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WATER QUALITY MONITORING IN THE MONASAVU RESERVOIR, FIVE WEIRS AND WAILOA RIVER: AUGUST 2004 AND MARCH 2006

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by

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WATER QUALITY IN THE MONASAVU RESERVOIR, FIVE WEIRS, AND WAILOA RIVER: AUGUST 2004 & MARCH 2006

1.0 INTRODUCTION

The monitoring of the water quality of the Monasavu reservoir, the five weirs namely Wainabua, Nabilabila, Wainikasou North and South, and Wainisavulevu, and the Wailoa River has been conducted for the Fiji Electricity Authority by the Institute of Applied Sciences of the University of the South Pacific since the 1980s. In the last few years, there have been some disruptions and cancellations due to problems involving landowners at Monasavu and the political coup of May 2000 with the last complete monitoring carried out in 2001. In 2004, monitoring continued with the winter monitoring conducted in August 2004. In early 2005, there was no communication back from FEA to follow up payment for the previous monitoring and to confirm with IAS to go ahead with the summer monitoring, thus this was not conducted till March 2006.

The following figures show the location of the Monasavu hydroelectric project in Viti Levu (Fig. 1), and the detailed map of the location of the dam, weirs and the feeder creeks/rivers around the reservoir (Fig. 2).

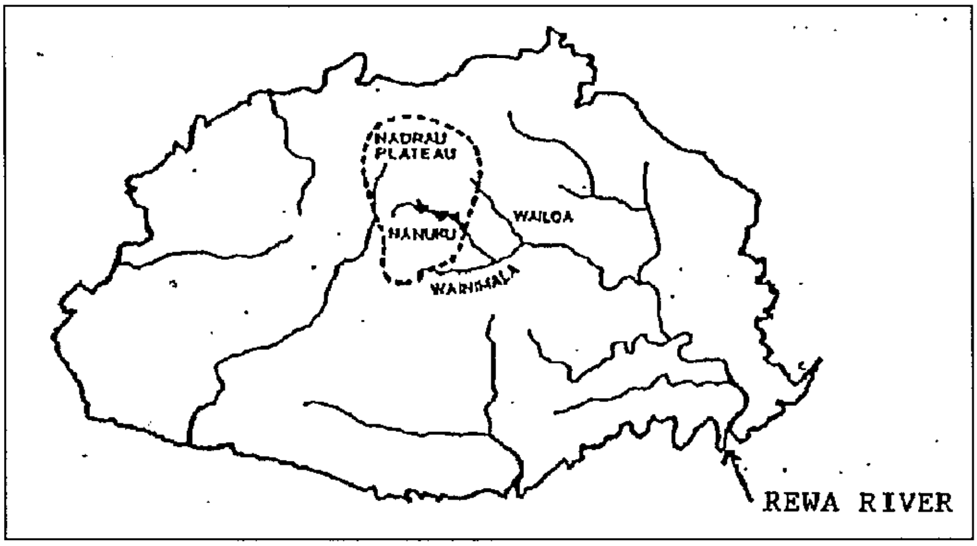


Figure 1. Map of Viti Levu showing the location of the Monasavu Hydroelectric scheme

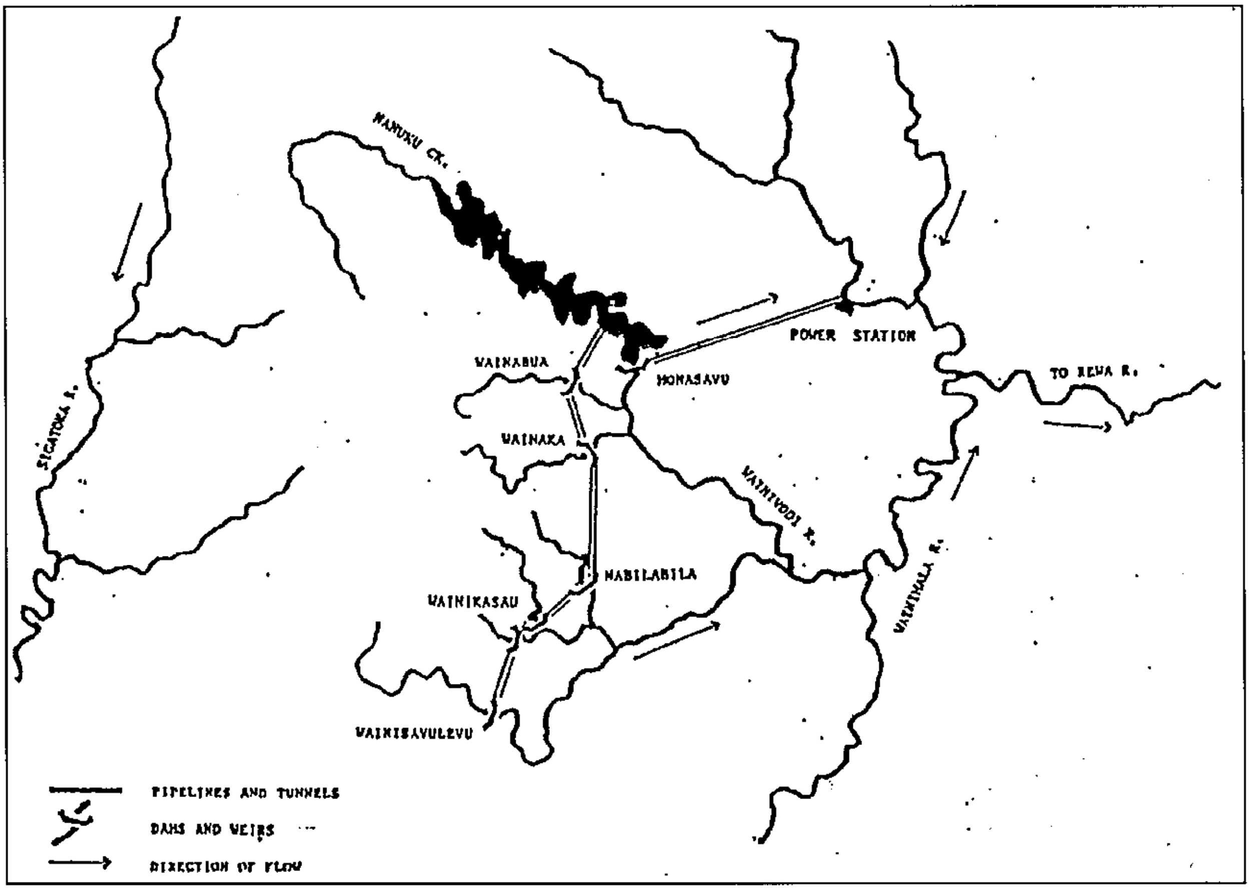


Figure 2. Detailed locations of dam, tunnels, creeks, and rivers in the Monasavu area

2.0 BACKGROUND

The principal aims of the study are threefold:

- to monitor the water chemistry in the reservoir;
- to monitor the Wailoa River upstream from the power station, at the tailrace and at Laselevu Village; and
- to monitor the water quality at the weir sites.

The Wailoa River receives water channeled from the reservoir to the Power Station. To assess the impact of the Power Station on the Wailoa River, three monitoring stations have always been monitored : a site upstream from the Power Station, one at tailrace (discharge point for the Power Station), and one site several kilometers downstream from tailrace at Laselevu Village.

The aim of the monitoring at the weir sites is to establish if logging in the catchment area is having an impact on the quality of the water in the creeks feeding the reservoir. In previous years, large aquatic weeds have become a problem at some of the weirs, clogging the weirs and disrupting the flow of water to the main reservoir.

Over the years, results of water chemistry analysis have indicated a gradual improvement in the quality of water in the reservoir (Morrison et al 1990, Lloyd *et al.* 1993, Tamata *et al.*, 1995). The water quality in the dam, Wailoa River and five weir sites has been good. The monitoring programme over the last 15 years has highlighted a number of trends in the water quality of the dam, the Wailoa River, and the weirs. Established trends include:

a) Water levels in the dam are usually lower in winter when it is the dry season.

b) Water quality within the dam has been improving over the years (Chand and Fung 1996). Nutrient levels and other parameters within the dam are generally within the standards recommended for Fiji under the Recreation Water Criteria (NEMP 1992).

c) There is normally a seasonal variation in temperature within the Monasavu reservoir. During summer, surface waters temperatures are usually higher contrasting sharply with cooler, more dense waters below. Stratification thus occurs due to thermal resistance to mixing resulting in the formation of different layers (Chand and Fung 1996). During winter (July), the cooler temperatures disrupt this stratification, thus the temperature range is relatively homothermic .

d) As a result of poor circulation in the water column in the summer, low oxygen levels prevail in the bottom layers due to the thermocline barrier and decomposition and respiration activities that use up oxygen. In winter, the distribution of dissolved oxygen is more uniform. Dissolved oxygen is always higher at the surface due to the combination of atmospheric aeration, turbulence, and photosynthetic processes of algae and phytoplankton.

e) Total alkalinity and pH have remained fairly stable during both winter and summer over the years within the dam.

f) Concentrations of ammonia, nitrates and phosphates are usually low at the surface where dissolved oxygen levels are high and phytoplankton activity is prominent in using up the nutrients. Levels increase towards the bottom as dissolved oxygen levels decrease and phytoplankton presence is less prominent. Nutrient levels seem to be slightly higher in the summer. This increased nutrient level may be due to increased rainfall and corresponding washout of nutrients from the soil surrounding the dam.

g) Over the years, the concentrations of the metals iron and manganese have decreased to very low levels and there is so far little risk of metal deposition on machinery in the power station. Levels are highest at depth and increase slightly during the summer when dissolved oxygen is low in the bottom layers. At low dissolved oxygen levels, the oxidised states of the metals become reduced releasing the metal elements into the water column.

3.0 THE MONITORING PROGRAMME, 2004

3.1 Organisation

The 2004/2006 monitoring programme consisted of visits in August 2004 representing the winter monitoring, and in March 2006 representing the summer monitoring. The summer monitoring was to be done in January 2005 but due to reasons mentioned previously it was not able to be done thus it was necessary to wait a whole year for the next summer monitoring. For each visit, three staff of the Environment Unit at the IAS traveled the Sawani/Serea Road to Monasavu, returning the next day.

Within the dam two depths (surface and bottom) instead of three depths at three sites were monitored. Water quality at the five weirs and at three points along the Wailoa River were also monitored.

3.2 Location of Sampling Sites

The sampling sites remain the same as in previous years. Three sites at two different depths (surface and bottom) were sampled within the reservoir, three stations were sampled within the Wailoa River, and five weirs were monitored. The locations of these sites are shown in Figures 3, 4 and 5. The details of the sites and parameters monitored at each site are summarised in Table 1.

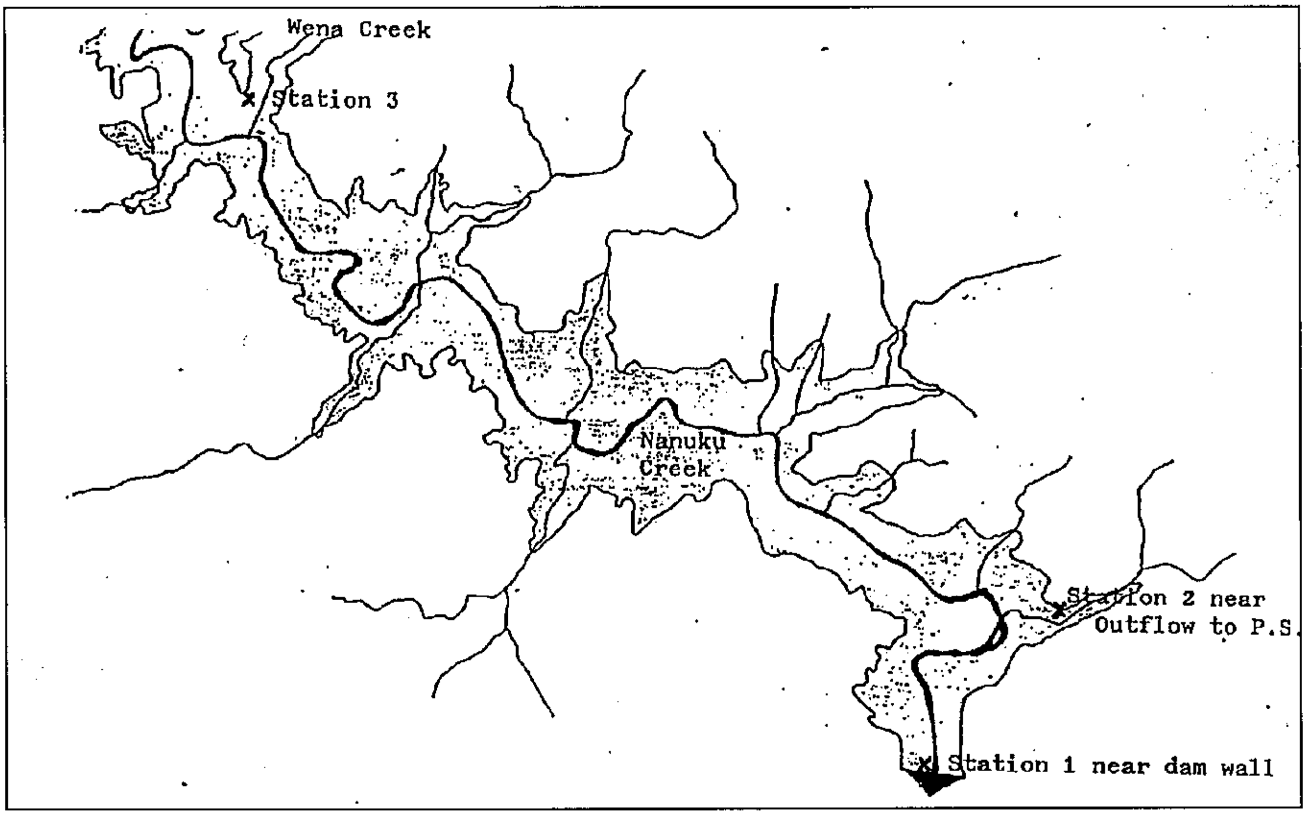


Figure 3. Locations of the sampling stations in the Monasavu Reservoir.

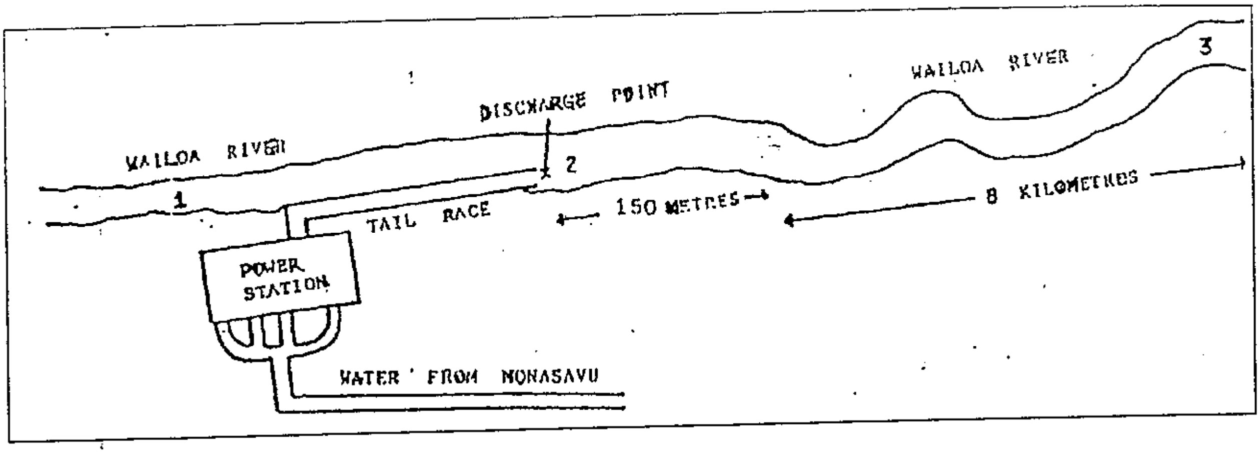


Figure 4. Sampling sites along the Wailoa River.
Site 1: 100 m upstream of power station discharge
Site 2: Tailrace (power station discharge water)
Site 3: On the Wailoa River at Laselevu village

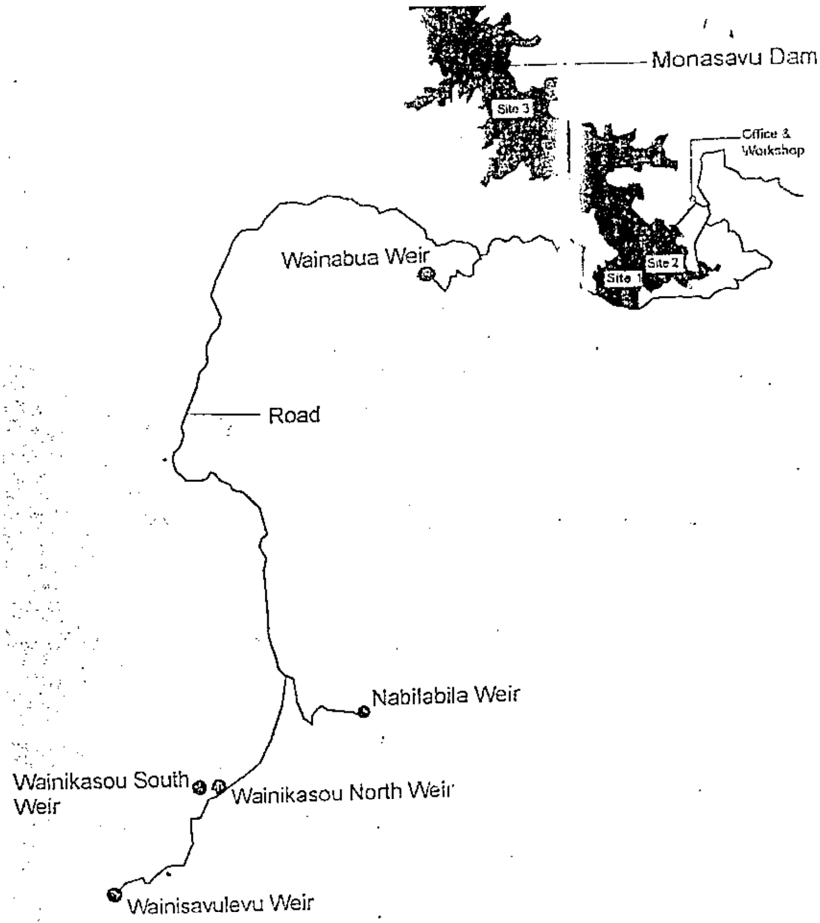


Figure 5. The Monasavu Dam and Weirs

Table 1. Summary of the 2004/2006 Water Quality Monitoring Programme at Monasavu

Location	Number of Sites Monitored	Description of Sites	Dates monitored	Parameters measured On-site	Parameters measured in Lab
Reservoir	3 sites each at 2 depths (surface, bottom)	Site 1 – Near the float near dam wall Site 2 – Moored to rake at outflow to power station Site 3 – Middle of Dam (near Wena Ck junction)	August 18th 2004 March 14th 2006	pH, conductivity, clarity, depth temperature/dissolved oxygen profiles, GPS readings	Nitrate, Ammonia, Phosphate, Total Suspended Solids, Turbidity, Iron and Manganese at Bottom sites
Wailoa River	3 sites	Above Wailoa Power Station Below Wailoa Power Station (tailrace water) Near Laselevu Village downstream	August 19th 2004 March 15th 2006	pH, conductivity. temperature, dissolved oxygen, clarity	Nitrate, Ammonia, Phosphate, Manganese, Iron, Total Suspended Solids, turbidity
Weirs	5 weirs	Wainabua Nabilabila Wainikasou North Wainikasou South Wainisavulevu	August 18th 2004 March 14th 2006	pH, conductivity, temperature, dissolved oxygen, clarity,	Total suspended solids, Nitrate, Phosphate, ammonia, turbidity

4.0 METHODOLOGY

The methodology of the field work and the laboratory tests were the same as in previous studies. Parameters for monitoring remained the same except for Total Phosphorus and alkalinity which were not sampled for. Total Phosphorus has not been detected in most of previous sampling and pH can substitute for alkalinity.

The reservoir and weirs were sampled on the first day with a boat used to sample the reservoir sites. The Wailoa River sites were sampled on the second day at the power station and off the road just before Laselevu village.

4.1 On-site Measurements

At all sites temperature, dissolved oxygen, pH, and conductivity were measured in the surface waters using a using a YSI handheld multimeter. At the three stations within the dam, temperature and dissolved oxygen were also measured at 1 meter intervals down to the bottom with a YSI Model dissolved oxygen meter. Water clarity was determined at all sites using a white and black secchi disc. The depth of the water at each station in the dam was also determined using the secchi disc. At the weirs the presence of macroalgae was noted.

4.2 Laboratory Analyses

Water samples were collected in clean acid-washed (10% HCl) plastic bottles and stored in ice. At the reservoir (dam), water samples were collected from the two depths: surface and bottom waters. A depth sampler was used to collect the water samples from the bottom waters. At the weir sites and Wailoa River sites water samples were collected from the surface waters only.

These samples were brought back to the laboratory within 24 hours and analysed for various parameters. A description of each analysis was given in the 1996 report (Chand and Fung). These procedures have remained the same.

Nitrate concentration was measured using the Cadmium Reduction/Colorimetric method and measurement of absorbance on the UV Spectrophotometer at 543 nm (IAS Methods of Analysis of Water, 1992).

Ammonia was analysed using the phenate method. Absorbance was measured on the spectrophotometer at 660 nm (APHA 1992).

Dissolved phosphate was measured using the Molybdenum blue-Colorimetric method and measurement of absorbance on the UV Spectrophotometer (IAS Methods 1992).

Total suspended and dissolved solids were measured using the Filtration/Gravimetric method (APHA 1981).

Metals were analysed by direct Atomic Absorption/Emission Spectrometry (APHA 1992).

5.0 RESULTS

During the August 2004 monitoring, the weather was overcast and drizzling whilst during the March 2006 monitoring the weather was fine and sunny.

The depth of the reservoir at the monitorings is presented below (Table 2.)

Table 2. Depth in meters of the 3 reservoir sites during the different monitorings

Site	*August 2004*	*March 2006*
Site 1- Moored to floaters near dam wall	36m	26m
Site 2 – Moored to rake	27m	18m
Site 3 – Middle of dam	13.8m	27m

The data on the water chemistry for the reservoir, weirs and Wailoa River for the 2004/2006 Monitoring are presented in Tables 3 & 4. The dissolved oxygen and temperature profiles for each of the three stations in the reservoir are shown in Figures 6 & 7 with the data tabulated in Appendix 1.

Table 3a. Water quality results for Monasavu Dam and Wailoa River – August 2004 (winter)

	Site 1 Surface	Site 1 Bottom	Site 2 Surface	Site 2 Bottom	Site 3 Surface	Site 3 Bottom	Wailoa Above PS	Wailoa Tailrace	Wailoa Laselevu
Depth (m)		36		27		13.8			
pH	7.1	7.9	7.4	7.5	6.9	7.3	8.0	7.1	7.9
Temperature °C)	21.8	20.2	22.3	20.2	22.6	20.9	21.3	21.1	21.5
Dissolved Oxygen (mg/L)	6.76	<0.3	7.56	3.31	6.8	0.31	7.21	6.05	7.55
Clarity (m)	2.0		1.6		2.1		Clear to bottom	Slightly greenish	Clear to bottom
Nitrate as NO_3 (µg/L)	48.8	35.7	41.6	53.8	37.3	35.9	21.6	70.0	31.0
Ammonia as NH_3 (mg/L)	<0.012	0.37	0.11	0.06	0.12	0.06	0.10	0.03	0.05
Phosphate PO_4 (mgL)	<0.018	<0.018	<0.018	<0.018	<0.018	<0.018	0.033	<0.018	<0.018
Total Suspended Solids (mg/L)	10	2	7	3	2	2	2	9	8
Total Fe (Iron) (µg/L)		220.0		24.5			6.2	25.4	28.8
Total Mn (Manganese) (µg/L)		1297.5		<18.0			<18	<18	<18
Comments	Fog						Fast flow		

Table 3b Water quality results for Monasavu Weirs – August 2004 (winter)

	Wainabua	Nabilabila	Wainaikasou North	Wainikasou South	Wainisavulevu
pH	7.6	7.3	7.4	7.5	6.9
Temperature (°C)	17.8	19.0	19.2	19.1	20.4
Dissolved Oxygen (mg/L)	6.85	6.61	6.65	6.78	6.76
Clarity (m)	Clear to bottom	Clear to bottom	Clear to bottom	Clear to bottom	2.2
Total Suspended Solids (mg/L)	16	14	7	7	9
Nitrate as NO_3 (µg/L)	30.5	22.2	9.6	13.5	12.7
Phosphate (mg/L)	0.038	0.029	0.027	<0.018	<0.018
Comments	No algae on bottom. Fast flowing	Debris on sides. Overflowing	Aquatic plants on bottom	Bottom covered with brown algae. Overflowing	Not in operation. Water greenish. No flow

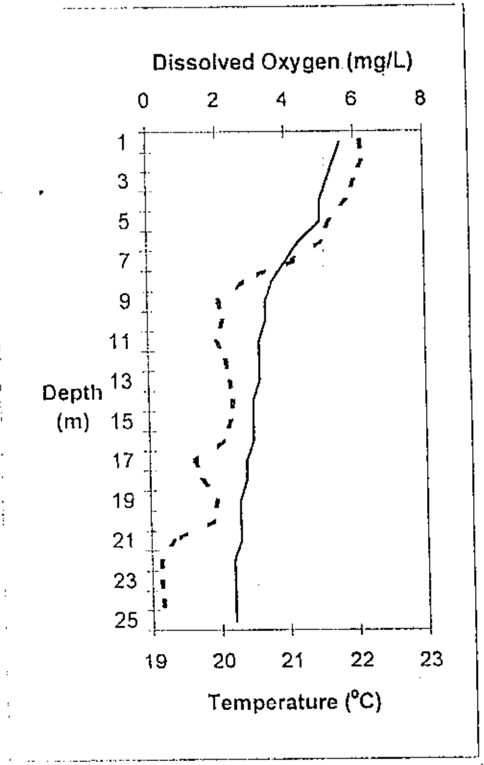
Table 4a. Water quality results for Monasavu Dam and Wailoa River – March 2006 (summer)

	Site 1 Surface	Site 1 Bottom	Site 2 Surface	Site 2 Bottom	Site 3 Surface	Site 3 Bottom	Wailoa Above PS	Wailoa Tailrace	Wailoa Laselevu
Depth (m)		26		18		27			
pH	6.39	7.9	6.25	7.5	7.76	7.3	6.22	6.11	6.91
Temperature °C)	27.01	22.56	26.86	23.43	26.86	22.66	24.61	24.84	24.73
Dissolved Oxygen (mg/L)	5.83	0.87	1.56	1.26	1.78	0.73	5.28	6.48	6.91
Clarity (m)	2.5		2		1.75		Clear to bottom	Slightly greenish	Clear to bottom
Turbidity (ntu)	3.3	3.2	3.4	2.1	3.7	2.9	2.2	2.7	2.4
Nitrate as NO_3 (mg/L)	0.04	0.04	0.04	0.04	0.04	0.22	0.18	0.18	0.09
Ammonia as NH_3 (mg/L)	0.05	0.34	0.02	0.04	0.02	0.04	0.02	0.04	0.02
Phosphate PO_4 (mgL)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.1	<0.02	<0.02
Total Suspended Solids (mg/L)	4	4	3	3	2	6	2	5	8
Total Fe (Iron) (µg/L)		911		275		469		71.5	
Total Mn (Manganese) (µg/L)		243		5.9		12.5		7.26	
Comments	Murky water.						Fast flow		

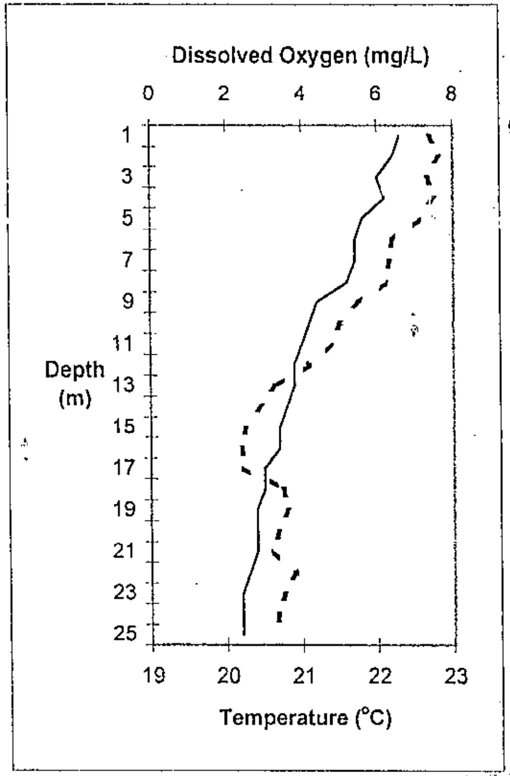
Table 4b. Water quality results for Monasavu Weirs – March 2006 (summer)

	Wainabua	Nabilabila	Wainaikasou North	Wainikasou South	Wainisavulevu
Turbidity (ntu)	2.1	2.3	2.4	2.2	4.3
pH	7.56	7.22	7.17	7.00	6.77
Temperature (°C)	19.99	20.30	20.34	20.26	20.5
Dissolved Oxygen (mg/L)	2.48	2.18	2.38	2.19	1.93
Clarity (m)	3.5	1.5	2. Clear to bottom	1.0	1.3
Total Suspended Solids (mg/L)	<1	2	<1	3	4
Nitrate as NO_3 (mg/L)	0.13	0.09	0.09	0.04	0.18
Phosphate (mg/L)	0.18	0.11	<0.02	0.07	<0.02
Comments		Watercress present	Clumps of water cress observed	Clumps of algae and water cress observed	No water flow. Collection of floating debris

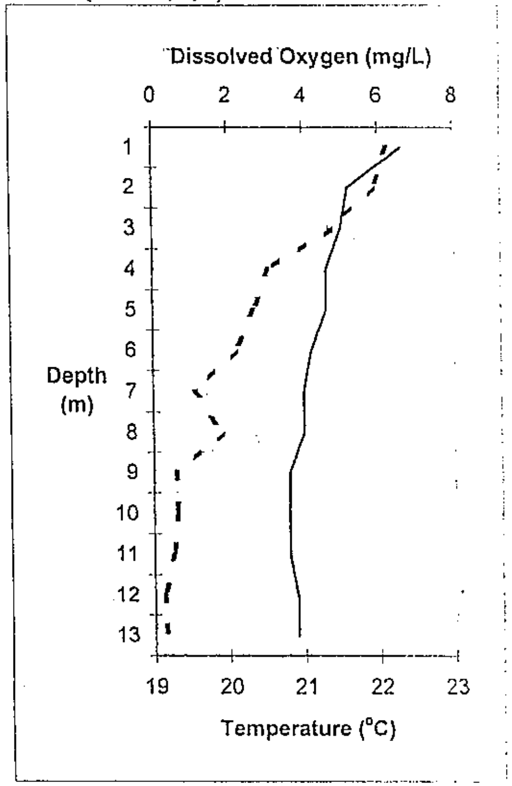
FIGURE 6. TEMPERATURE/DISSOLVED OXYGEN PROFILES FOR MONASAVU DAM, August 2004(Site 1,2,3)



a) Site 1 (Moored to Floaters)



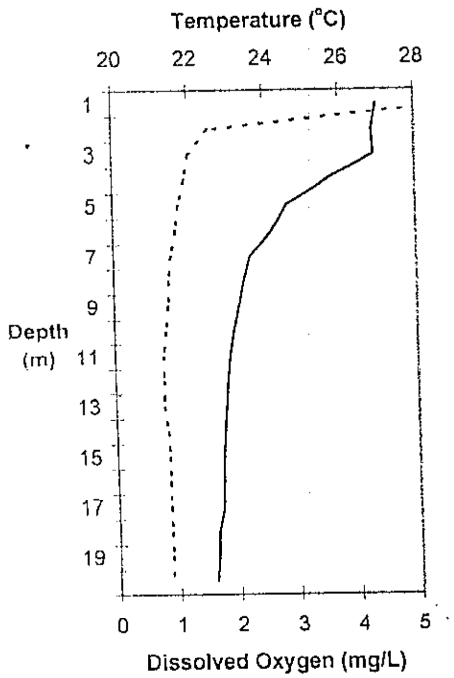
b) Site 2 (Moored to Rake)



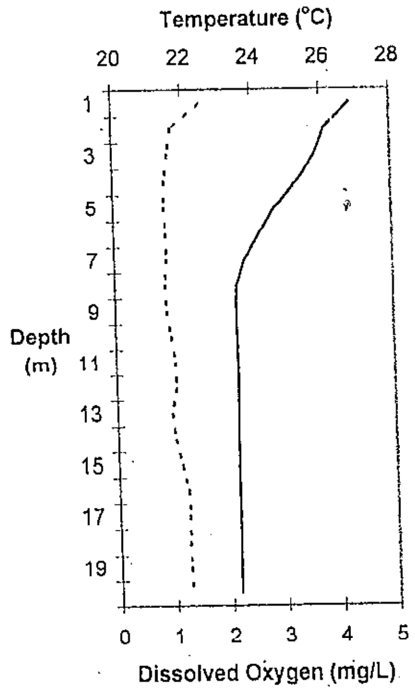
c) Site 3 (Middle of Dam)

Key:

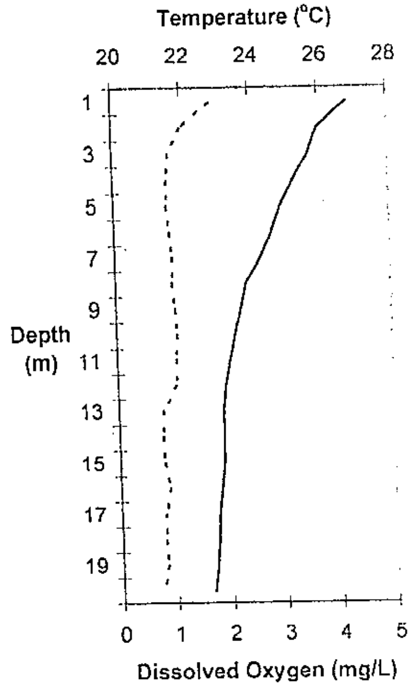
FIGURE 7. TEMPERATURE/DISSOLVED OXYGEN PROFILES FOR MONASAVU DAM, March 2006 (Site 1,2,3)



a) Site 1 (Moored to Floaters)



b) Site 2 (Moored to Rake)



c) Site 3 (Middle of Dam)

Key:

6.0 WATER QUALITY AT MONASAVU

6.1 The Monasavu Reservoir

(a) Depth

The depth of the reservoir was already fairly low during the 2004 monitoring. Depth further decreased dramatically between the 2004 and 2006 monitorings, particularly at Site 1 (near the dam wall) and Site 2 (at rake) where depth was 10 meters shallower. This is a cause of concern, as dam levels have been steadily decreasing over the last 5 years. The increase in depth at Site 3 during the 2006 monitoring is probably a result of the sampling undertaken at a different location as in 2004.

(b) Temperature and Dissolved Oxygen Profiles

During the August 2004 winter monitoring, the temperature values within the reservoir were fairly constant throughout the water column at all three sites (Figures 6a, b, c). Surface temperatures were around 21 to 22°C, declining slightly towards the bottom to values around 20°C. Dissolved oxygen values, on the other hand, varied drastically with depth. DO values at the surface were fairly high, ranging from 6.19 to 7.38 mg/L, decreasing steadily with increasing depth. The stratification is most obvious for Site 1 where DO values at the bottom were around 0 mg/L. Site 3 although shallower, was similar to Site 1 most probably due to the build up of organic material. At the bottom of Site 2, the flow of the water out through the channel to the Power Station creates much turbulence and mixing causing DO level to fluctuate thus is slightly higher (~3 mg/L) than at Site 1.

During the March 2006 summer monitoring, overall temperatures were slightly higher than in winter and thermal stratification throughout the water column greater. Surface temperatures were between 26 and 27°C declining towards the bottom to values between 22 and 23°C. Dissolved oxygen levels were very low as compared to previous monitorings. DO values at the surface were between 1 and 2 mg/L except for Site 1 which was 5.83 mg/L, decreasing to around 0 mg/L at depth (Figures 7a, b, c). The low dam levels together with increased organic matter could be resulting in low DO levels.

(c) pH

The Monasavu reservoir is a typical bicarbonate-type lake, with average pH values ranging from 6 to 9. Values of pH for the three sites within the reservoir during the 2004 winter monitoring ranged from 6.9 to 7.9. The values for the 2006 summer monitoring ranged from 6.25 to 7.9. These values are within the recommended standard and are similar to previous years values.

(d) Clarity & Turbidity

The clarity of the water in the reservoir is always influenced by the quality of the water in the weirs and the prevailing weather conditions. There was little difference in clarity between the two monitorings and all sites were above the recommended minimum visibility of 1.2 meters for recreational waters (NEMP 1992). During the 2004 winter monitoring, clarity was between 1.6 and 2.1m and in the 2006 summer monitoring, clarity was between 1.75 and 2.5m.

(e) Nutrients

Nitrates and Ammonia

For nitrates, during the 2004 winter monitoring, levels were between 35.7 μg/L and 53.8 μg/L. During the 2006 summer monitoring values were all 40 μg/L except for at the bottom of Site 3 where it was 220 μg/L. The normal pattern of nitrate distribution is that surface waters have less nitrate due to the consumption of nitrates as a result of photosynthetic activity. In addition, nitrate levels are often higher during winter due to reduced photosynthetic activity. The high level at the bottom of Site 3 could be due to the build up of organic matter as the dam becomes shallower over the last few years due to the lack of rainfall.

Ammonia levels in winter 2004 ranged from <0.012 to 0.37 mg/L. The summer 2006 ammonia levels ranged from 0.02 to 0.34 mg/L. As in previous years, the bottom of Site 1, which is the deepest part of the reservoir, had the highest value. This is consistent with the trend that ammonia levels increase with depth due to anoxic conditions in bottom waters.

Phosphates

Phosphates remained at relatively low levels at all sites in both monitorings. No phosphate was detected at any sites either time.

General

The reservoir receives a major portion of its nutrients (nitrates, phosphates) from the decomposition of organic matter in the form of remaining tree trunks and the remains of the original flora/vegetation of the reservoir area. In the mid to surface waters decomposition is usually aerobic and releases nitrates, phosphates and carbon dioxide into the water. These nutrients are utilised by photosynthetic organisms in the surface waters thus they are depleted of these nutrients. With increasing depth, these organisms decrease and nutrients tend to increase in concentration. At bottom depths, conditions are normally anaerobic. Under these conditions organic matter is broken down by bacteria into methane, a little carbon dioxide and ammonia, thus the high ammonia concentration at bottom waters of each station. Although, for several years now, the concentrations of the main nutrients have more or less stabilised around a certain range which is very low, the low water levels could result in increased levels at depth especially at Site 3. This is likely due to trees in the lake being fully decomposed.

(f) Total Iron and Total Manganese

During the winter 2004 monitoring, total iron levels were 24.5 μg/L at the bottom of Site 2 and 220 μg/L at the bottom of Site 1. Total manganese levels were <18 μg/L at the bottom of Site 2 and 1297 μg/L at the bottom of Site 1. The results for summer 2006 for total iron levels were between 275 and 911 μg/L, the highest value again being from the bottom of Site 1. The summer total manganese results were between 5.9 and 243 μg/L, with the highest values again at the bottom of Site 1. The higher level of iron and manganese in bottom waters results from the redox reactivity of the metals: oxidation of the metals at the surface. The metal oxides then precipitate out and sink to the bottom. In the bottom waters, anoxic conditions bring about the dissolution of iron and manganese from the sediments into the water column. The low concentrations of metals in the reservoir in general, with the exception of the deeper bottom waters, has been the trend over previous years.

(g) Total Suspended Solids

Total suspended solids (TSS) levels for the 2004 winter monitoring ranged from 2 to 10 mg/L, the highest being at the surface of Site 1 and for the 2006 summer monitoring the range was 2 to 6 mg/L, the highest level being at the bottom of site 3. These values are within the recommended standard for freshwater which is <6 mg/L except for at Site 1 (ANZECC 2000).

6.2 The Wailoa River

Water is drawn to the Wailoa Power station from the bottom of site 2 within the reservoir. As usual, three sites along the Wailoa River were compared to see if the power station (or the Monasavu Hydropower Plant) is having an impact on the quality of water in the river and the communities dependent on the river (Laselevu village etc.). A comparison between the values obtained for pH, dissolved oxygen, and metals at the bottom of site 2 with those obtained at tailrace below the power station, will indicate whether water quality changes through the power station and the possibility of deposition of metals on the machinery in the power station.

(a) Temperature, Dissolved Oxygen, pH

There was no significant difference in temperature for the three sites in Laselevu river during the 2004 winter monitoring. Water temperature was around 21°C. In the 2006 summer monitoring, temperature at the three sites were around 24°C. Temperatures in winter were lower than during summer, as expected.

Dissolved oxygen levels indicated well-saturated water at all three sites for both monitorings. DO levels ranged from 6.05 to 7.55 mg/L during 2004 winter monitoring, and from 5.28 to 6.91 during 2006 summer monitoring. These values are in line with the recommended level for freshwater which is >5mg/L. There is no significant difference in DO levels along the river. There is also an improvement in DO levels as the water goes through the power station and gets aerated (Table 5.)

pH values have always been consistent among the three sites. pH values during winter 2004 ranged from 7.1 to 8.0, and during summer from 6.11 to 6.91.

Table 5. Comparison of data from Site 2 bottom waters and Tailrace water

Parameter		Site 2 Bottom	Wailoa Tailrace
Dissolved Oxygen (mg/L)	Winter 2004	3.31	6.05
	Summer 2006	1.26	6.48
pH	Winter 2004	7.5	7.1
	Summer 2006	7.5	6.11
Ammonia (μg/L)	Winter 2004	0.06	0.03
	Summer 2006	0.04	0.04

(b) Nutrients

Nitrates and Ammonia

In winter 2004, nitrate levels at the three sites varied from 21.6 to 70.0 µg/L, with the highest value at tailrace. The level, however, decreases by the Laselevu village site. In summer 2006, nitrate levels were slightly higher from 90 to 180 ug/L. Higher nitrate levels in summer correspond to increase in rainfall and thus the amounts of nutrients being washed from the soil. During winter 2004, ammonia levels ranged from 0.03 to 0.1mg/L. During summer 2006 ammonia levels ranged from 0.02 to 0.04 mg/L. The level at tailrace was not significantly higher than at the other sites thus is not a concern.

Phosphates

Phosphate values were low for all sites for both monitorings. Phosphate levels were <0.018 mg/L at two sites (Tailrace and Laselevu) for both monitorings. Only at the site upstream from the Power Station did the phosphate level differ, but only very slightly, recording 0.03 mg/L in winter 2004 and 0.1 mg/L in summer 2006. This trend is similar to previous monitorings.

(c) Total Suspended Solids

TSS levels at the three sites in winter 2004 ranged from 2 to 9 mg/L with the highest being at tailrace. During summer 2006, levels ranged from 2 to 8 mg/L with the highest value at Laselevu. The ANZECC recommended level for freshwater in <6mg/L. The slightly higher values are probably just a result of the turbulence from the flowing of the water at tailrace and Laselevu sites.

(d) Total Iron and Total Manganese

Total iron levels during the winter 2004 monitoring were between 6.2 and 28.8 µg/L. Total manganese levels were <18 µg/L at all sites. During the summer 2006 monitoring metals were only monitored at tailrace. Total iron levels are much higher at tailrace than upstream. However, levels were below the EPA (Environment Protection Authority (U.S) freshwater guideline for aquatic life which is 1000 µg/L.

Comparing the level of metals at the bottom of Site 2 in the reservoir to that at tailrace (Table 6), in winter 2004 they are very similar, implying that deposition of iron on machinery in the power station did not occur. However in 2006 monitoring iron levels were lower in tailrace water indicating that some deposition may be occurring. In addition levels were much higher than in 2004. Manganese levels were also detected in the tailrace water

Table 6. Comparison of Total Iron and Total Manganese content at Site 2 bottom waters and tailrace

		Bottom Site 2	Tailrace
Total Iron (ug/L)	Winter 2004	24.5	25.4
	Summer 2006	275	71.5
Total Manganese (ug/L)	Winter 2004	<18	<18
	Summer 2006	5.9	7.26

6.3 The Weirs

During both the 2004 and 2006 monitoring it was observed that Wainisavulevu was not in operation as no water flow was observed.

(a) Temperature, Dissolved Oxygen, pH

As to be expected, the temperature range for summer 2006, 19°C - 20.5°C was slightly higher than the range for winter 2004, 17.8 - 20.4°C. These are the usual values for the weirs.

Dissolved oxygen levels in the weirs in 2004 and 2006 were around 6 mg/L. They were all within the acceptable range for aquatic systems (5 mg/L or above) however, they were lower than previous years (Table 7). This could be due to the shallower water levels in the dam and increased organic matter.

Table 7. Variation in dissolved oxygen levels (mg/L) at the five weirs

Year	Wainabua		Nabilabila		Wainkasou North		Wainkasou South		Wainisavulevu	
	winter	summer	winter	Summer	winter	summer	winter	summer	winter	summer
2004/ 2006	6.85	6.85	6.61	6.61	6.65	6.65	6.78	6.78	6.76	6.76
2001	9.3	8.7	9.72	8.6	9.75	8.2	10.04	8.0	8.97	7.7
1999	8.5	7.69	8.8	7.77	8.03	7.66	8.83	8.37	8.28	7.35
1998	-	6.8	-	8.32	-	8.63	-	8.25	-	7.24
1997	8.2	7.2	9.4	8.45	8.2	9.1	8.2	7.8	9.0	7.8
1995	8.2	8.6	9.2	9.5	8.8	9.9	8.4	11.2	8.0	8.3

pH values for winter 2004 were 6.9 – 7.6 and for summer 2006 were 6.77 – 7.56. All values satisfy the acceptable pH range of 6 – 9.

(b) Nutrients

Nitrates

Nitrate levels during winter 2004 ranged from 9.6 to 30.5 μg/L with Wainabua having the highest level. During summer 2006, nitrate levels ranged from 40 μg/L to 180 μg/L. Certain weirs (such as Wainabua) that have high nitrate levels, especially in the summer, could be contributing to high levels in the reservoir.

Phosphates

During winter 2004, phosphate levels ranged from <0.018 to 0.038 mg/L, the highest being at Wainabua. The levels of phosphates in the reservoir in summer 2006 are similar, from <0.02 to 0.18 mg/L with the highest again being at Wainabua.

(c) Clarity

Clarity at the weirs in winter 2004 was very good with the bottom visible at all weirs except for at Wainisavulevu where it was 2.2m. During the summer 2006 monitoring, clarity ranged from 1m to 3.5 m. The usual range of clarity values has been between <1m to 5m with local precipitation affecting clarity values. Clarity of >1.2m is good for freshwater.

(d) Total Suspended Solids (TSS)

Winter 2004 TSS values ranged from 7 to 16 mg/L, the higher TSS being recorded at Wainabua. In summer 2006, the TSS range was <1 to 4 mg/L, the highest TSS recorded for Wainisavulevu. These values are within the ranges obtained in previous monitorings.

(e) Aquatic Weeds

During the winter 2004 monitoring, at Wainikasou North there was thick growth of aquatic plants on the bottom of the weir. Brown algae was also observed at Wainikasou South. During the summer 2006 monitoring, clumps of algae and watercress were observed at Nabilabila, Wainikasou North and Wainakasou South.

7.0 SUMMARY

From the discussion above, the main issues that arose during this period of monitoring of the reservoir, Wailoa river, and weirs are as follows.

7.1 The Monasavu Reservoir

- The low levels of the dam continue to influence water quality within the reservoir. This is due to the lack of rainfall in recent years and has resulted in the sites monitored in 2006 being 10 meters shallower than in 2004.

- While temperature of the water in the reservoir has not changed much in the last five years, the level of dissolved oxygen has been generally much lower than usual. This is normal for sites at depth however in 2006 even the surface waters had very low dissolved oxygen levels. The low water levels and increased organic matter from the decaying vegetation would have led to the low DO levels. Calm weather conditions also lead to lower DO in the surface waters.

- Nitrate levels were slightly high at depth. This is also attributed to the low water levels and decaying organic matter in the reservoir.

7.2 The Wailoa River

- The flow and volume of the Wailoa River is such that most impact of the power station (which would have been recorded at the tailrace), is quickly absorbed. As a result, water quality apart from total iron does not vary significantly at the three sites along the Wailoa River, upstream of the plant, at the tailrace and at Laselevu village. Total iron levels however were found to be higher at tailrace and at Laselevu village.

- As in previous monitorings, total iron was high at tailrace. In addition, the level was significantly lower than at the bottom of Site 2 in the reservoir indicating that some deposition may have occurred through the power station.

7.3 Weirs

- In both monitorings, Wainisavulevu weir was not in operation.

- Dissolved oxygen levels were found to be lower than in previous monitorings and this could also be a result of the low water levels due to the lack of rainfall resulting in low flow and thus the build up of decaying organic matter in the weirs.

- The level of nutrients in Wainabua was again found to be high and could be contributing to high level of nutrients in the reservoir.

8.0 CONCLUSION

For both the 2004 and 2006 monitorings, changes in water quality were mainly influenced by the low water levels in the dam and weirs. This was due to the lack of rainfall experienced over the last 7 years or so. This has resulted in low dissolved oxygen levels in the dam and the weirs and slightly higher nutrient levels. Water quality in the Wailoa River has not been affected except for total iron level. Elevated iron levels at the Bottom of Site 2 in the reservoir and at tailrace may be of concern and should be further monitored in the future.

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APPENDICES

APPENDIX 1. Temperature and Dissolved Oxygen Data for the Monasavu Reservoir

Winter 2004

	SITE 1-MOORED TO FLOATERS		**SITE 2-MOORED TO RAKE**		**SITE 3-MIDDLE OF DAM**	
Depth (m)	**DO (mg/L)**	**Temp. (ѳC)**	**DO (mg/L)**	**Temp. (°C)**	**DO (mg/L)**	**Temp. (°C)**
Surface						
1	6.19	21.8	7.38	22.3	6.23	22.3
2	6.24	21.7	7.65	22.2	5.87	21.6
3	6.01	21.6	7.32	22.0	4.74	21.5
4	5.78	21.5	7.53	22.1	3.07	21.3
5	5.29	21.5	7.09	21.8	2.68	21.3
6	4.99	21.2	6.39	21.7	2.19	21.1
7	4.21	21.0	6.33	21.7	1.10	21.0
8	2.72	20.8	6.21	21.6	1.82	21.0
9	2.05	20.7	5.52	21.2	0.60	20.8
10	2.17	20.7	5.03	21.1	0.63	20.8
11	1.97	20.6	4.75	21.0	0.53	20.8
12	2.23	20.6	4.18	20.9	0.27	20.9
13	2.34	20.6	3.31	20.9	0.31	20.9
14	2.43	20.5	2.95	20.8		
15	2.37	20.5	2.51	20.7		
16	2.10	20.5	2.40	20.7		
17	1.3	20.4	2.44	20.5		
18	1.5	20.4	3.48	20.5		
19	1.95	20.3	3.63	20.4		
20	1.79	20.3	3.37	20.4		
21	0.68	20.3	3.23	20.4		
22	0.28	20.2	3.80	20.3		
23	0.27	20.2	3.53	20.2		
24	0.31	20.2	3.35	20.2		
25	0.36	20.2	3.31	20.2		
26						

Summer 2006

	Site 1 – moored to floaters		Site 2- moored to rake		Site 3 – Middle of dam	
Depth	**TEMP (^{0}C)**	**DO (mg/L)**	**TEMP (^{0}C)**	**DO (mg/L)**	**TEMP (^{0}C)**	**DO (mg/L)**
1	27.01	5.83	26.86	1.56	26.86	1.78
2	26.88	1.60	26.12	1.06	25.98	1.26
3	26.92	1.26	25.83	0.99	25.70	1.02
4	25.65	1.19	25.32	0.92	25.24	0.97
5	24.58	1.08	24.66	0.91	24.84	0.96
6	24.20	1.03	24.18	0.93	24.57	1.00
7	23.61	0.95	23.75	0.94	24.23	1.05
8	23.43	0.90	23.50	0.90	23.80	1.03
9	23.29	0.89	23.48	0.92	23.63	1.07
10	23.14	0.84	23.49	0.99	23.44	1.10
11	23.03	0.80	23.50	1.06	23.28	1.08
12	22.96	0.80	23.50	1.07	23.13	1.07
13	22.91	0.79	23.48	0.98	23.04	0.80
14	22.86	0.85	23.46	1.03	23.04	0.79
15	22.82	0.86	23.46	1.14	23.03	0.81
16	22.80	0.86	23.45	1.24	22.94	0.90
17	22.78	0.86	23.45	1.26	22.85	0.80
18	22.64	0.87	23.45	1.24	22.81	0.79
19	22.62	0.88	23.44	1.25	22.75	0.82
20	22.56	0.87	23.43	1.26	22.66	0.73