DOA shall determine the suitability of the flowmeter. The user is responsible for the cost of purchase and installation of the flowmeter. Calibration, service and replacement of flowmeters on a routine basis are necessary to accurately monitor the daily water use and detect losses. The user can request a meter check free of charge. The presumed water loss may be due to faulty flowmeter readings instead of a leak. It will be impossible to determine the true water use of the MIS customers with defective meters. This unrecorded “lost” may be more significant that leakage and seepage losses. The highest maintenance priority must be given to replacing defective meters on a timely basis. Each flowmeter requires at least biennial calibration.

It is not uncommon to have seepage losses in excess of one mgd in small reservoirs in Hawaii because of the highly structured (resist compaction) and well-drained soil. This is true of the Molokai soil series (an Oxisol) found at the Kualapuu reservoir. The seepage loss can be estimated by measuring the pan evaporation at the site (best to locate the pan in the water of the reservoir), estimating the water surface area (simplest by aerial photograph if a known area is in the photograph) and measuring the change in water depth over time. During the seepage measurement, it is desirable to keep water from entering or exiting the reservoir via the inlet and outlet since large capacity flowmeters are not accurate enough. This can be accomplished by diverting the transmission pipeline water directly into the distribution pipeline. The seepage losses can be estimated from the change of reservoir depth after subtracting the evaporation loss. DOA has qualified personnel to perform these measurements.

Pan evaporation measurements (open Class A pan) or evapotranspiration estimates (using automated weather stations with rainfall, temperature, solar radiation, relative humidity and wind data) are desirable to estimate evapotranspiration losses (consumptive use). The proper location of the weather station is important in accurately estimating the crop's water use requirement. The weather station should not be located near the reservoir where the evaporating water will affect the readings nor over bare soil where radiant heat can interfere with accurate readings. The weather station needs to be clear of tall obstructions and at a location that represents the crop's microclimate as close as possible. More than one weather station may be required. The data can be collected remotely, stored on data loggers and can be polled by telephone via connection by wire, radio or microwave. The weather station requires annual calibration. These data could be made available (poll station by telephone) to all MIS farmers in real time to determine the most efficient water use for optimum harvest yields. Determining how much and how to apply water is the first step in any water conservation effort. This will be a valuable service to the farmers. In addition, the DOA could provide feedback or develop incentives/disincentives for customers based on their water use and the normal expected evapotranspiration for the billing period. The digital weather data could be archived for use in crop models driven by weather information to determine optimum irrigation amounts and agronomic practices for optimal yields in central Molokai. New crops can be evaluated using the weather data and crop models to find alternative crops that are better adapted to the windy central Molokai.

Pan evaporation loss (Table 7) from the 100-acre reservoir surface is expected to be as much as 20% of the daily west portal flow (Table 2) during the hot summer months when water is least available. Oils and films covering the surface of the water have been used elsewhere with mixed success. A review of past studies would help to determine if this method is feasible and what material can be used to the reduce evaporation in Kualapuu reservoir. Kaluakoi currently uses the MIS water for drinking; hence, most chemicals cannot be added to the reservoir until a separate pipeline is constructed from Well 17 to Kaluakoi customers. It is recommended that the MIS water be only used for agricultural purposes.

The simplest means of reducing evaporation loss is to place the water from the transmission line directly into the distribution system instead of the reservoir. This will also bypass most of the water quality problems associated with the reservoir. The excess water from the transmission line must be placed into the reservoir to prevent the entire transmission system from backing up. An engineering solution would minimize manual control. Customers without pressure reducing valves must be warned of the higher water pressure with transmission water to prevent damage to low pressure drip irrigation systems. It is the users responsibility to reduce the pressure at their farm per DOA administrative rule Chapter 4-152, section 4-152-5. The user can use an inexpensive gate valve with a pressure gauge to reduce the pressure, but the drawback is that the user must manually adjust the gate valve with changing MIS pressures. An alternative is for DOA to install a pressure-regulating valve on the MIS transmission pipeline, which is expected to be costly. Higher pressures at the farm site can be an advantage for most farmers where smaller pipe diameters and longer irrigation lateral lengths could be used reducing the farm irrigation system cost. However, the higher pressure must be maintained otherwise poor water distribution and inefficient irrigation will result with pressures lower than the system’s designed operating pressure. Direct feeding through the bypass will help maintain pressures, especially during a drought when the static head in the reservoir is small due to shallow water depth.

A clean irrigation water source can lead to water saving. Less water will be used to back flush the irrigation system of contaminants. Back flushing takes 5 to 15 minutes for most filter stations. A 10-acre drip-irrigated system usually is designed to irrigate at about 30 gpm per acre. Flushing for 10 minutes can use 3,000 gallons per flush and up to four flush cycles per day may be required when the water is dirty resulting in a total loss of 12,000 gallons per day for 10 acres or enough to irrigate 3 acres. For 1,000 acres, flushing losses could be as high as 1.2 mgd. It is recommended that the DOA conduct a survey to document the number of users with filters, the actual flushing losses and problems related to water quality. In drip irrigation, clean water will result in less plugging of drip emitters, improved distribution uniformity, and higher production per unit of water.

Water Conservation By Improving the Irrigation Efficiency

Total water use by all MIS users by month from 1989 to 2000 is shown in Figure 3. Water use in the summer peaked at 5.5 to 9.5 mgd and was significantly more than during winter at 2.5 to 4.5 mgd. The water use during the summer usually exceeds the west portal flows (Table 2) resulting in lower depths in the Kualapuu reservoir (Appendix C). Conservation efforts are required even in the wet winter to increase water storage for the dry summer.

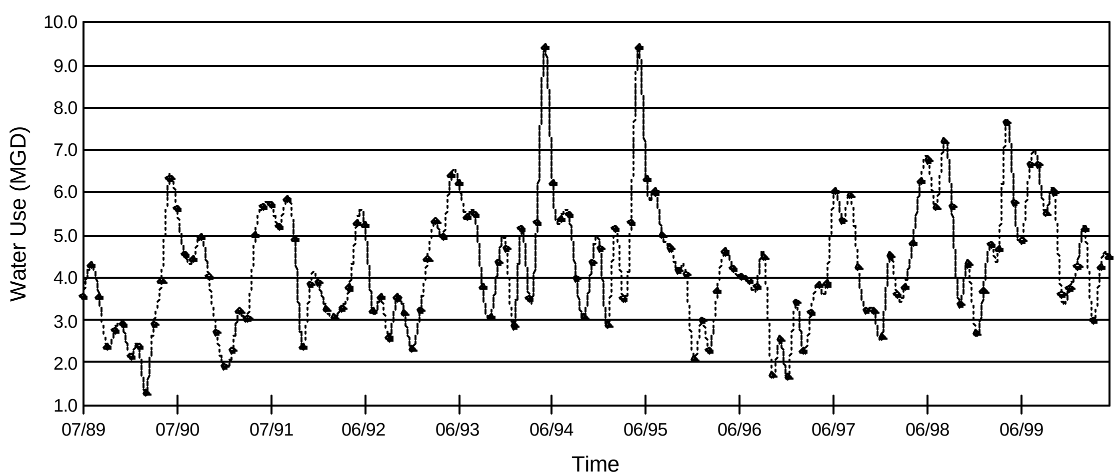

Figure 3. Daily average water use (mgd) for all MIS user meter readings from

July 1989 to April 2000.

Review of the farmer water use for June and July 2001 shows that some farmers were grossly over-irrigating or their systems had large leaks (Appendix E). If 50% of the account acres were assumed to be under cultivation, then 26 accounts exceeded the desirable amount of 0.7 panfactor in a time when the DOA recommended a water reduction of 30% (Table 10). The total area for 8 accounts with the highest use per acre was only 23 acres or 0.8% of the total acres but represented 10% of the total volume of water used for both months (Table 11). Assuming all acres were under cultivation, eight accounts exceeded 1.2 panfactor where the panfactor ranged from 1.26 to 3.20. This suggests a mismanagement of water or more acres being irrigated than the assessed acres. An audit of the actual acres irrigated against the assessed acres for selected accounts is recommended.

Table 10. Estimate of irrigation adequacy when farmers cultivate 100, 75 and 50% of the assessed acres, and the total amount of water used for the months of June and July 2001. Irrigation adequacy is expressed as a percent of the water applied to the estimated crop requirement of 0.7 panfactor where the pan evaporation was estimated at 0.38 inches per day for both months. The column for acres is for accounts assuming 100% of acres in cultivation.

Irrigation Adequacy	ET Class (Ratio of PE)	Number of Accounts for Percent of Acres Cultivated			Acres	Total Water Use	
		100%	75%	50%		Gallons	Percent
>100%	>0.7	8	10	26	23	23,639,000	10
75-100%	.525-0.7	2	12	15	7	2,511,000	1
50-75%	0.35-.525	16	20	17	174	50,474,000	21
<50%	<0.35	213	197	181	2,727	159,155,000	68
	Totals	**239**	**239**	**239**	**2,931**	**235,779,000**	**100**

Table 11. MIS water users exceeding the estimated crop requirement of 0.7 panfactor for June and July 2001. Calculations are based on a crop demand of 0.266 inch per day at 0.38 inch pan evaporation and assuming 100, 75 and 50% of acres under crop production. Panfactor is the ratio of applied water (inch per acre) to pan evaporation (inch).

		Water Use (gallons)			Calculated Panfactor		
Acct	**Acres**	**Jun 2001**	**Jul 2001**	**Total**	**100%**	**75%**	**50%**
5075	3	2,576,000	3,569,000	6,145,000	3.20	4.27	6.40
5212	2	1,050,000	1,128,000	2,178,000	1.70	2.27	3.40
5189	2	1,052,000	1,105,000	2,157,000	1.69	2.25	3.37
5240	2	755,000	1,218,000	1,973,000	1.54	2.06	3.08
5186	8	2,855,000	4,680,000	7,535,000	1.47	1.96	2.94
5257	2	704,000	906,000	1,610,000	1.26	1.68	2.52
5150	2	1,048,000	0	1,048,000	0.82	1.09	1.64
5168	2	436,000	557,000	993,000	0.78	1.03	1.55
5159	2	379,000	359,000	738,000	0.58	0.77	1.15
5040	5	662,000	1,111,000	1,773,000	0.55	0.74	1.11
5118	2	295,000	335,000	630,000	0.49	0.66	0.98
5256	2	213,000	395,000	608,000	0.48	0.63	0.95
5060	39	1,068,000	10,714,000	11,782,000	0.47	0.63	0.94
5069	90	12,941,000	14,101,000	27,042,000	0.47	0.63	0.94
5089	2	213,000	381,000	594,000	0.46	0.62	0.93
5120	2	293,000	299,000	592,000	0.46	0.62	0.93
5079	2	312,000	266,000	578,000	0.45	0.60	0.90
5232	2	281,000	264,000	545,000	0.43	0.57	0.85
5017	2	237,000	294,000	531,000	0.42	0.55	0.83
5244	2	298,000	230,000	528,000	0.41	0.55	0.83
5237	10	1,146,000	1,431,000	2,577,000	0.40	0.54	0.81
5234	2	178,000	334,000	512,000	0.40	0.53	0.80
5119	2	206,000	286,000	492,000	0.38	0.51	0.77
5170	10	1,053,000	1,273,000	2,326,000	0.36	0.48	0.73
5031	2	272,000	185,000	457,000	0.36	0.48	0.71
5000	3	317,000	363,000	680,000	0.35	0.47	0.71
Total	**204**	**30,840,000**	**45,784,000**	**76,624,000**			

The majority of users had 2 to 5 acres with 176 of 239 accounts falling in this size class. There were only nine accounts with more than 50 acres, but these had a total of 1,312 acres or 45% of all acres (Table 12). Only one large account (50-100 acres size) applied adequate amounts of irrigation. All of the other eight large accounts were irrigating at less than adequate amounts. Of the 239 accounts, 141 and 160 accounts had no water use in June and July, respectively. The lack of crop production may be related to the water shortage, too high temperatures for some cool climate vegetable crops, seasonality of operations as for the seed industry or low market prices.

Table 12. Number of accounts and water use of customers grouped by class-size of five-acre units

			June 2001		July 2001		Total	
Class	**#Acct.**	**Acres**	**#Users**	**Gallons**	**#Users**	**Gallons**	**Gallons**	**Gal./acre**
5	176	420	106	18,479,000	120	23,427,000	41,906,000	99,776
10	12	100	7	6,188,000	8	8,865,000	15,053,000	150,530
15	5	65	4	1,110,000	4	1,515,000	2,625,000	40,385
20	6	111	2	2,980,000	2	2,480,000	5,460,000	49,189
25	7	166	2	981,000	2	1,505,000	2,486,000	14,976
30	17	493	11	11,142,000	14	17,995,000	29,137,000	59,101
35	4	140	1	202,000	1	202,000	404,000	2,886
40	2	79	2	4,808,000	2	15,637,000	20,445,000	258,797
45	1	45	1	2,238,000	1	5,359,000	7,597,000	168,822
60	1	60	0	0	0	0	0	0
90	2	180	1	12,941,000	1	14,101,000	27,042,000	150,233
95	3	282	2	4,777,000	2	12,875,000	17,652,000	62,596
150	1	150	1	3,834,000	1	5,709,000	9,543,000	63,620
180	1	180	0	0	1	5,000	5,000	28
460	1	460	1	27,597,000	1	28,827,000	56,424,000	122,661
2-50	230	1,619	136	48,128,000	154	76,985,000	125,113,000	77,278
50-460	9	1,312	5	49,149,000	6	61,517,000	110,666,000	84,349

The DOA can help by providing evapotranspiration estimates for the farmer and notifying the users when use exceeds the norm. It would be beneficial to include on the water bill the amount of water necessary to meet evapotranspiration and compare to the amount used by the customer. The DOA can work in cooperation with University of Hawaii Extension Service to target individuals in need of education and assistance to make farming a profitable endeavor.

The conversion of sprinkler to drip irrigation is highly desirable in central Molokai because of the strong winds and high evaporation losses. Poor irrigation efficiencies with sprinkler irrigation are due to wind-distorted patterns and higher than Class A pan evaporation losses. Sprinkler-applied water can also adversely affect the germination of small seeds, decrease rainfall infiltration, and increase runoff and soil erosion due to soil surface crusting from water droplet impact. Besides conserving water, drip irrigation provides an efficient means of uniformly and frequently applying fertilizers. The limiting factor is the initial cost of a drip system, but the payback can be rapid if higher yields are achievable.

NEW SOURCES OF WATER

More water in Waikolu valley is not readily available other than by increased pumping from existing wells. DLNR map (Figure 4) suggest that only 0.7 mgd is available for development in Waikolu. More surface runoff water and groundwater are found in the Pelekunu and Wailau valleys but none are considered developable because of environmental and cultural obstacles. The northeast streams are considered to be some of the most pristine areas in Hawaii for native species such as the o'opu, hihiwai and 'opae. Environmental groups and individuals will object strongly in having any water diverted from these valleys. Two constraints to Pelekunu development as stated by M&E Pacific (1991) were its proposed kapu status and to it being the property of the Nature Conservancy. Some community members feel that development of this source of water may lead to unwanted urbanization of west and central Molokai and further displacement of the native Hawaiians. It is unlikely that a compromise can be reached among all the diverse groups. Hence, studying the development of this source is not recommended.

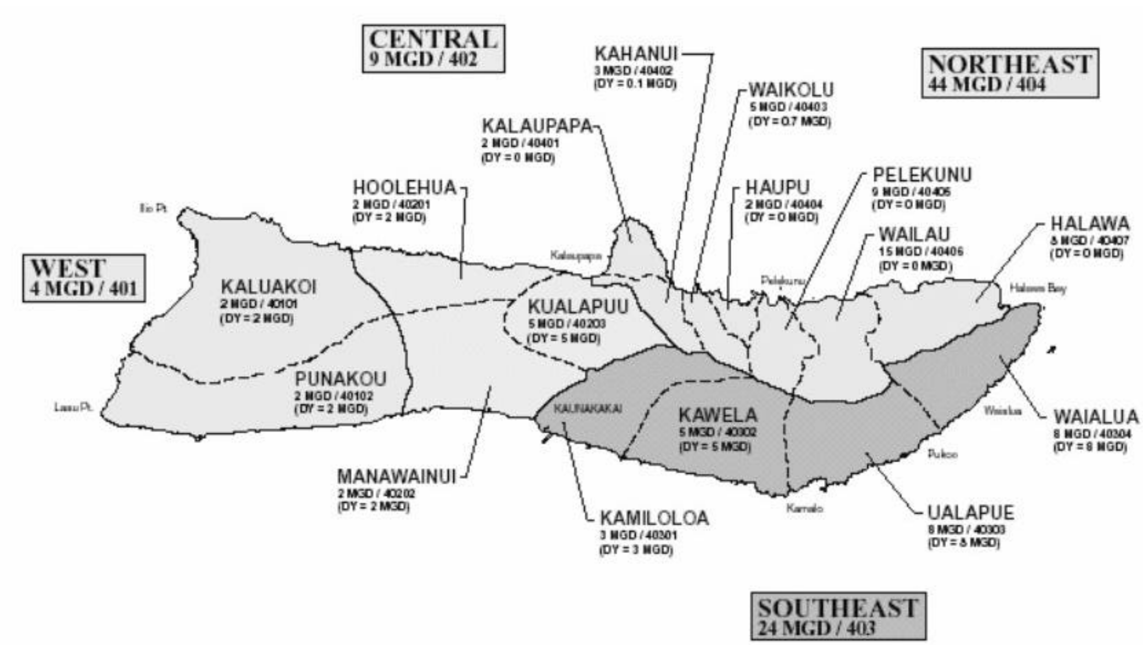

Figure 4. Sustainable yield/aquifer code for the Island of Molokai. DY = Developable yield. The sustainable and developable yields are estimated at 81 and 38 mgd. Source: DLNR map dated October 17, 1996.

The MIS Advisory Users Group, the Water Initiative Group and DOA have considered other water sources. Some new sources are: (1) capturing intermittent storm runoff, (2) low flow streams, and (3) brackish well sources. For the new source to be cost effective, the captured water should be above the MIS system to allow transmission of water by gravity instead of pumping. Possible runoff sources are from the higher reaches of Manawainui and Kaunakakai gulches. The flows of both gulches tend to be intermittent. Records of USGS stream gauges 4130 and 4120 for Manawainui and 4053 for Kaunakakai need to be studied to determine the available flows. Rough estimates are 0.8 mgd of divertible water from each gulch (communication with Paul Matsuo). The possibility of damming these gulches to allow recharge of groundwater for future pumping has also been considered.

Running a pipeline from the Kawela gulch at about the 1,000-ft elevation to the MIS is still being investigated by the DOA. Approximately 1.5 mgd of storm flows may be available for diversion consisting of overflow from Molokai Ranch's diversion. The water will be able to travel by gravity to MIS. This is currently the largest source available to the MIS.

Diversion of Waihanau stream was considered where about 0.5 mgd of stream flow is available for diversion. However, majority of the Water Initiative Group felt that the DOA should not consider using this water. The homesteaders were concerned that they will lose their full rights to this water if it is connected to the MIS where they have only a two-thirds preference. This source of water is targeted as a reserve for the future expansion in the DHHL Kalamaula agricultural subdivision (Water Initiative Group draft 2 of July 18, 2001 meeting).

A brackish well close to the MIS west portal with a yield of about 0.7 mgd is a possible source but contains about 700 ppm of chlorides. This water must be diluted to make it safe for sensitive crops. Concentrations of less than 200 ppm are desirable to minimize salinity and sodicity hazards. Chloride analyses of the Waikolu water from 1976 to 1984 indicated a very low level of about 12 ppm. The resulting mix of 5.8 mgd of Waikolu water and 0.7 mgd of the brackish well water will result in an estimated chloride content of 86 ppm, which is suitable for most if not all crops. As a comparison, the

County of Honolulu potable well water ranges from 16 to 250 ppm where most sources are less than 150 ppm of chlorides (source: communications on October 4, 2001 with the Honolulu Board of Water Supply, Chemical Laboratory). Analysis of the brackish water for calcium, magnesium, potassium and sodium will be important to the farmer if this water is used. The water can be a source of potassium, which will reduce the fertilization cost to the farmer. However, brackish water often contains too much magnesium relative to calcium that may require amending the soil with calcium. Excess sodium can lead to drainage and soil aeration problems. However, the Molokai soil in the Kualapuu and Hoolehua areas are very tolerant of salinity and sodicity affects. Minor soil physical property changes occurred with continuous application of saline water with electrical conductivity of 2 to 6 milliohms per cm or about 600 to 2,500 ppm of chloride in sugarcane at Pioneer Mill with the same Molokai soil (unpublished data by Pioneer Mill). Normal Kona storms were sufficed to leach the accumulated salts from the rooting zone.

Other brackish sources considered are located on the leeward coast at about the 300-ft elevation. Construction of a series of shallow wells was considered to give a total yield of about 0.25 mgd. However the cost of pumping the water to the Kualapuu reservoir will be high.

Kaluakoi Well 17 (21^{o} 9' 5" north latitude and 157^{o} 1' 30" west longitude) has a present pumping capacity of 2.37 mgd. Well 17 is 1,062 ft deep and is located at 981 ft elevation. The water is of good quality in terms of salinity and sodicity with chloride content averaging 60 ppm with a range of 54 to 121 ppm from 1952 to 1984. The chloride levels of this well are required to be monitored by contractual agreement between Kaluakoi and the State of Hawaii, but no data were found after 1984. More pumping from this well could lead to increased saltwater intrusion and lead to soil salinity and sodicity problems. This pump is already attached to the MIS and is used to replace water removed by Kaluakoi. One concern is the impact of more pumping of Well 17 on the water quality of other wells at lower elevations, especially on potable water. This question needs to be addressed and studied if Well 17 is to be an option. One community member interviewed favored the closure of this well, while most want it reserved for potable use only. The cost of pumping is expected to be too high for agricultural uses.

DHHL's Well 16 (21^o 8' 57" north latitude and 157^o 1' 10" west longitude) is close to Well 17 and to the MIS transmission pipeline, but it has not been used at least since 1961 (DNLR, 1961). The water quality is good with an average chloride content of 67 ppm. This well is 1,095 ft deep and is at the 1,005 ft elevation. This deep well water is expected to be too expensive for agricultural use but may be a potential source of potable water for the Kalamaula homesteads.

The sources recommended for consideration by the Water Initiative Group in times of emergency were the Kakalahale well, the Molokai Ranch surplus and County of Maui sources. This group felt an essential part of obtaining more water was to protect and improve the watershed by planting and managing trees, controlling feral goats, and improving diversions to promote recharge instead of runoff.

The total amount of new water from brackish wells, Waihanau, Kawela, Kaunakakai and Manawainui is estimated at 4.55 mgd. The gross average annual flow will be 10.35 mgd combined with the current west portal flow of 5.80 from Waikolu valley. Assuming 10% losses, 9.315 mgd can irrigate 2,329 acres at 4,000 gpa per day. About 4,660 acres can be supported assuming that only half of the area to be cultivated on the annual basis. With these assumptions, the maximum expansion of the customer base with the new water is an additional 1,730 acres from the present 2,391 acres.

RIGHTS OF THE DEPARTMENT OF HAWAIIAN HOME LANDS

The Hawaiians rights to the MIS water are documented in the current law HRS Chapter 168, Irrigation and Water Utilization Projects. Section168-4 Preference reads as follows:

> *"To the extent that the same may be necessary from time to time for the satisfaction of their water needs, domestic and agricultural, the Hawaiian homes commission and lessees of the Hawaiian homes commission shall at all times, upon actual need therefore being shown to the board of agriculture, have a prior right to two-thirds of the water developed for the Molokai irrigation and water utilization project by the tunnel development extending to Waikolu valley and ground water developed west of Waikolu valley, which was planned by the board of land and natural resources as the first stage of the Molokai irrigation project. [L 1987, c 306, pt §2]"*

Section 168-4 originated as part of Act 227 in 1943, which created the MIS. In its original form, it appears to give prior and absolute right to all MIS water to the native Hawaiians and homesteaders. In 1955, the law was amended to reduce the homesteader preference to two-thirds of the water developed from the MIS and has not changed since. This part of law is often referred to as the two-thirds preference, which protects the native Hawaiians and DHHL rights to the MIS water to enable present and future development of Homestead lots. The lack of water is said to be the single most limiting impediment for development of Hawaiian Homestead lands on Molokai.

The key phrases in section 168-4 are "actual need," and "first stage." The DHHL lessees' uses are based on actual needs. The "actual need" is not defined in the DOA administrative rules in Chapter 4-152. This law addresses the current water sources in Waikolu valley. However, as mentioned in a letter from Attorney General to DOA dated December 28, 2000, it is not clear whether the preference would extend to any water developed after the first stage of the MIS. The DOA did not ask the question nor did the Attorney General render an opinion. Whether the two-thirds preference will apply to any new sources developed for the MIS is still open to debate and will require a legal opinion from the State of Hawaii Attorney General. It is recommended that the DOA seek this opinion from the Attorney General as soon as possible.

Since 1992, the water use of non-DHHL users exceeded that of the DHHL users (Table 13 and Appendix F). In 1994, DHHL and non-DHHL uses were 786.2 (43.5%) and 1,019.2 (56.5%) million gallons, respectively. It is assumed that this water use trend continued after 1994 to present. No water use data by the user type were found after June 30, 1994. This trend might change in the future if the acres presently in coffee are discontinued. This single non-DHHL customer exceeded 20% of the total MIS water used in June and July 2001. In 1994, the acreage was split roughly in half between DHHL and non-DHHL users (Table 13). The two-thirds law suggests that in time of water shortage, the DHHL users will probably be able to maintain crop production while the other users will have to irrigate at less than consumptive use. Low yields or crop loss may result for the non-DHHL users if the drought continues. The only alternative for the non-DHHL users is to anticipate droughts and then to limit or stop production when necessary.

Table 13. Annual water uses and charges for MIS water and assessment. Several fold differences in the annual assessments were partially due to adjustments relating to voided third party agreements. Evaluation of the assessment collection procedures is needed to explain all of the differences.

	Water (million gallons)					
FY	**DHHL**	**Others**	**All**	**Assessment**	**Water charge**	**Total charges**
1990	na	na	1,166.1	$156,584	$173,838	$330,422
1991	807.0	636.8	1,443.8	$32,755	$285,142	$317,896
1992	726.0	812.2	1,538.2	$36,632	$246,113	$282,745
1993	648.8	806.6	1,455.5	$164,624	$232,874	$397,498
1994	786.2	1,019.2	1,805.4	$43,014	$288,872	$331,886
1995	na	na	1,811.8	$43,014	$289,764	$332,779
1996	na	na	1,529.8	$44,600	$244,765	$289,364
1997	na	na	1,176.5	$44,510	$188,251	$232,762
1998	na	na	1,626.3	$168,350	$260,201	$428,551
1999	na	na	1,896.6	$166,533	$303,463	$469,996
2000	na	na	1,774.8	$44,456	$382,347	$426,804

The Water Initiative Group recommended "*the DOA should settle more clearly the two-thirds preference issue and put it into practice*." The law implies that the preference applies only to the water developed for the MIS in Stage I. Subsequent water development requires a legal interpretation. The DOA administrative rules in Chapter 4-

152 should be amended to reflect the two-thirds preference in the law and its enforcement. The DOA administrative rule, Chapter 4-152, section 4-152-4, covers conservation measures and interruption of water supply, but the implementation of two-thirds preference issue is not specifically addressed. Section 4-152-4 relative to this issue reads as follows:

> *"(b) Whenever in the board's opinion special conservation measures are deemed necessary in order to forestall water shortage and a consequent emergency, the board may restrict or ration the use of water by any reasonable method of control.*
>
> *(e) Shortage of irrigation water supply for the Molokai irrigation system during seasonal drought periods may occur. During these periods, the department shall supply only the amounts of irrigation water and at the times as in the best judgment of the department will assure all consumers of receiving a fair share of the irrigation water available."*

Implementation of the two-thirds preference will require the DOA to estimate the "actual need" of each DHHL user before determining the amount of water available to non-preference users. The MIS water is intended for agricultural use only; therefore, the maximum use is expected to be equivalent to the crop's potential evapotranspiration (PET), which is a function of weather. To minimize bias, it is suggested that the DOA use PET for the assessed acres in crop production to estimate the user's "actual need." Water use may vary significantly by month (Figure 3). 41% and 33% of customers used no water in June and July of 2001, respectively (Table 12). Recalculation of allowable amounts may be necessary because the available water in the MIS can change significantly from month to month. Another question is whether the west portal flow (total available water before system losses) or the reservoir height should be used to enforce the two-thirds preference of the law. It would be easier to trigger the two-thirds law using a "critical" water depth (depth at which 100% of the user actual needs cannot be met) in the reservoir. Thereafter the west portal flow (after adjusting for losses) could be used to implement the two-thirds law until the reservoir depth increases above the critical depth. The water use records for July 2001 suggest that this situation may now exist, although it cannot be confirmed without estimates of DHHL users' actual needs. If so, the two-thirds preference should come into play favoring water allocation to DHHL users.

A condition requiring mandatory water restriction should exist before the two-thirds preference law will be enforced. Enforcement could be based on users' monthly meter readings (a month after-the-fact). This emphasizes the need for accurate flowmeters. The amounts of water available to each user will have to be estimated and communicated to the user at least monthly. A penalty clause, such as higher rates and/or a penalty fee, could be implemented and enforced whenever users exceeded the allowable limits. Enforcement may require additional DOA staffing and/or the development of appropriate computer software.

Another law relevant to this water rights issue is the State Water Code, HRS section 174C-101, Native Hawaiian water rights, part (a), which recognizes the homesteaders rights to "current" and "foreseeable" water rights (communication with Malia Akutagawa on October 26, 2001). It reads as follows:

> *"Provisions of this chapter shall not be construed to amend or modify rights or entitlements to water as provided for by the Hawaiian Homes Commission Act, 1920, as amended, and by chapters 167 and 168, relating to the Molokai irrigation system. Decisions of the commission on water resource management relating to the planning for, regulation, management, and conservation of water resources in the State shall, to the extent applicable and consistent with other legal requirements and authority, incorporate and protect adequate reserves of water for current and foreseeable development and use of Hawaiian home lands as set forth in section 221 of the Hawaiian Homes Commission Act. [L 1987, c 45, pt of §2; am L 1991, c 325, §8]."*

It was suggested that the DOA should not only estimate DHHL's "actual need" but also the "foreseeable need" in order to determine the amount of water available to non-preference users. Any future projection will be difficult to quantify and subject to debate.

ISSUES AND CONCERNS OF THE MOLOKAI COMMUNITY

The issues and concerns documented in past surveys by Kahane (1987), M&E Pacific (1991) and Molokai Agriculture Development Master Plan (1993) are the same today. Some common themes were having sufficient water, maintenance and efficient management of the MIS, Hawaiian rights, water and natural resources, and soil and water conservation. Some deemed further development of Molokai and the MIS as necessary to the economy, while others felt it would adversely affect the rights and lifestyle of the Hawaiians.

Some of the issues and concerns in Kahane (1987) survey were as follows:

1. Use of MIS water for drinking.
2. Accuracy of flow measurements.
3. Storage and filling of reservoir over the winter.
4. Operation of pumps to fill the reservoir.
5. Cost of electricity.
6. Maintenance of clogged air-relief, blow-off valves, and intakes.
7. MIS staffing size compared to other State run water systems.
8. Clarification of the two-thirds preference in the law.
9. Long range planning.

The Molokai Agriculture Development Master Plan (1993) documented additional issues and concerns as follows:

1. Cultural concerns of the native Hawaiians.
2. Lack of sufficient water for current and projected uses from existing sources.
3. Preservation of ecosystems in the watersheds.
4. Sustainability of potable aquifers.
5. Protection of the land from water and wind erosion especially in sloping

terrain where soil surfaces were devoid of cover.

6. Nonpoint source (sediments, animal waste, pesticides and fertilizers) pollution effects on water quality of streams, aquifer and coastal water.
7. Water conservation.

The MIS users and the community were not always in agreement, but some of their current issues and concerns are as follow:

1. Improvement of the efficiency of the MIS by reducing losses (replacing meters, performing the necessary fixes and regular scheduled maintenance) and maximizing water collection.
2. Conservation and system improvements instead of development of new water sources.
3. Reliability of MIS water flow and clean water quality.
4. Inadequate staffing for operation and maintenance of the system. Need for more maintenance for maximum collection, transmission, storage and distribution of water, such as: routine pump maintenance, cleaning of intakes and valves, and meter checks and replacements were other tasks mentioned.
5. Concern about who should bear the cost for water between DHHL and other users and between the MIS users and the State.
6. Concern that expansion of the MIS service area is not a reasonable option without increasing water availability.
7. Conflicts over non-DHHL water use within the MIS service boundaries.
8. Availability of Molokai Ranch surplus water to MIS.
9. Concern over more pumping of groundwater for agricultural uses. Issues are related to cost, impact on surrounding wells, especially potable wells, and the use and long-term soil effects of brackish water for irrigation.
10. Lack of sustainability of groundwater in Waikolu valley.

11. Environmental and cultural concerns over collection of water from Pelekunu valley.

12. Availability of enough water to sustain current activities let alone expansion.

13. Objections to use of Kaluakoi Well 17 water for agriculture because of high pumping cost and because of its possible effect on the Kualapuu aquifer, which is the main source of potable water.

14. Concerns about Kaluakoi Well 17 water being pumped into and withdrawn from the MIS.

RECOMMENDATIONS

Expansion Potential of the MIS

The current customer base of 2,931 acres may be doubled to a maximum 6,000 acres if the following can be achieved:

1. Reduce current losses by at least 25% to gain an annual average of 1.45 mgd.
2. Increase pumping output by 0.5 mgd in Waikolu valley to a moving average of 1.4 mgd.
3. Develop new sources such as from brackish wells and stream diversions on Kawela, Kaunakakai gulch and Manawainui gulch for a total of 4.05 mgd.

The calculation for the new acres assumes that only half of the area will be in crop production and the cultivated area will use an average of 4,000 gpa per day.

Molokai's best agriculture lands with irrigation are located in central Molokai in Hoolehua area (State of Hawaii, DLNR, 1966). The current MIS service area in Hoolehua has about 9,960 acres, but not all can be serviced even with 6.0 mgd of additional water. Therefore, the expansion of the MIS to Kalamaula homestead land is not recommended. The Molokai Water Initiative Group and the MIS Advisory Committee advocated the use of Waihanau stream diversion of about 0.5 mgd for future Kalamaula development, which is sufficient to irrigate about 123 cultivated acres or support about 250 agricultural acres annually.

Development of New Water Sources

The following long-term actions are recommended:

1. Study the feasibility and the effect on the environment of collection of runoff water from other sources. Possible sites for collection are on Manawainui, Kaunakakai, and Kawela gulches with intermittent stream flows. The bulk of the capture will be storm runoff. Another possible source is Molokai Ranch overflow as in the case for Kawela. Sources located higher than the Kualapuu reservoir are desired in order to transport the water by gravity instead of by pumping.

2. Investigate the use of non-potable brackish well water for mixing with Waikolu valley water for irrigation. The Waikolu valley water contains lower chloride content than most potable well sources elsewhere in the State of Hawaii. Mixing this water with a brackish source of 700 ppm of chloride can still yield a mixture having better quality than most potable wells on Oahu.

3. Negotiate an agreement to share or purchase Molokai Ranch water especially in times of declared water rationing.

Improvements of the Current System

The following short-term actions are recommended to improve the collection and storage of the MIS water:

1. Inject water from the transmission pipeline directly into the distribution system. Evaporation losses can be minimized; cleaner water is achievable, and higher pressure will be available with direct injection. Redesign of the system will be required to screen the water first before entering the distribution system and to prevent excess water from backing up the transmission pipeline. The excess flow above normal customer use must be redirected into the reservoir for storage. A solution to this engineering problem is needed.

2. Consider dividing the Kualapuu reservoir into smaller compartments then covering to reduce evaporation losses.

3. Measure water losses due to seepage in the Kualapuu reservoir. Seepage losses should be measured to determine if the magnitude of water loss warrant resealing or relining the reservoir. For the short-term, bypassing the reservoir may be the only option if seepage losses are high. Seepage loss measurement as proposed in this report is relatively simple and should be performed on a regular annual or biennial basis to detect potential problems. All DOA reservoirs storing water for extended periods will benefit from seepage loss measurements.

4. Review the literature on the use of oils, polymers and other materials to reduce evaporation losses from an open reservoir such as Kualapuu reservoir.

5. Determine how best to minimize soil erosion on the interior banks of the Kualapuu reservoir. NRCS should be contacted to provide corrective courses of actions.

6. Consider treating or draining the reservoir water to eliminate fishes, snails and other organisms that can clog irrigation systems. The logistics of draining the reservoir while still providing water to the customer must be studied.

7. Inspect the tunnel's floor lining for cracks and measure the water permeability of the concrete floor to determine if a sealant is necessary.

8. Modify the face of the waterfall at Dam 2 to capture more water in periods of high rainfall.

9. Study the feasibility of electricity generation for pumps in Waikolu valley.

10. Install weather stations for DOA and customer use.

11. Replace defective flowmeters as soon as possible.

<u>Management Actions to Improve the MIS</u>

1. Write administrative rules to document how the DOA will estimate the DHHL users "actual need" and to implement the two-thirds preference law. A computer program will be required to calculate the allowable water available to each DHHL user based on monthly customer needs, the available amount of water and the monthly meter readings. A perquisite is having accurate meter readings. This program is expected to be a subroutine of the monthly billing and implemented when the DOA declares a mandatory water rationing.

2. Obtain a legal opinion to determine if the two-thirds preference applies to water developed after the first stage of the MIS project.

3. Limit MIS water to only agricultural uses.

4. Create a maintenance priority work schedule and document task completion. Replacement of defective flowmeters should be given top priority.

5. Conduct timely maintenance of the MIS for optimal efficiency. The DOA should

draft a justification for additional staffing in Molokai or a plan to use existing staffing to provide optimal service and results.

6. Consider amending the well permits in Waikolu to pump more than 0.853 mgd in times of emergency. A moving average of 1.4 mgd is suggested because environmental data supports pumping of 1.55 mgd in 1996 (Water Resource Associates, 1999). The sustainable capacity is estimated to be about 2.5 mgd at 1,000 ft or 3.02 mgd at 750 ft elevation. Monitoring of the water depth of Well 4 should be a condition before allowing more pumping in the valley to prevent over-pumping of the valley.

7. Service pumps on a regular basis and document maintenance to minimize expensive repairs and lost opportunity to fill the reservoir. Adequate pumping capacity currently exists in Waikolu valley.

8. Document pumping of Wells 5 and 6.

9. Digitize all data collected for the MIS, such as water flows, pumping, reservoir depth, rainfall and customer use, for timely analysis to make informed management decision and monitor compliance of pumping permits and Kaluakoi-DOA water agreement.

10. Compare the amount of available water collected and the customer use to the quantity of water stored in the reservoir on a routine basis to identify losses.

11. Verify the actual acres irrigated against the assessed acres.

12. Inspect diversion intakes in Waikolu valley on a regular basis and schedule more frequent visits with increasing amounts of rainfall events or use flowmeters and/or remote cameras to monitor each dam for obstruction of the collection grates.

13. Verify annually or at least on a regular basis that all flowmeters are functioning and accurate. The most important meters are those feeding water into the MIS transmission pipeline to give an accurate account of the available flow per day. The east portal flowmeter triggers the well pumps, and west portal flowmeter determines the amount of water collected from Waikolu valley. The portal

flowmeters are the responsibility of the DOA, while USGS meters can serve as checks or backups. Accurate flowmeters are needed on other water sources entering into MIS from Molokai Ranch overflow at the MIS-Molokai Ranch systems junction and from Kaluakoi Well 17. Kaluakoi is responsible for maintaining and reading that meter, but the DOA should at least annually audit their data for compliance to contractual agreement and confirm the accuracy of the flowmeters. Another flowmeter of major importance is where Kaluakoi is removing water from the MIS. The priority of flowmeter audits should be Kaluakoi, tunnel portals, large users then others users.

14. Provide the farmers with weather data and assistance to improve irrigation efficiency and conserve water. The DOA should make weather data available in real time, and provide a comparison of actual and predicted water use on the monthly bill. The DOA should target individuals exceeding the crop requirement by confirming the accuracy of the user's flowmeter and the area in crop production. The University of Hawaii Cooperative Extension agents can provide technical expertise to help the farmer maximize yields with water.

15. Subsidize or give incentives for the conversion of sprinkler and furrow irrigation systems to drip irrigation. Sprinklers are ineffective because of high winds in central Molokai, which distort the spray patterns and evaporation of too much water. Furrow irrigation cannot deliver water efficiently to the crop, especially with high soil infiltration rates in the Molokai soil series at Hoolehua. Higher yields may be possible with less water using drip irrigation making more water available to other users.

16. Conduct an annual survey of each user on the acreage of each crop grown, the type of irrigation system, the use of filters and frequency and duration of back flushing, and specific water related problems.

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APPENDIX A. Senate Resolution No. 34 S.D. 1. Molokai Irrigation System Evaluation

Report Title:

Molokai Irrigation System; Evaluation (SD1)

THE SENATE

TWENTY-FIRST LEGISLATURE, 2001

STATE OF HAWAII

S.R. NO. 34 S.D. 1

SENATE RESOLUTION

REQUESTING AN ASSESSMENT OF AND IMPROVEMENT RECOMMENDATIONS FOR THE MOLOKAI IRRIGATION SYSTEM.

WHEREAS, Molokai's water shortage has reached a critical stage and the stability of Molokai's agriculture industry is in jeopardy; and

WHEREAS, unless action is taken immediately, Molokai's farmers will not have the water needed to maintain their farming operations; and

WHEREAS, the Molokai Irrigation System (MIS) was designed to serve up to 17,640 acres of farm land in Molokai's arid Ho'olehua plain, most of which is owned by the Department of Hawaiian Home Lands, and to have a capacity of 21 million gallons of water per day; and

WHEREAS, the expansion of the MIS into Pelekunu and Wailau Valleys to provide the aforementioned capacity have not occurred, and are not likely to be developed for environmental and other considerations; and

WHEREAS, two-thirds of the water developed by the MIS has preference in favor of the Department of Hawaiian Home Lands and/or their lessees; and

WHEREAS, the growth in demand for water from the system has occurred such that over one-half of the water is used by non-preference users; and

WHEREAS, while the non-preference users have a junior claim to water from the system and would be dramatically affected by rationing of system capacity, they provide a significant percentage of farm related employment and economic input to the island; and

WHEREAS, expansion of the MIS to agriculture lots in Kalamaula has been in discussion for years; and

WHEREAS, concerted, comprehensive, and cooperative efforts must be initiated to assess the practical limits of expanding the available supply of water to the MIS system together with appropriate limits to expansion of the MIS customer base, with due consideration to the preference of the Department of Hawaiian Home Lands and its lessees; now, therefore,

BE IT RESOLVED by the Senate of the Twenty-First Legislature of the State of Hawaii, Regular Session of 2001, that the Agribusiness Development Corporation, Department of Agriculture, and Department of Hawaiian Home Lands are requested to work jointly with the Molokai community to identify the expansion potential of the Molokai Irrigation System by adding new water sources and the appropriate size of the customer base that can be reliably supported by an expanded system with due concern for the preferential rights of the Department of Hawaiian Home Lands and its lessees, and to develop a plan for improvements to the Molokai Irrigation System for the long-term; and

BE IT FURTHER RESOLVED that long-term assessments and improvement recommendations for the Molokai Irrigation System shall address the expansion of the Molokai Irrigation System to agricultural lots belonging to Kalamaula homestead farmers; and

APPENDIX A (continued)

BE IT FURTHER RESOLVED that the Agribusiness Development Corporation with the assistance of the Department of Agriculture and Department of Hawaiian Home Lands shall prepare and submit the plan, their recommendations, and any proposed legislation to the legislature not less than twenty days before the convening of the Regular Session of 2002; and

BE IT FURTHER RESOLVED that certified copies of this Resolution be transmitted to the Chairperson of the Board of the Agribusiness Development Corporation, Chairperson of the Board of Agriculture, and Chairperson of Hawaiian Home Commission.