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Appendix G Hydrological Assessment

Appendix G Hydrological Assessment

G.1 Introduction

For the hydrological assessment of the Nadarivatu Scheme, data provided by the design engineers for the Qaliwana and Nukunuku catchments was used to describe the existing flow regime in the Sigatoka and Ba Rivers and to predict the potential downstream impacts from hydropower generation.

This report firstly describes the flow characteristics of the Sigatoka River at the site of the Korolevu Weir, then the Ba River at the site of the Ba Power Station. Using the energy generation profiles from the design engineers, this report assesses the downstream effects of taking water from the Sigatoka River and discharging it to the Ba River, under various river flow conditions.

G.2 Hydrological Data Quality

Hydrological data for the Nukunuku, Qaliwana, and the Ba has been interpreted by MWH from a combination of rainfall and recorded flow data to estimate inflow to the proposed weir for scheme utilisation. Flow data for the Nukunuku and Qaliwana creeks was obtained for the period of 1981-1992 and 2004-early 2005. Rainfall-runoff modelling was used to generate a stream flow time series from 1990-1999. To be consistent with the design of the scheme, the data used by MWH has been accepted as the baseline hydrology for the impact assessment.

No flow or rainfall data was obtained for the Ba catchment so a synthetic stream flow time series was generated based on the data generated for the Qaliwana Creek.

The Bulu hydrological recording station (number 439401) provided data for the Qaliwana Creek. The Nukunuku hydrological recording station at Lewa (number 430400) is located close to the proposed Korolevu Weir site and provided data for the Nukunuku Creek. The current flow records for both stations are of a relatively low standard due to data gaps, uncertain accuracy of stage to flow ratings and apparent inconsistency between rainfall and flow response. Many gaps exist in the data, along with inconsistencies of flow between the two sites.

In addition, there are difficulties comparing the rainfall and flow records from the Qaliwana and Nukunuku catchments, including:

- Inconsistencies in flow patterns between the sites.
- Unrealistic low flow duration, particularly in the Nukunuku catchment.
- Inconsistencies in the stage – flow relationships derived for the record.
- Inconsistencies in daily rainfall totals between sites.
- Inconsistencies with rainfall and flow responses.
- Measured rainfall does not coincide with catchment flow records for most of the monitoring period.
- The occurrence of many gaps in the 11 year period of record for stream flows, and many large gaps in the rainfall records spanning 1982 – 2002 for the two catchments.

Despite the acknowledged inadequacies in data quality, the following analyses have utilised the available flow records as the best available representation of discharge from the Qaliwana and Nukunuku catchments. Comparison of actual flow record is made with modelled discharge derived from rainfall runoff modelling undertaken by MWH (2004a).

Qaliwana

Comparison of the earlier 1981 - 1992 flow record from the Bulu site, to the recent monitoring obtained for the period of 2004 – 2005, and the modelling of runoff done by MWH (2004a) for power investigations, gives flow statistics similar to that of the existing record (Table 1)[1].

- **Table 1 Comparison of existing flow record to modelled flow record**

	1981 - 1992	Modelled 1990 - 1999	Recent 2004 - 2005
Mean flow (m^3/s)	3.52	3.48	3.37
Daily Min (m^3/s)	0.12	0.23	0.21
Daily max (m^3/s)	623.00	191.00	155.00

The mean flows are comparable for each period of record, with variability about the low flows.

Nukunuku

Comparison of the earlier 1981 - 1992 flow record from the Lewa site, to the recent monitoring obtained for the period of 2004 – 2005, and the modelling of runoff done by MWH (2004) for power investigations, gives flow statistics similar to that of the existing record (Table 2).

- **Table 2 Comparison of existing flow record to modelled flow record**

	1981 - 1992	Modelled 1990 - 1999	Recent 2004 - 2005
Mean flow (m^3/s)	0.860	1.21	0.62
Daily Min (m^3/s)	0.002	0.08	0.13
Daily max (m^3/s)	120.000	55.53	8.14

The mean flows are comparable for each period of record. However, the recent data suggests a lower period of specific catchment runoff, probably due to more moderate storm events, with greater variability about the low flows. The Nukunuku catchment also has no known water takes thus the stream above the Lewa site can also be regarded as an unmodified flow regime.

G.3 Sigatoka River catchment

The Sigatoka River has a catchment area of approximately 530 km^2. The headwaters of the Sigatoka catchment comprises of two tributaries flowing north to south: the Nukunuku Creek

[1] Note that there are no known water takes from the Qaliwana Creek above the Bulu site so flow regime can be regarded as unmodified in relation to water uses.

with a catchment area of 19.2 km^2; and the Qaliwana Creek with a catchment area of 54.9 km^2. They meet at the Korolevu Weir.

The Qaliwana and Nukunuku sub-catchments are broadly characterised by:

- High flow variability due to rainfall patterns, topography and short, relatively steep catchments.
- Relatively rapid base-flow recession and low minimum flows due to catchment topography and geology.
- Low minimum flows occurring relatively frequently, although for limited duration.

The rainfall records collected to date have been assessed for mean annual catchment rainfall using multiple station records (MWH, 2004a). Based on the average annual rainfall estimate, the specific catchment outflows are given in Table 3 below.

Table 3 Specific catchment data and outflows

Statistic	Qaliwana at Bulu	Nukunuku at Lewa
Catchment area	54.9 km^2	19.2 km^2
Annual average rainfall	2965 mm	2750 mm
Mean flow	3518 L/s	863 L/s
Specific mean flow	64 L/s/km^2	45 L/s/km^2
Catchment runoff	68.2%	51.5%

The resulting catchment runoff (the amount of surface water present in streams for any specified contributing catchment area) of the Qaliwana at 68.2% tends to be at the upper end of expected specific flow. The Nukunuku catchment is smaller, and average rainfall is also lower, resulting is a lower specific mean flow than that of the Qaliwana catchment.

An assessment of the 1981 – 1992 flow records from Bulu and Lewa hydrological flow stations is made in Table 4.

Table 4 Flow statistics for the Qaliwana at Bulu and Nukunuku at Lewa (1981 – 1992) from hydrological records

Statistic	Qaliwana at Bulu (m^3/s)	Nukunuku at Lewa (m^3/s)
Mean flow	3.518	0.863
Median flow	1.000	0.147
Minimum flow	0.012	0.001
Maximum flow	1,074.000	200.000
MALF	0.189	0.021
Q7 10	0.111	0.003
95%ile	0.162	0.017

Notes: MALF is the seven day mean annual low flow.
Q7 10 is the seven day 10-year return period low flow.
The 95%ile flow is the low flow that is attained or exceeded 95% of the time.

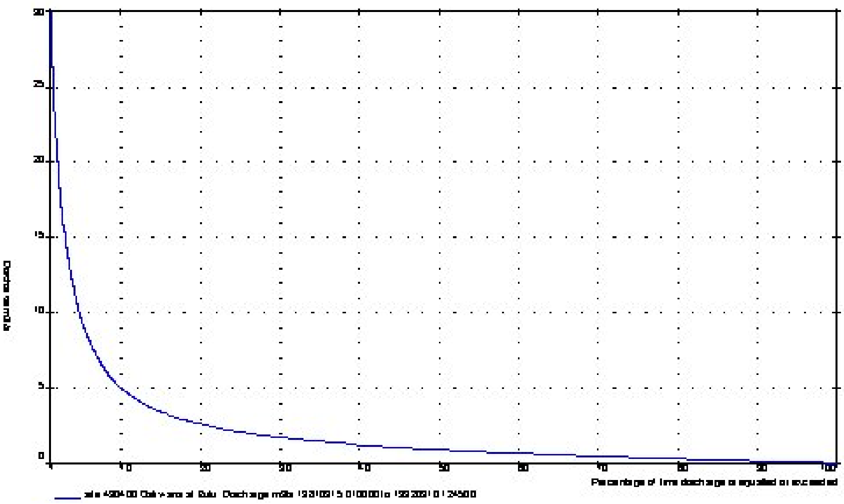
The results in Table 4 show that for both catchments, a large variation in flows exists, and the overall flow regime is dominated by large floods interspersed with extended periods of flow recession / low flows. The mean flows are much greater than the median flows, which is typical for high elevation catchments with high intensity.

For both catchments, the mean flow occurs around the 15%ile, which means that this flow is equalled or exceeded only 15% of the time.

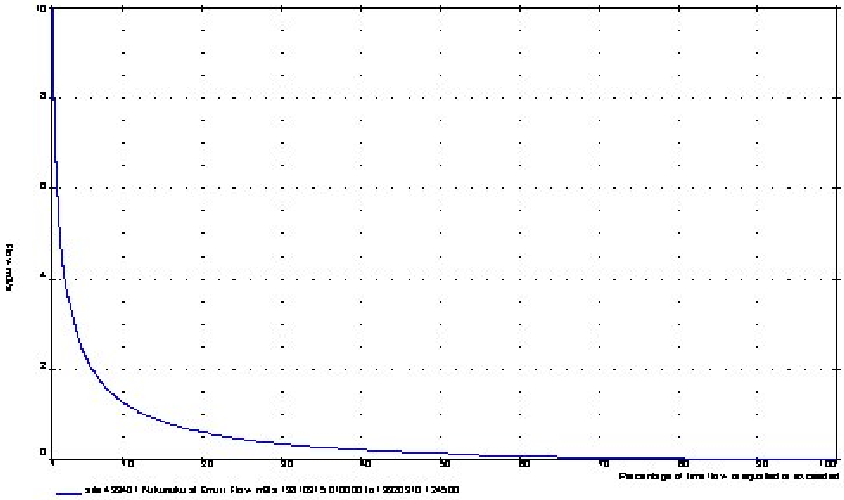
Maximum instantaneous flows for the Qaliwana have been recorded at 1,000 m^3/s, compared with a maximum daily mean flow of 623 m^3/s indicating that the catchment has a relatively rapid base flow recession.

Low flow analysis of the data indicates that both catchments have little base-flow storage capacity. This is probably due to the underlying strata being fractured basalt that drains rapidly. The soils are clay formed by tropical weathering. This limits infiltration and so there is a quick runoff response with little base-flow component. This is shown clearly in the flow distribution curves for the Qaliwana and Nukunuku in Figure 1 and Figure 2 respectively. The overall shape of the flow duration curve means there is a large duration of low flows in the catchment. Higher flows occur for a limited amount of time.

- **Figure 1 Flow distribution for the Qaliwana catchment at Bulu (1981-1992)**



- **Figure 2 Flow distribution for the Nukunuku catchment at Lewa (1981 – 1992)**



Peak flows are relatively high compared to normal flows in the catchments. This type of flow regime is typical of catchments in the steep gradient of the hilly headwaters of catchments that receive a lot of rain, not necessarily because of the land cover.

This is explained by the flow hydrographs and flow duration curves:

- Flows in the Nukunuku and Qaliwana Rivers for 95% of the time are less than 5 and 10 m^3/s respectively.
- Many flood ‘spikes’ are in the recorded flow records for the rivers.
- For 5% of the time that river flows are higher, most of the flow is distributed in the top 1% of the duration curve.

This implies that catchment flows are “highly variable” and reflect the distribution of rainfall intensity (short duration, high volume), catchment aspect (steep, high elevation) and hydrogeology (fractured rock, quickly draining, low base flow input).

G.3.1 Ba River - synthesised flow regime

The Ba River has a catchment area of approximately 45 km^2 and flows in a north to south direction upstream of the proposed discharge point from the Ba Power Station. Downstream of the discharge the river turns to flow in a north-west direction to the north coast of Viti Levu.

There are no flow records for the Ba River so a synthetic stream flow time series was generated based on the records for the Qaliwana and Nukunuku Creeks for the period 1981 – 1992. Estimation of Ba catchment flows at the Ba Power Station has been done on a linear basis, considering catchment area, mean annual rainfall, and specific flow, with comparison of the two stations.

Table 5 shows the relationship of the Ba catchment to the Qaliwana and Nukunuku catchments for predicted catchment specific flows.

- **Table 5 Predicted specific catchment flows for the Nukunuku, Qaliwana and Ba**

Catchment	Area (km2)	Average Annual Rainfall (m)	Total Catchment Water Volume (Mm3)	Specific Catchment Flow (L/s/km2)	Mean Flow (L/s)	% of Qaliwana Flow	% of Nukunuku Flow
Nukunuku	19.2	2.75	52.8	45	863	25	100
Qaliwana	54.9	2.97	162.77	64	3518	100	407
Ba	49.5	2.5	123.75	57	2821.5	80	327

The summation of catchment area and rainfall to give a total available catchment water volume was regressed against specific flow for the Qaliwana and Nukunuku catchments, to predict specific flow for the Ba catchment. The resulting specific flow was then used to calculate and compare mean flows for the records. The predicted mean flow for the Ba catchment is 0.8 of flow at Bulu and 3.27 times the flow at Lewa.

The relationship of mean flow between catchments was then applied to the existing Bulu and Lewa data for the period of 1981 – 1992, which gave the following flow statistics for the Ba River (Table 6).

- **Table 6 Flow statistics for the Ba River (estimated from synthetic record 1981 - 1992)**

Statistic	Flow (m^3/s)
Mean flow	3.025
Median flow	0.800
Min daily flow	0.010
Max daily flow	506
MALF	0.118
Q7 10	0.790
95%ile	0.839

G.3.2 Sigatoka and Ba Catchment Flow Contribution

In order to determine the effects of changing the flow regimes with the proposed scheme, the relative proportion of flow from the head water catchments is expressed as a percentage of the total catchment at specified locations downstream of head water sub-catchments are shown in Table 7 and Table 8. Catchment specific flows have been derived from the mapping of Sigatoka and Ba River catchments into individual (major) sub-catchments.

- **Table 7 Percentage of flow contribution to Sigatoka River of head water catchment**

River location	Distance downstream (km)	Sub-catchment area (km^2)	Mean rainfall (m)	Percentage of flow contribution to river
Qaliwana and Nukunuku confluence	0	91.32	2.75	100.0
Sigatoka at Naidraeu	7.15	18.82	2.75	83.6
Sigatoka at Jauvakarua	21.13	122.28	2.75	40.5
Sigatoka at Namoli	29.35	100.69	2.5	29.2
Sigatoka at Nukulau	35.60	124.02	2.5	21.7
Sigatoka at Lote Ck	43.32	69.52	2.3	19.2

River location	Distance downstream (km)	Sub-catchment area (km^2)	Mean rainfall (m)	Percentage of flow contribution to river
confluence				
Sigatoka at Korovau	49.41	117.09	2.3	16.1
Sigatoka upstream of Kelyas	57.68	314.77	2.3	11.1
Sigatoka at Sigatoka (estuary)	126.17	533.83	2.1	7.6

- **Table 8 Percentage of flow contribution of head water catchment to the Ba River**

River location	Distance downstream (km)	Sub-catchment area (km^2)	Mean rainfall (m)	Percentage of flow contribution to river
Ba at Powerhouse	0	44.12	2.5	100.0
Ba at Aurata Ck confluence	7.87	73.18	2.5	37.6
Ba at Nahara Ck confluence	16.08	195.64	2.4	14.5
Ba at Navala	23.75	93.66	2.3	11.3
Ba at Huniku Ck confluence	28.68	58.15	2.3	9.9
Ba at Nalanga (estuary)	62.03	474.16	2.1	5.2

The above estimates of catchment specific discharge are based on the sum of the sub-catchment area and mean annual rainfall depths. The percentage of flow contribution from head water catchments however, is irrespective of flow variability and timing within sub-catchments, and only represents a generalised flow regime based on the calculated catchment specific discharge.

Table 7 shows that the flow contribution of the Qaliwana and Nukunuku catchments to the Sigatoka River is estimated to be approximately 29% at Namoli Village, which is nearly 30 km downstream. The overall contribution to the total Sigatoka River flow is estimated to be approximately 8%.

Flow contribution of the Ba catchment above the proposed powerhouse discharge site to the Ba River, ranges from approximately 38% at the Aurata Creek confluence, 7.87 km downstream, to 5% of the total Ba River flow.

G.4 Potential Impacts and Management Controls

This section covers the hydrological (flow) implications of the hydropower scheme on the Sigatoka River below the Korolevu Weir and the Ba River below the proposed Ba Powerhouse discharge point.

G.4.1 Change to natural flow regimes

The operation of the Nadarivatu Hydropower Scheme gives rise to the following changes to the flow regimes of the associated Sigatoka and Ba catchments:

- A decrease in the mean flow of the Sigatoka River, and a residual flow below the Korolevu Weir of $0.2m^3/s$ for most of the year. It will result in extended periods of stable, low flow (at or near the residual flow of 0.2m^3/s) punctuated by flushing flows resulting from periods of high rainfall.

- At median flow in the Sigatoka River this results in a 7% decrease at the river mouth.
- An increase in the mean flow of the Ba catchment.
- A maximum increase in flow at any time in the Ba River of 15m^3/s. At median flows, this is equal to 100% increase in flows at the river mouth. At a median power station discharge and median river flow, this is equal to a 10% increase in flows at the river mouth.
- During low flow periods the Ba River will experience a daily pattern of increased flows in the anytime between 8am and 8pm, from the power station discharge.

The following sections describe the effects of the scheme on flows in the Sigatoka and Ba rivers.

G.4.2 Sigatoka River

Figure 3 illustrates the impact of the proposed scheme on the Sigatoka River downstream of the proposed weir utilising data from 1994 to 1995. The dark hydrograph shows the natural river flow without the weir, and the light hydrograph the flow with the weir in place and the water diverted to the power scheme.

Figure 3 Mean daily Qaliwana and Nukunuku Creek inflows to the weir/lake and resulting spillway and residual flow to the Sigatoka River for the period 1 January 1994 to 31 December 1995.

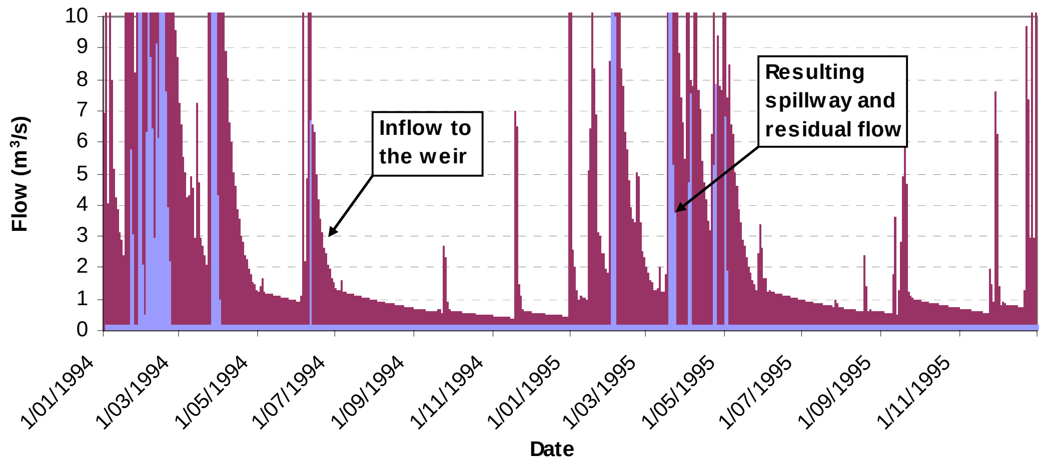
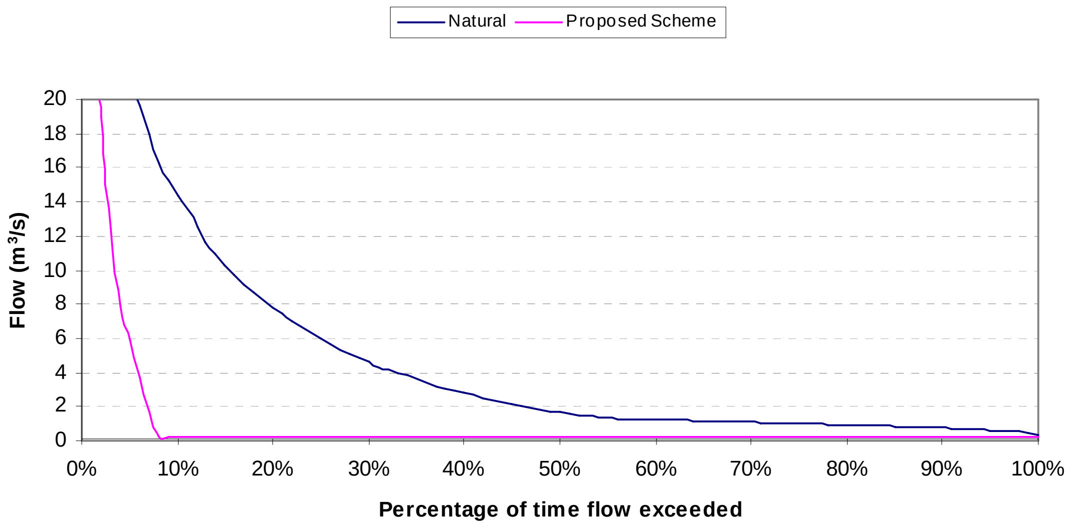


Figure 3 shows that flows downstream of the diversion weir will be significantly reduced with the minimum flow of 0.2 m^3/s only exceeded approximately 8% of the time as shown in Figure 4. Large floods will be reduced slightly but the more frequent floods will be significantly reduced.

Figure 4 Flow Duration Curve for Qaliwana and Nukunuku Creek combined flow at the confluence.



Flow statistics for natural and modified flow from the confluence of the Qaliwana and Nukunuku Creeks are shown in Table 9.

Table 9 Flow statistics for the Qaliwana and Nukunuku Creek flows at the confluence.

Statistic	Natural flow (m^3/s)	Modified weir flow (m^3/s)
Mean flow	5.89	1.76
Median flow	1.68	0.20
Min daily flow	0.38	0.20
Max daily flow	312.84	297.84
Mean Annual Low Flow (MALF)	0.56	0.20
7Q 10	0.44	0.20
5%ile	0.61	0.20

The magnitude flushing flows will not be significantly altered by the scheme from those occurring under the natural flow regime.

Effect on the downstream catchment

The main effects of the proposed Nadarivatu scheme on the Sigatoka River are the decreased flows.

The change in flow regime will impact on the stream morphology and riverine ecosystem. The prolonged periods of reduced flows has the potential to cause changes to the stream bed because medium to small floods that move sediments will be essentially removed. Flow depths will be reduced and this could impact on fish movement, invertebrate habitat and riparian vegetation.

To illustrate the overall impact of the operation of the Nadarivatu scheme on cumulative river flows estimates of catchment specific discharge were derived from an assessment of sub-catchment area and mean annual rainfall depth. These estimates were used to derive the percentage reduction in median flow resulting from the Nadarivatu scheme at various locations downstream from the weir outlined in Table 10 below.

Table 10 Percentage of modified median flow contribution to Sigatoka River of headwater catchments for proposed Nadarivatu Scheme.

River location	Distance downstream (km)	Median flow (m^3/s)	Resulting median flow for Proposed Scheme (m^3/s)	Resulting percentage of natural median flow remaining in-stream for Proposed Scheme (%)
Qaliwana and Nukunuku confluence	0	1.68	0.20	11.9
Sigatoka at Naidraeu	7.15	2.01	0.53	26.3
Sigatoka at Jauvakarua	21.13	4.15	2.67	64.3
Sigatoka at Namoli	29.35	5.75	4.27	74.3
Sigatoka at Nukulau	35.60	7.73	6.25	80.8
Sigatoka at Lote Ck confluence	43.32	8.74	7.26	83.1
Sigatoka at Korovau	49.41	10.46	8.98	85.9
Sigatoka upstream of Kelyas	57.68	15.07	13.59	90.2
Sigatoka at Sigatoka	**126.17**	**22.21**	**20.73**	**93.3**

The estimates of residual flow show a significant impact on river flows immediately downstream of the weir. However, the impact will reduce as incremental inflow adds variability to the flow regime, see Table 10. At the coast the impact will be negligible (the flow is decreased to 93% of the median river flow). A more detailed assessment and quantification of impacts should be done and mitigation measures proposed where impacts will be significant.

G.4.3 Ba River

The flow effects of the power scheme water use in the Ba catchment represents an increase in flow for the catchment. There is no impact of the scheme on flow reduction.

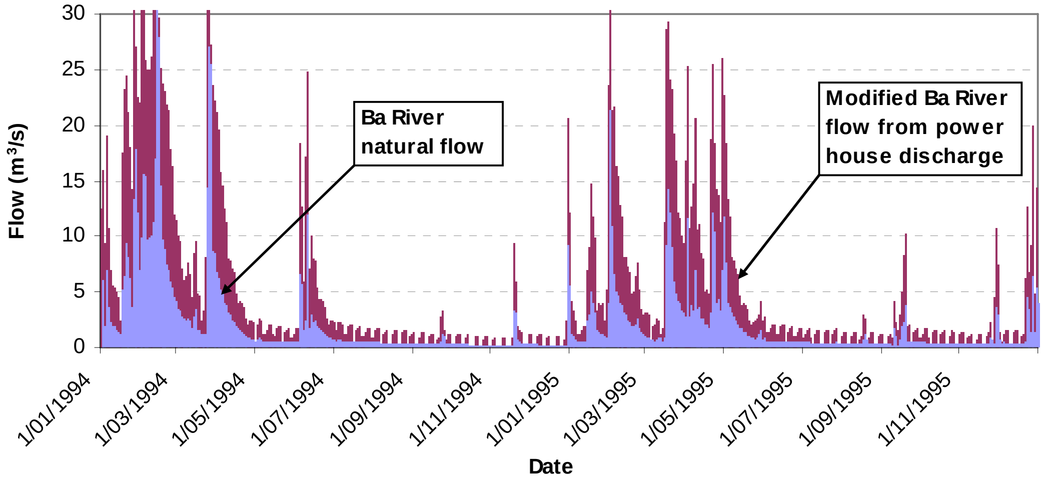
The powerhouse is located on the left bank of the Ba River at Buyabuya Village. A peak discharge of $15m^3/s$ is proposed from the power station to the Ba River.

Figure 5 shows the average daily natural Ba River flows (the light hydrograph) together with modified average daily flows (the dark hydrograph) as a result of the proposed scheme discharge for the 1994 to 1995[2] year. The plot shows that flows will be elevated for five or

[2] Estimated from rainfall data and correlation to Sigatoka catchment flow data.

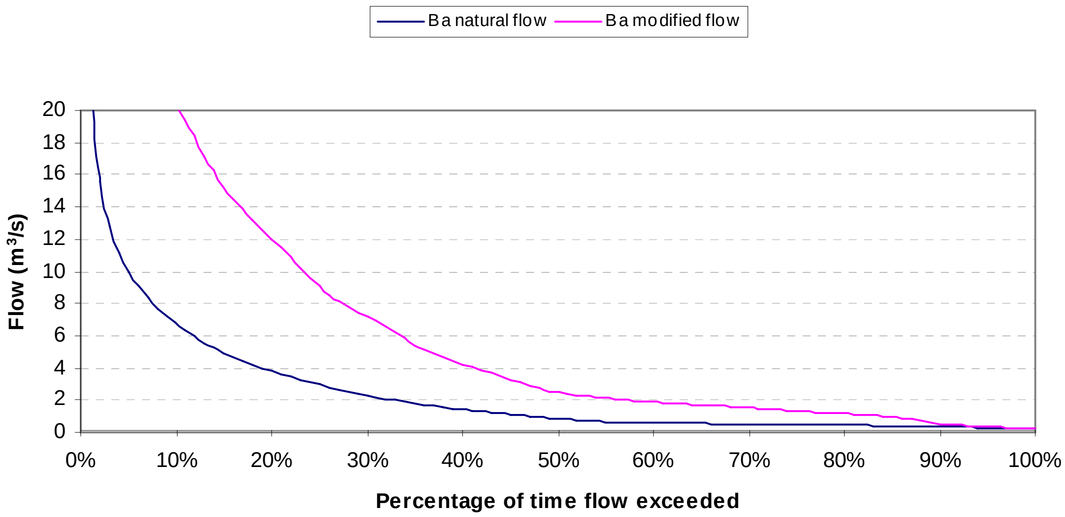
six out of every seven days because it is not planned to generate every day. Furthermore, generation generally will only be part of the day so the actual increase in flow due to generation will be higher than the average for the day (maximum 15 m^3/s).

▪ **Figure 5 Mean daily Ba River flow and modified flow as a result of the proposed Nadarivatu Scheme discharge for the period 1 January 1994 to 31 December 1995.**



The duration of increased flows in the Ba River relative to the natural flows immediately downstream of the powerhouse is shown clearly in Figure 6.

▪ **Figure 6 Flow Duration Curve for Ba River downstream of powerhouse**



Estimates of Ba River flow statistics for natural and modified flows are given in Table 11.

Table 11 Flow statistics for Ba River flow below Powerhouse 1990 – 1999[3]

Statistic	Natural flow (m^3/s)	Modified weir flow (m^3/s)
Mean flow	2.79	6.92
Median flow	0.83	2.47
Min daily flow	0.18	0.18
Max daily flow	152.63	167.63
MALF	0.26	0.63
Q7 10	0.21	0.46
5%ile	0.29	0.36

As is expected, all resulting flows of the Ba River under the proposed scheme are increased except for the minimum flow which remains at 0.18 m^3/s.

The impact of the addition of median flows from the powerhouse to the Ba River on the flow downstream is shown in Table 12. The natural median flows for the Ba River have been approximated from the catchment specific discharges in Table 8. Thus it should be noted that the median flows derived in Table 12 are independent of flow variability and timing within sub-catchments, and only represent a generalised median flow regime based on the calculated catchment specific discharges.

Table 12 Estimated percentage increase in median flow in the Ba River for median power station discharge.

River location	Distance downstream (km)	Median flow (m^3/s)	Resulting median flow (m^3/s)	Resulting percentage increase from natural median flow (%)
Ba at Powerhouse	0	0.83	2.47	197.6
Ba at Aurata Ck confluence	7.87	2.21	3.85	74.3
Ba at Nahara Ck confluence	16.08	5.74	7.38	28.6
Ba at Navala	23.75	7.36	9.00	22.3
Ba at Huniku Ck confluence	28.68	8.37	10.01	19.6
Ba at Nalaga	**62.03**	**15.86**	**17.50**	**10.3**

The resulting median flows in the Ba River from the operation of the proposed Nadarivatu scheme produce a percentage increase in median flow at Nalaga of 10.3%.

In order to describe the maximum possible impact on flows in the Ba River, Table 13 shows the percentage increase in median river flows as a result of a maximum powerhouse discharge of 15m^3/s.

[3] Modelled data, excluding 1998 due to lack of accurate data.

Table 13 Estimated percentage increase in Ba River median flow for a 15m^3/s powerhouse discharge.

River location	Distance downstream (km)	Median flow (m^3/s)	Resulting flow (m^3/s)	Resulting percentage increase from natural median flow (%)
Ba at Powerhouse	0	0.83	15.83	1807.2
Ba at Aurata Ck confluence	7.87	2.21	17.21	679.8
Ba at Nahara Ck confluence	16.08	5.74	20.74	261.3
Ba at Navala	23.75	7.36	22.36	203.8
Ba at Huniku Ck confluence	28.68	8.37	23.37	179.3
Ba at Nalaga	**62.03**	**15.86**	**30.86**	**94.6**

Table 13 shows that for a 15m^3/s maximum discharge to the Ba River at the proposed powerhouse location, the Navala Village approximately 24km downstream, could potentially see a 200% increase in median river flow. Overall, in the Ba River at Nalaga (62km downstream), there is potential for median flow to double if the scheme is operated continuously at full capacity for an extended duration. These figures do not imply a doubling of the median flow for the Ba River, rather the resulting flow regime at natural median flows for the small amount of the time annually when the powerhouse is operating at maximum discharge capacity. In the reach immediately downstream of the powerhouse discharge impacts on the stream morphology and riverine ecosystems could be significant.

The increased flows could result in significant erosion of the river bed and reshaping of the channel. The increased flows could also impact on the in-stream habitat and riparian vegetation. A more detailed assessment will be required to quantify the potential impacts.

Because the scheme is ‘run of river’ due to limited storage, the worst case scenario described above will not occur often, as maximum power station discharges are likely to occur during high flows or receding flows in the Ba River, where extra flow in the river will have less effect.

Changes in river profile

One advantage of hydropower generation is that start-up and shut-down times are short. However, the disadvantage is that flow in the river can change rapidly with no warning given to downstream users of the river. The impact on downstream users will relate to the change in water depth, velocity and inundated width of the river. The proposed discharge from the Ba Powerhouse will have an effect on river depths. The scale of effect in terms of overall rise of water levels and the timing of a maximum 15 m^3/s generation “pulse” down the Ba River has been estimated using topographical maps and simple hydrology.

Flow velocities for the 15m^3/s discharge have been derived by Manning’s equation, in conjunction with the scaling of river widths and elevations from the 1:250,000 topographical map of Fiji. Manning’s ‘n’ used for the flow routing was 0.055, which generally relates to an incised channel with highly variable stream-bed configuration, boulders and rocky outcrops within the flow channel. The time lag for the full effect of the $15m^3/s$ flow pulse has been estimated at 10% of the total travel time between specified sites.

In general, velocities decrease down the Ba River with a corresponding decrease in gradient, whilst river widths increase with a corresponding increase in area and wetted perimeter of flow.

The effect of the flow pulse would not occur at Navala village (approx. 24km downstream of the Ba powerhouse) until about 5 hours after the discharge commenced. At rates of rise less than 2 m/hour, the water level rise should not pose any threat to in-stream water users. There is ample time in most cases for users of the river to be aware of an increase in flow, and enable safe exit of the river as appropriate. At the Ba powerhouse, much sharper rises may be experienced, and at this site, suitable measures may be taken to warn river users of flow variability, particularly the residents of Buyabuya village.

G.5 References

MWH 2004a. Sustainable Energy Ltd Report for Sigatoka-Ba Hydro Power Project Preliminary Design MWH New Zealand Ltd, November 2004. Dunedin.

Appendix H Archaeological Report

ARCHAEOLOGICAL IMPACT ASSESSMENT REPORT FOR BA/SIGATOKA HYDRO-ELECTRIFICATION PROJECT

Ba Highlands

Report prepared for Sinclair Knight Merz by the Archaeology Department, Fiji Museum 2004

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Acknowledgement

The Fiji Museum wishes to thank the Environmental Impact Consultants Sinclair Knight Merz for their initiative and determination to the protection and preservation of archaeological sites of cultural importance and significance.

We would also like to acknowledge the Chairman and staff of the Native Lands and Fisheries Commission for their assistance in the research into records of the area of concern. Our utmost appreciation to the Chiefs and people of the Yavusa Cawanisa and Yavusa Nubu at Lewa and Nadala villages for their moral support and guidance during the course of the field survey. Our sincere gratitude to Savenaca Boladroka the Turaga Ni Koro Lewa Village and field assistants Marika Rawasoi, Sikeli Naucabalavu, Apisai Kurucivi, Seremai Raganivatu (2) all of Lewa Village and Jesoni Senimatiavi of Vatumoli Settlement, who made tremendous contributions to this AIA in guiding us to the sites. We would also like to thank Seremaia Raganivatu (1), Sikeli Matawalu Sokovata and Isei Turaga for giving us their accounts of the Oral Traditions of the Yavusa Cawanisa and Yavusa Nubu respectively and it's surrounding areas.

Synopsis

Fiji Electricity Authority the developers of the demarcated area consulted Sinclair Knight Merz to conduct an Environmental Impact Assessment in the headwaters of the Ba/Sigatoka area. The designated area has been earmarked for the proposed electrification project development for the country.

The Environmental Impact Consultants, Sinclair Knight Merz, commissioned and fully funded the Fiji Museum to conduct an Archaeological Impact Assessment in the designated area of the upper reaches of the Ba/Sigatoka rivers.

The Archaeological Impact Assessment conducted during the course of this project involved site identification, surface surveying, site mapping and the recording of Oral Tradition. Seven sites were identified and surveyed during this field survey. The sites identified are significant to the people of the Yavusa Cawanisa of Lewa Village and the Yavusa Nubu of Nadala Village and its surrounding villages respectively.

Introduction

The report of the Archaeological Impact Assessment conducted in the demarcated area draws from the findings of the Archaeology Department who conducted this assessment in regards to sites of Cultural and Historical significance. This Archaeological Impact assessment is to be included in the Environmental Impact Assessment report prepared by the consultants for Fiji Electricity Authority.

The field survey of the demarcated area was conducted in two phases with the first phase conducted in August and the second phase in October 2004. The first phase of the project concentrated in the Lewa Intake and the proposed Ba Hydro Power Station areas, while the second phase of the project centred in the Qaliwana intake area. Traversing this areas of the sites identified is quite demanding due to the ruggedness of the terrain with much grassland and light forest in the actual sites.

Fiji Museum Archaeology Department Officers with the Environmental Scientist stayed in Tavua and travelled daily to conduct the survey in the demarcated area for 3 days in phase one and spent a day on phase two of the project. The field survey included site identification, mapping, site survey and the recording of Oral Tradition.

This report is a preliminary assessment of the cultural significance and archaeological values of the designated area. The areas identified are to be protected subject to the interest of the landowners and the jurisdiction of the Preservation of Objects of Archaeological and Palaeontological Interest Act.

Method

In phase one of the projects the field survey team-travelled daily from Tavua to Lewa and Marou villages and foot surveyed the sites within the areas of concern. While in the second phase the team foot surveyed the Qaliwana areas and identified a site. The sites identified are: -

Lewa Intake area:

- Ekubu Site
- Korolevu Site
- Butoni 1 Site
- Nabilia Site
- Nubutiritiri Site
- Butoni 2 Site

Ba River

- Tabunacici Site

Qaliwana Intake Area

- Bulu Site

The above-mentioned cultural sites were identified, surveyed, mapped and recorded. Mapping was conducted using a SUNTO COMPASS and a 50 METRE TAPE and Global Positioning System reading was also taken on some of these sites. The GPS used is a PANASONIC HANDHELD PLOTTER KX-G5700.

Elders of the two Yavusa mentioned above freely gave their accounts of the Oral traditions of the area which was recorded and stored in the Fiji Museum.

Results

The Archaeological Impact Assessment team identified 8 sites and mapped 3 of the sites. All these sites have been registered and recorded with the Fiji Museum.

Recorded Sites

Ekubu Site

This site is south of the Korolevu trig along the same ridge with GPS location - Lon: 177’ 5590, Lat: 17’ 3987. Three house mounds were located in the site and all these mounds have stone linings. The area is covered with grass reeds and also surrounded by pine trees. The site has been disturbed in most of the areas with pine planting and cultivation. Animals are grazing and roaming freely within this site. This site has been damaged a lot due to the development of the area for forestation. The site is significant to the Ekubu mataqali members who are residing in Lewa, Marou and Buyabuya villages. The Ekubu clan members moved and resided on this site from Navinoti after the installation ceremony of the first Tui Cawanisa at Korolevu was conducted.

Korolevu Site

Korolevu site is the installation site of the first Tui Cawanisa and is identifiable by the Korolevu Trig with GPS location – Lon: 177' 5602, Lat: 17' 3999. Two ditches surround the site; the first is at the midway from the road to the top of the installation mound on the south side. The second ditch is at the base of the hill where the installation mound is, whereupon the stone mound is at the top of the hill overlooking the Ba and Sigatoka rivers. Pottery shards were found on this site, in an area that is now used for farming. The identified shards have incised pattern designs on them. This site is significant to the Yavusa (Tribe) Cawanisa that comprises several clans (mataqali) in several villages apart from the Chiefly village of Lewa.

Butoni Site

A very unique site in that all the four mounds identified have graves inside. These graves also have upright stones except the topmost mound. All the mounds have stone linings. No pottery was found on the site. The site is beside the Sigatoka River and is below the Hydrological Recording Station. The GPS location of the site is Lon: 177' 5649, Lat: 17' 3957. Mapping of this site was conducted.

Nabilia Site

The site is surrounded by stonewalls from the north to the south and east to the west with GPS location – Lon: 177' 5656, Lat: 17' 3932. The stonewall is about 90 cm high and 90cm wide and the wall stretches for about 60m wide and 80 length. Sixteen house mounds with stone linings were located due to visibility though there are more. The site is covered with bush and light forest with bamboo trees towards the riverside of the site. Site has been partly disturbed by the grazing of animals but the Turaga ni Koro of Lewa Village has fenced it in for the time being. No pottery or shells was found on the surface of this site. The stonewall that runs by the Sigatoka river is also a protective barrier for the old village site. The site is situated at the junction of the Nakula creek as it joins on to the Sigatoka river.

Nubutiritiri Site

The site is east of the Hydrological Recording Station (opposite side of the Sigatoka River) with GPS location – Lon: 177’ 5644, Lat: 17’ 3958. This site has been utterly destroyed a lot due to the fencing in of cattle in this particular area. The site is now utilised as a breeding (raising) area for cattle that has resulted in the devastation of the house mounds. Only a mound is still intact though with stone linings, this is because this particular house mound is not in the fenced in area, it is by the river and clearly visible.

Butoni 2
The site is by the creek and two house mounds were identified during the field survey. These two mounds have stone linings, but are covered in bush and shrub with light forest. Not much could be gathered about this site from our local historian.

Tabunacici
The site has only a single house mound with stone linings and is situated by the Tabunabeka Creek, at the junction with the Ba River with GPS location – Lon: 177’ 5503, Lat: 17’ 4023. A plain body shard (pottery) was found on the side of the house mound, facing the Ba River. Mapping of the site was done.

Bulu
The Bulu site has 18 house mounds and stonewall facing (lining) that are still intact but some have eroded due to heavy rain. One of the house mounds is heavily eroded because it’s located on a hilly area. Other probable causes of disturbance would be forestation and the logging of trees in the area. This site is significant because it was where the descendants of the Yavusa Nubu once lived. This site is above the Qaliwana River. No pottery or shells were found on the surface of this site.

Conclusion

The sites recorded are significant to the people of the Yavusa (tribe) of Cawanisa and Bulu respectively. Though according to the oral tradition gathered some of these sites were occupied by other tribes whose members are living in other parts of Fiji today. Most of the house mounds in these sites have stone linings (facings) that are still intact and visible.

One of the sites mentioned has been utterly devastated due to the ignorance of the landowners to the protection of old sites even though it was mentioned a lot in the oral tradition records. This has resulted to the destroying of house mounds, stone linings and archaeological data that could have been gathered from the surface.

Some of these sites have unique features with graves and upright stones inside the house mounds and also the, stonewall at one of the sites is quiet fascinating because it surrounded the entire site.

Oral Tradition recorded stated that house mounds are on both sides of the upper Sigatoka river in the Cawanisa land boundary though these are metres apart. The Archaeological Impact Assessment team managed to identify and corroborate this oral tradition

Recommendations

The Fiji Museum recommends that the sites mentioned and identified be protected and fenced in. This is to eliminate the movement of animals especially cattle and if it continues will further damage the sites. The Fiji Museum recommends that the onus be on the developers to expand the area of the site, provide a buffer zone and fence in these areas if possible subjecting to their funding.

If during the commencement of the developing of the designated area and with the approval of the developers and landowners to the fencing of the archaeological sites, the Fiji Museum wishes to be notified to be a part of the team to oversee the protection of the cultural sites.

The Fiji Museum also requests the developers to notify the Fiji Museum if during their course of work, they uncover any other cultural sites or material. In such an event salvage archaeology and further survey and mapping would be conducted.

Appendix

Photographs
Transcripts of translated Oral Traditions.
Fiji Map – showing area of concerntration
Site Maps

Photographs

House mound with stone linings, Ekubu Site

Grave with upright stone, Butoni Site

Seremaia clearing weeds from stonewall at Nabilia Site

Nubutiritiri Site

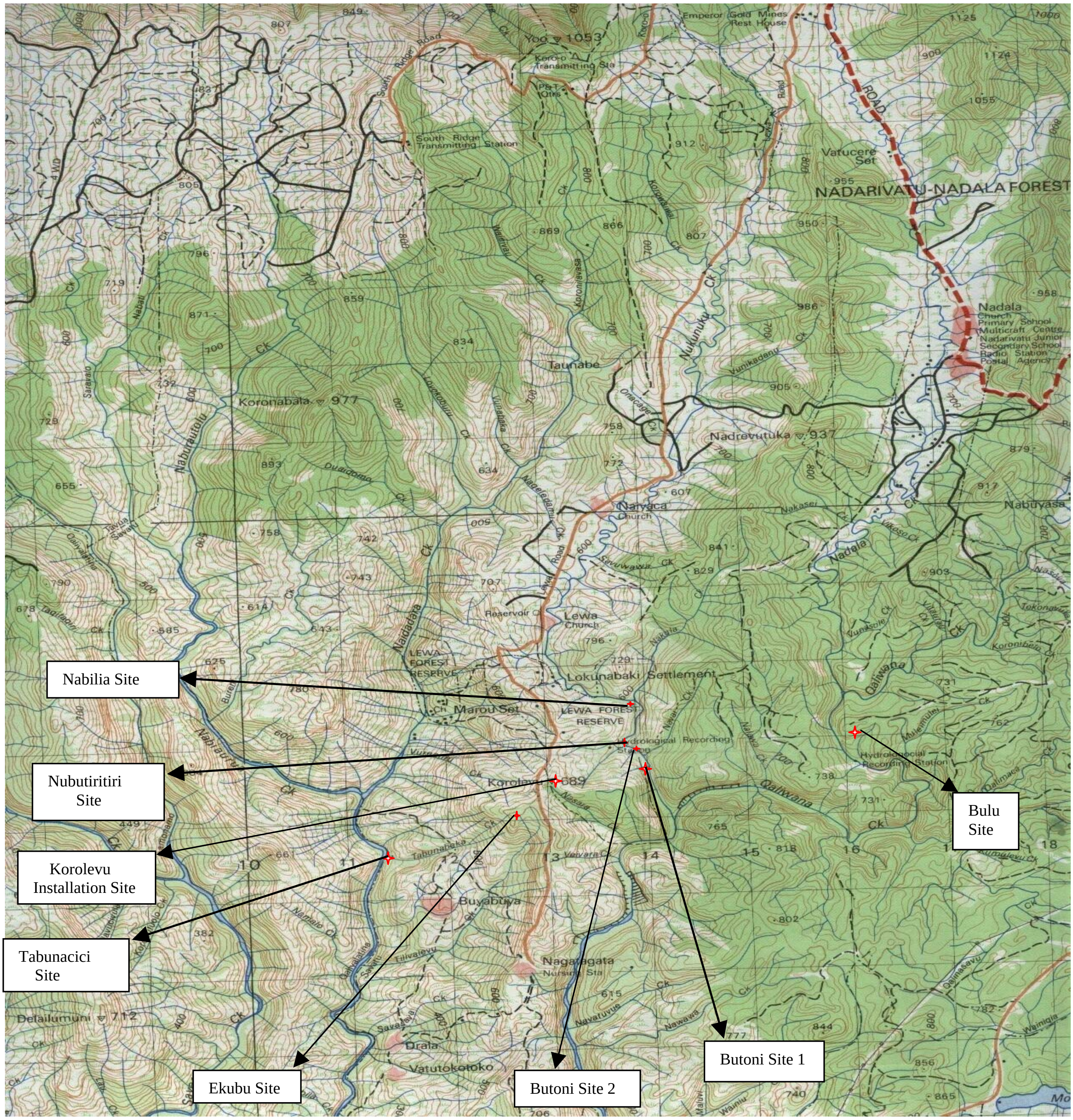
House mound with stone linings, Butoni Site

Maleli on Causeway while Seremaia stands in ditch, Korolevu site

Installation mound, Korolevu Site

House mound with stone linings, Bulu Site

Stone linings on side of house mound, Bulu Site


Nabilia Site
Nubutiritiri Site
Korolevu Installation Site
Tabunacici Site
Ekubu Site
Butoni Site 2
Butoni Site 1
Bulu Site
NADARIVATU-NADALA FOREST
Nadala
Nadrevutuka
Koronabala
Lokunabaki Settlement
Marou Set
Buyabuya
Nagatagata
Drala
Vatutokotoko
Delailumuni

Appendix I 2004 Water Quality and Biological Survey

Baseline Water Quality and Biological Survey of the Proposed New Hydroelectricity Generating Facility Sites at the Headwaters of the Ba and Sigatoka Rivers.

SUMMARY

A baseline survey of the water quality, freshwater invertebrates and fish, herpetofauna, flora and birds was conducted in the area of the proposed Monasavu Dam Extension by a team from the Institute of Applied Science between 24rd August and 3rd Septembert, 2004.

A baseline water quality assessment was conducted to provide baseline information that could be used for determining the effects on surface water quality within the location areas arising from the construction and operation of the new dam. Water quality sampling was conducted at 9 sites at five locations and involved measurements of water temperature, dissolved oxygen, conductivity, depth and width of creek (estimated), colour, clarity, Total Suspended Solids, pH, nitrate, phosphate, Total Phosphorus, Total Iron, Total Manganese and ammonia. The water quality results indicate good/satisfactory water quality for freshwater. Results which indicate levels above those recommended or which differ from other sites (such as for phosphate, ammonia and total suspended solid levels) may either be as a result of human activities close by such as agricultural activities or domestic pollution or due to high background levels.

The freshwater invertebrates were sampled at eight sites from both within the water and on aquatic vegetation along the river banks. A total of 30 species of invertebrates were found at the 8 sites with Qaliwana being the most diverse with 21 species. These species included populations of the endemic gastropod *Fijidoma maculata* whose distribution is restricted to fast flowing inland streams and rivers. The building of the dam, the power house and the construction of roads in the Sigatoka–Ba catchment area will cause a lot of siltation of the streams. The populations of gastropods and prawns below the Power House are likely to disappear. All invertebrates (with the possible exception of *M. tuberculata*) living in the part of the Nadala and Qaliwana creeks that will be flooded by the construction of the dam, will eventually disappear. Over time most invertebrates should become re-established in the streams that have been affected by the construction of the hydropower scheme once the silt and grit is washed away however as in the case of the Nabukavesi Ck between 1989-1994, some rare species may be lost.

A combination of previous fish reports, visual observations, night gleaning, hand line and hook methods and interviews with surrounding villages were used to compile the fish list of the Tabunabeka Creek, Ba River, the Nukunuku River, the Nadala River and the Qaliwana River. Six species found through field surveys while village interviews resulted in an additional eight fish species. Most of these species are common and widely distributed in Fiji. The major environmental changes that the project construction may bring about generally include the

altering and blocking of the natural flow of the river subsequently interfering with fish migration and destroying native fish populations.

Diurnal surveys were conducted for skinks and nocturnal surveys for frogs and geckoes in nine sites around the Lewa intake (Butoni), Lewa village, the Ba outlet (Tabanacici and Tuba Bariya Creek), Marou Settlement, Vunasole Stream, Tuvuya pool, Buyabuya village, Qaliwana Creek and Delainavunitokalau between the 25th August and 1st September, 2004. Five species were found including one frog, two geckoes and two skinks. Of these, two are endemics (Fiji tree frog, *Platymantis vitiensis,* Pygmy snake-eyed skink, *Cryptoblepharus eximus*), two native (Barred tree skink, *Emoia trossula* and the Skink-toed gecko, *Nactus pelagicus*) and one introduced (House gecko *Hemidactylus frenatus*). All were uncommon. The low abundance of these species is probably due to a combination of poor weather conditions for surveying and the relatively disturbed nature of the habitat.

The flora and vegetation types of the proposed development area were identified using a combination of literature reviews, interview of foresters and conservation personnel and field surveys.The overall diversity of the native flora in the area was relatively low when compared to intact forest systems elsewhere with a total of 170 native taxa recorded. The most diverse area was Qaliwana with 176 vascular plant species. This was followed by Nadala Ck with 162 species and Nukunuku Ck with 154 species. The least diverse area was Tubunabeka with 70 species. Only two of the 42 listed rare and threatened vascular species for Viti Levu were found during the surveys. The vegetation types in the area ranged from transition forest in the Qaliwana area to heavily disturbed and logged forest in the Nukunuku and Nadala areas. Eleven invasive species were recorded in the area with *Spathodea campunulata, Piper aduncum* and *Lantana camara* being the most common.

The bird species in the proposed development area were identified using a combination of literature reviews, targeted field surveys and interviews of the local villagers. A total of 35 species were found in the area including 13 endemic species and two species listed as threatened under IUCN criteria. Fifteen species were found in the Tubunabeka Ck area, 27 in the Nukunuku Ck area and 30 species in the Nadala/Qaliwana Ck area. Eight mammal species were found in the area – six of which are introduced species including rats and domestic animals. Further surveys in more favourable conditions and over a longer time period should be conducted to determine the status of the threatened species in the area.

ACKNOWLEDGEMENTS

We would like to thank the following organizations and personnel for their help during this survey:

1) FEA Staff at Monasavu for accommodation
2) Jone Tokairavua (Dept. of Forestry) and Timoci Koliavu (SPRH) for help in the field
3) Savenaca Boladroka (Turaga ni koro, Lewa), Sikeli Naucabalavu, Marika Rawasoi, Sakiusa Tokalau and Sitiveni Naroro from Lewa and Marou villages
4) Guides and villagers from Buyabuya Village for help in the field
5) Ratu Isei Turagakula, Apolosa Rauvesoi, Mataiasi Nabutu, Peni Vuniwai, Peni B. Matawalu, Ratu Manoa Naleba from Nadala Village for help in the field

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INTRODUCTION

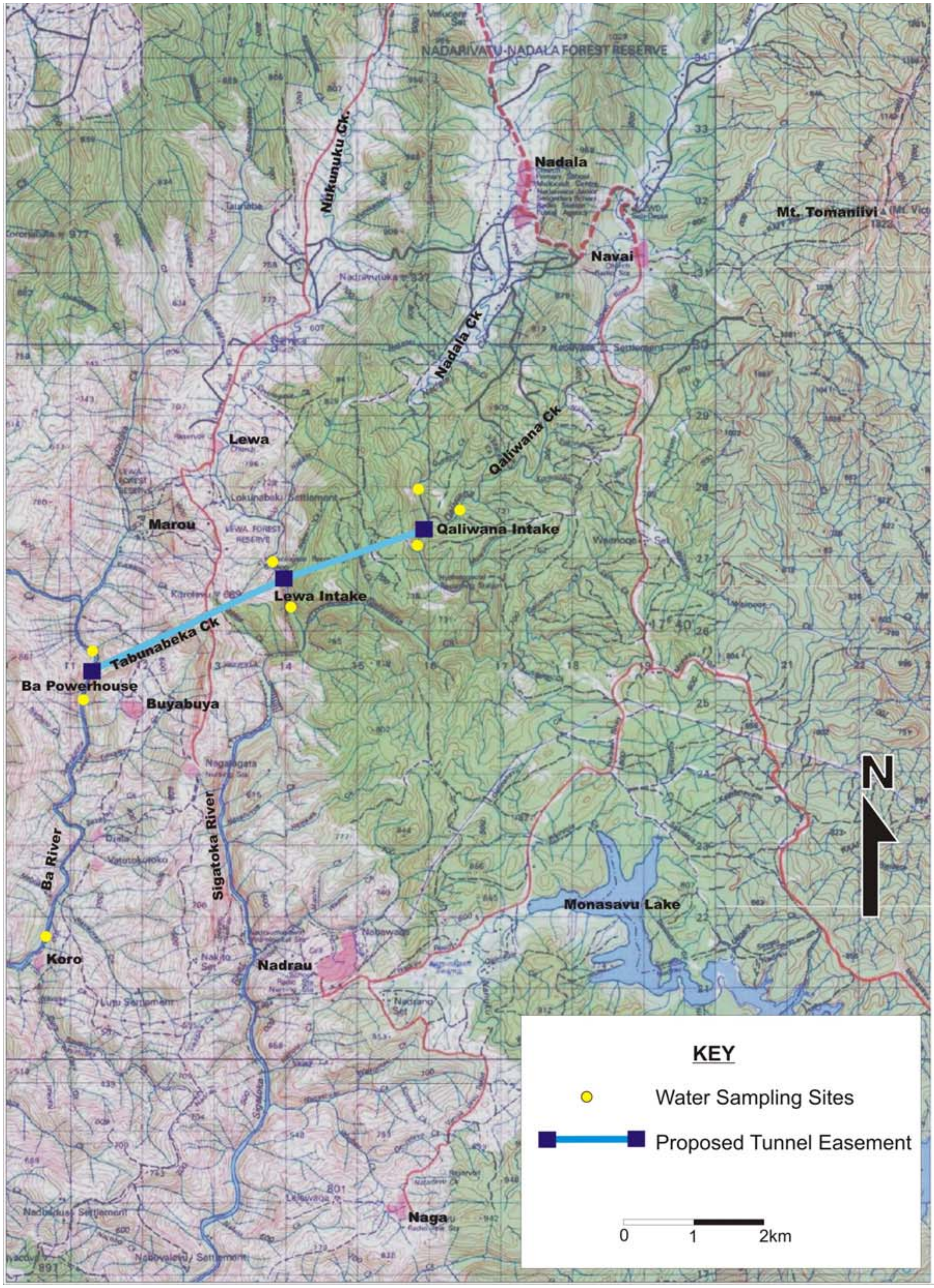
The Institute of Applied Sciences of the University of the South Pacific was commissioned by Sinclair Knight Mertz to undertake a preliminary biological and water quality baseline impact assessment of the sites proposed to be part of a new hydroelectricity generating facility by Sustainable Energy Limited (SEL). The proposed development would include the construction of two dams and two power stations along the headwaters of the Ba and Sigatoka Rivers. The proposed impacted areas would be:

i. immediately down stream of the junction between Nadala and Qaliwana Creeks,
ii. at the Nukunuku Creek dam and Lewa power house and
iii. a power house near the junction where the Tubunabeka Creek enters the Ba River.

The survey was carried out on behalf of SEL in its commitment to protect and minimise the damages and loss of Fiji's biodiversity and to ensure that any harmful effects of the scheme are mitigated prior to the completion of the EIA report for the proposed area of development.

The following IAS/USP personnel who were involved in the fieldwork survey and assessment, data analysis and compilation of the project:
Ms. Batiri Thaman and Mr. Baravi Thaman – water quality; Dr Alison Haynes – freshwater invertebrates; Mr. David Boseto and Mr. Aaron Jenkins – freshwater fish and fisheries; Ms. Nunia Thomas and Dr. Clare Morrison – herpetofauna; Mr. Marika Tuiwawa – flora and vegetation ecology; Mr. Alivereti Naikatini – avifauna and mammals.

Figure 1. Proposed hydroelectricity generating site at the headwaters of the Ba and Sigatoka Rivers, Viti Levu and field survey sites.



WATER QUALITY BASELINE REPORT

Batiri Thaman

1.0 INTRODUCTION

The Institute of Applied Sciences of the University of the South Pacific was commissioned by Sinclair Knight Merz to undertake a baseline water quality assessment of the sites proposed to be part of a new dam by FEA. The water quality study was part of a more comprehensive environmental assessment.

1.1 IMPACTS OF CONSTRUCTION ON WATER QUALITY

Effects on surface water quality within the location areas could arise from the construction and operation of the new dam. Impacts from construction are likely to be mainly from increased turbidity from erosion in borrow and cut-and-fill areas and already exposed areas.

Impacts from operation would include increased organic matter in the dam water and trapping of nutrients. This may lead to weed blooms within the dam and/or increase in nutrient levels in overflow water downstream or at outflow point. On the other hand trapping of nutrients could lead to decreased levels in downstream areas affecting fisheries. Other parameters such as pH, dissolved oxygen and Total Suspended Solids of outflow water may be different from natural water quality of the water body it is entering. Siltation of the dam from erosion in the watershed should also be monitored during operation to ensure the dam does not fill up prematurely.

In addition to water quality, depending on the flow that is allowed to overflow from the dam and the Lewa intake, a decrease in water flow downstream could be disruptive to downstream fisheries and other uses. The contribution of the dammed creeks to total flow of water in Sigatoka River should be investigated as well as the effect of the additional volume of outflow water on Ba River at the Ba powerstation (ADB 1993).

1.2 PREVIOUS STUDIES

Previous water quality studies in the area include the monitoring carried out following the construction of the Monasavu dam, which was completed in 1982. Monitoring was carried out within the dam and the Wailoa River (where outflow discharges to) from 1982 to 1985. Results from Monasavu dam indicated that during the warmer months there was little oxygen below 20 to 30 meters but in cooler months there was a more uniform distribution. pH within the dam ranged from 6 to 9. Conductivity was in range of 60-90µS. Amounts of ammonia and total phosphorous were high following dam construction but decreased from 1983 to 1985 indicating decreasing amounts of organic matter being decomposed at the bottom of the reservoir (Brodie et al. 1987).

Results from monitoring in Wailoa River indicated a marked initial impact with a distinct smell of sulphides. Discharge water was low in dissolved oxygen, slightly lower pH, relatively high in iron, manganese, ammonia and hydrogen sulphide. However, further downstream (150m) pH and dissolved oxygen levels returned to normal. Oxygenation of water at the power station would oxidise ammonia, hydrogen sulphide and the reduced forms of iron and manganese. Oxidation of the metals results in precipitation out as insoluble particulates. This may cause deposition that may lead to mechanical problems at the powerstation. In addition, downstream from the powerstation iron and manganese were still higher than above it, the effect being more pronounced during summer months. There was also a slight increase in nitrogen and decrease in phosphorus downstream from the Powerstation as compared to water above. However, impact on the Wailoa River was minimal after the initial six months (Brodie et al. 1987).

2.0 METHODS

2.1 SITES

Water quality sampling was conducted at 9 sites at five locations. The locations were the Qaliwana intake, Lewa intake, Ba River powerstation, near Koro village and a control site.

Fieldwork was carried out by a field assistant of IAS. Samples were collected from Lewa intake and Ba powerhouse on the 25th of August, Qaliwana intake on the 31st of August and Koro village on the 2nd of September and the control site on the 29th of September. Weather during surveys was wet i.e. high flow conditions for all sites except for the control site.

The eight sites sampled were:

1. Above the Qaliwana intake within Nadala Creek
2. Above the Qaliwana intake within Qaliwana Creek
3. Below the Qaliwana intake within Qaliwana Creek
4. Above the Lewa intake within Nukunuku Creek
5. Below the Lewa intake within Nukunuku Creek.
6. Above the Ba River powerstation within Ba River
7. Below the Ba River powerstation along the Ba River
8. Just upstream of Koro village along the Ba River.
9. A control site located in the upper reaches of Nukunuku Creek before Lewa village

See Table 1 for details of sampling sites.

2.2 SAMPLING METHODOLOGY

At each site, on-site measurements were taken for water temperature, dissolved oxygen, and conductivity using a YSI Multimeter. Measurements were taken just below the surface (about 10 cm depth). The Multimeter was calibrated prior to fieldwork. Other characteristics of the site such as depth (using a meter ruler) and width of creek (estimated), colour, clarity, nature of substrate, surrounding flora, observed freshwater fauna and location (GPS) were recorded. A water sample was also taken at each site for analysis for Total Suspended Solids, pH, nitrate, phosphate, Total Phosphorus, Total Iron, Total Manganese and ammonia in the IAS laboratory.

3.0 RESULTS

Results of the on-site measurements and lab analysis are tabulated in Table 2. Temperature at the sites was between 20.9 and 22 degrees celsius. This is typical during the cool months of the year.

Dissolved Oxygen levels varied from 6.7 to 7.67 and were all above the minimum recommended level of 6 mg/L.

Conductivity at all sites was around the recommended value for upland freshwater (110 μS/cm) except for Site 8. Site 8 however is further downstream from other sites within Ba River and thus may be considered more of a lowland freshwater river.

Although clarity was cloudy at some sites, the bottom was visible at all sites. For those sites deeper than 1.2 m (minimum clarity depth), the bottom was visible indicating satisfactory clarity.

pH at all sites was between 6.9 and 8.1. All were within the recommended guideline of 6.5 to 8.5.

Nutrient levels (nitrate and phosphate) were low at all sites. Phosphate was slightly high at Site 8, just above Koro village. Ammonia was above the recommended standard of 0.03 mg/L at Sites 1,2,3, and 7.

Total Suspended Solids were below the recommended level of 6 mg/L except for site 6 (above powerstation) which was 11mg/L.

Total Fe values were relatively high within Nukunuku Ck (sites 4 & 5) but these could be normal background levels due to surrounding soils.

4.0 DISCUSSION

The water quality results indicate good/satisfactory water quality for freshwater. Results which indicate levels above those recommended or which differ from other sites (such as for phosphate, ammonia and total suspended solid levels) may either be as a result of human activities close by such as agricultural activities or domestic pollution or due to high background levels. The water quality results presented however, are for high flow conditions and should be used as a baseline which should be compared during future monitorings during construction and operation of the dam, intake and powerstation to determine if any of these activities are having a detrimental impact on freshwater quality.

In general the key impacts that the proposed project may have on the surface water quality are:

During construction:

- Siltation and increased turbidity of the creeks at the Qaliwana and Lewa intake following damming of the area as a result of erosion from exposed areas and construction activities. This could affect living matter the extent to which depends on a number of factors including clearing of the area and weather conditions.

During operation:

- Decrease in water flow downstream from Qaliwana and Lewa intakes and possible effects on fisheries and other uses such as navigation and possible increase in flow downstream from Ba Powerstation. This increase could effect the erosion of banks.
- Alteration of the quality of water downstream from Qaliwana and Lewa intakes. If water is allowed to overflow there would be a possible increase in nutrients, increase in total suspended solids, and low dissolved oxygen. If water is dammed totally there would likely be a decrease in nutrients. Both scenarios could impair water for downstream uses.
- Alteration in water quality within Ba River downstream from outflow at powerstation. This would be as a result of water flowing out with elevated nutrient levels, high suspended solids, low dissolved oxygen levels, increase total iron and total manganese level. If water quality is altered it could affect users downstream such as at Koro village through increased turbidity and possible eutrophication.

- Water quality within the dam will be high in nutrients following construction and could lead to weed blooms that may interfere with operation of dam. In addition, dissolved oxygen will be low at depth which leads to anaerobic conditions, the build up of ammonia and increased levels of total Fe and total Mn. In addition, logging and land use activities in the surrounding catchment of the dam should be controlled during operation to avoid excessive silt eroding into the dam.

5.0 RECOMMENDATIONS AND MITIGATION MEASURES

Recommendations include:

- Undertake monitoring of current sites during construction of dam and intakes and during operation to determine whether the dam construction and operation are having an impact on surface water quality and thus measures could be taken to mitigate. This monitoring should also be carried out in both dry and wet weather conditions. The same parameters with the addition of turbidity and sulphate should be monitored and this could be undertaken by trained personnel of SKM or by the Institute of Applied Sciences.
- To minimise impact on water quality in downstream areas from Qaliwana and Lewa intakes ensure appropriate volume of water is allowed to overflow.
- To minimise impact on water quality at Ba powerstation outflow ensure water is withdrawn from reservoir at optimal depth to avoid high nutrient levels at surface and anaerobic bottom waters.
- Once in operation, monitor additional sites within the dam to determine if erosion is causing an increase in silt.
- Conduct monitoring of the current site during low flow or normal conditions i.e. dry weather.

Table 1. Descriptions of sites for water quality sampling

SITE	LOCATION	DATE/TIME	WEATHER	COLOUR	WIDTH (m)	DEPTH (m)	SUBSTRATE	FLORA/FAUNA
1 - Qaliwana intake above	Qaliwana Ck.	31/8 - 2:15PM	fine	slightly milky	10-12m	0.5-1m	boulders, pebbles	disturbed secondary forest
2 - Qaliwana intake above	Nadala Ck.	31/8 - 5:30PM	fine	slightly milky	5-7m	0.5m	boulders, pebbles	disturbed secondary forest
3 - Qaliwana intake below	Qaliwana Ck.	31/8 - 12:30PM	fine	slightly milky	10-15m	0.5-1m	boulders, pebbles	disturbed secondary forest
4 - Lewa intake above	Nukunuku Ck.	25/8 - 12:30PM	overcast	milky	12m	<0.5m	boulders, pebbles	disturbed secondary forest
5 - Lewa intake below	Nukunuku Ck.	25/8 - 12:30PM	overcast	milky	10-12m	0.5-1.5m	boulders, pebbles	disturbed secondary forest
6 - Ba Powerhouse above	Ba River	5:30PM	overcast	milky	8-10m	<0.5m	rock wall, boulders	riparian, grassland
7 - Ba Powerhouse below	Ba River	6:00PM	overcast	milky	20-25m	1-1.5m	boulders, pebbles	riparian, grassland
8 - Koro village above	Ba River	2/9 - 4:30PM	fine	slightly greenish	10-12m	1.5m	rock wall & boulders	disturbed, grassland
9 – Control site	Nukunuku Ck - upper	29/2 - 4:30 pm	fine	clear	4-5m	0.5 – 1 m	boulders, pebbles, some sand	disturbed secondary forest

Table 2. Water quality results

Site/ Parameter	1	2	3	4	5	6	7	8	9	Guidelines *
Temperature (°C)	21.1	21.7	21.2	20.9	21	21.4	21.5	21.6	22.0	
Dissolved Oxygen (mg/L)	6.94	7.13	7.12	7.1	7.1	6.7	7.09	7.67	6.72	6 or greater
Conductivity (µS/cm)	54.7	56.4	56.6	56.3	56.3	83.8	85.6	124.8	72.0	110 µS/cm**
Clarity	slightly cloudy	slightly cloud	slightly cloudy (	cloudy	cloudy	cloudy	cloudy	slightly greenish	clear	>1.2 m
pH	7.5	6.9	7.2	7.5	7.5	7.8	8.0	8.1	7.5	6.5 – 8.5 6.6-8.0**
Nitrate (mg/L)	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	<0.034	0.04	<0.034	0.12 mg/L** 0.34 mg/L TN**
Phosphate (mg/L)	<0.018	<0.018	<0.018	<0.018	<0.018	0.029	0.028	0.04	0.018	0.035 mg/L TP **
Total P (mg/L)	<0.018	<0.018	<0.018	<0.018	0.02	0.04	0.04	<0.05	0.02	0.035 mg/L TP **
Ammonia (mg/L)	0.14	0.3	0.2	0.02	<0.012	0.03	0.03	0.5	<0.012	0.03***
TSS (mg/L)	1	2	3	5	2	11	2	2	4	6 (SPM Suspended Particulate matter)**
Total Manganese (µg/L)	<18.0	27.5	<18.0	<18.0	37.4	23.0	28.6	48.2	<18.0	47**
Total Iron (µg/L)	107.5	163.9	165.3	387.3	427.0	170.0	164.5	<18.0	49.4	1000***

* Fiji Draft Sustainable Development Bill – specific criteria for Class 2 (Freshwater)
** ANZECC (2000)
***ANZECC (1992)

FRESHWATER INVERTEBRATES

Alison Haynes

1.0 INTRODUCTION

1.1 IMPORTANCE OF THE INVERTEBRATE FAUNA

Fish (except Gobidae which graze on Algae) and large prawns depend on invertebrates e.g. insect larvae, freshwater snails and small prawns for food. It is therefore, important that sufficient invertebrates are present in a stream to maintain the desired number of fish and prawns for village food. Haynes (1999) established that the number of invertebrate species was much reduced when silt or mud were deposited on stream bottoms during road making and logging In general the number of invertebrate species present decreases with increasing siltation.

1.2 PREVIOUS STUDIES

In April – May 1977 the freshwater invertebrates and fish were studied in the Nunuku creek, above the Monasavu falls, where the Monasavu dam is now built (INR, 1977). The 19 species of invertebrates found included the gastropods *Melanoides tuberculata, Physastra nasuta, Fluviopupa pupoides,* 4 species of caddisfly larvae, mayfly nymphs, dragonfly and damselfly nymphs, beetle larvae, 2 species of prawns, leeches, flat worms, moth larvae, similid larvae, back swimmers, water striders and crickets. The lake, that was formed behind the dam, was monitored for invertebrates by the Institute of Natural Resources from 1982 – 1994 for the Fiji Electricity Authority. The nineteen invertebrate species originally found in Nanuku Creek had fallen to 6 species in 1990 and to only 2 in 1994 (Haynes, 1994).

Another biological survey for the Fiji Electricity Authority was carried out by the Institute of Natural Resources in 1979 in the Wainisavulevu Creek. Similar invertebrate species were present as in the Nanuku Creek.

To date there has been no previous study of the invertebrates in the upper catchments of the Sigatoka and Ba Rivers.

2.0 METHODOLOGY

2.1 SAMPLING SITES

The freshwater invertebrates were sampled at eight sites. Three sites were in the Nukunuku Ck (sites 1 –3). Site 1, was sampled at Lewa village on 25 August 2004, site 2, 100 m above the Hydrological station and site 3, 100 m below the Hydrological station were sampled on 26 August. The creek was in flood and the water was discoloured at all three sites. Nadala Ck, which joins the Qaliwana Ck, was sampled on 27 August, below Nadala village, opposite the secondary school at site 4. Qaliwana Ck was sampled at sites 5 - 7. Site 5, sampled on 27 August, was at Nabuyasa village. Site 6, just above where the Qaliwana is joined by Nadala Ck and site 7, below the Hydrological recording station, were sampled on 31 August. Ba River was sampled on 29 August at site 8. Because the sides of the Naidadara Ck were very steep, the Ba catchment was sampled only once 200 m below the proposed power station at site 8.

2.2 SAMPLING METHODS

At each sampling site the invertebrates clinging to at least 15 stones (121 – 300 mm acrosss) were sampled along a 10 m stretch of stream. A 1 mm mesh net was held downstream while the stone or boulder was moved into the net. The contents of the net and organisms adhering to the boulder were washed into a plastic bag. The invertebrates were kept alive in water in the plastic bag, or when this was impracticable they were preserved in 80% ethanol. Later they were identified under a dissecting microscope.

Six, or more, net sweeps of the side vegetation and water weed (if present) were taken along the site and the invertebrates similarly preserved and identified. All samples have been preserved in 80% ethanol for further reference.

3.0 RESULTS

3.1 GENERAL

A total of 30 species of invertebrates were found at the 8 sites. They are listed in Table 3 where the presence or absence of each species at each site is noted. Whether the species were found on the stones on the stream bottom or on the plants in the stream is also noted. At most sites more species were present on stones than on the plants but at site 6, in Qaliwana Creek above the proposed dam 9 species were found on plants and only 5 on the stony bottom. The reason is that a large quantity of the water weed, *Elodea* provided an additional habitat for some invertebrates. Photographs in Appendix A show many of the invertebrates that were found.

Present in all sites were *Melanoides tuberculata*, small atyid shrimps, mayfly nymphs, damselfly nymphs and net-building caddis fly larvae. These invertebrates usually live in clear, fast flowing inland streams.

Most Fijian insects that lay their eggs in freshwater water are native to Fiji (some may also be found in Samoa or Vanuatu) and many are endemic to Fiji e.g. caddis fly *Abacaria fijiana* and damselflies of the genus *Nesobasis.* Unfortunately, little research has been undertaken on freshwater insects so that most larvae/nymphs have not been matched with the adult form.

3.2 NUKUNUKU CREEK

Fifteen species were collected from the three sites in Nukunuku Ck. All species were those often found in inland streams.

3.3 NADALA CREEK

Nine species were present at the one site (site 4) sampled in the Nadala Ck. The endemic atyid shrimp, *Caridina fijiana* , which has been found only in Nadala and Nukunuku Creeks, was abundant at site 4. Many females carried eggs suggesting abbreviated or direct larval development.

3.4 QALIWANA CREEK

This was the most species-rich stream with 21 species found at the 3 sites. As well as the usual insect fauna, the gastropods, *Physastra nasuta* and the small endemic hydrobiid snail *Fluviopupa pupoidea* were found. *Physastra nasuta* was present at all sites and was abundant at site 5. It is widespread throughout Fiji and many other Pacific islands. *Fluviopupa pupoidea*, reaching 4 mm high, was found at sites 5 and 6 in small numbers. It is widespread throughout Viti Levu in small inland streams.

The most interesting find was 2 large green dragonfly nymphs (55 mm long) at site 6, above the junction of Nadala and Qaliwana Cks and the proposed dam. These large dragonfly nymphs appear to be of an undescribed species.

3.5 BA RIVER

Site 8 in the Ba River, below the proposed power house site, was noteworthy because of the abundance of prawns and gastropods. Six species of prawns and four species of gastropods were collected. All species of prawns were abundant and they are regularly caught by villagers for food. The neritid gastropod *Neritina pulligera,* used for food in some parts of Viti Levu, was also found. The species is widespread near the sea in Fiji and inland in pools and on rocks.

The collection of the endemic thiarid gastropod *Fijidoma maculata* in the Ba River, was a significant find. Previously it had been found only in the Rewa catchment, in the Wainibuka and Wailoa rivers.

4.0 DISCUSSION

4.1 IMPORTANT ENDEMIC SPECIES

The endemic gastropod *Fijidoma maculata* is important because its distribution is restricted to fast flowing inland streams and rivers. It belongs to the family Thiaridae, the same family as the tall gastropods *Melanoides tuberculata* and *M. lutosa,* but because it lives in swift currents, it has evolved a round shaped shell similar to neritids such as *Neritina pulligera* (Haynes, 1988). *Melanoides* species live in the quiet water at the sides of streams or in pools. A large population of *F. maculata* lives in the upper Wainibuka River adjacent to the Kings Road but it is threatened by siltation caused by road widening and improvement. A population in the Wailoa River near Laselevu village was found to be very small in November 2003 after the cleaning of the tunnel from Monasavu Lake to the Wailoa Power Station. Gastropods are particularly sensitive to siltation as their food source, the algal film on the stream bottom, becomes covered in silt.

Other important populations are:

1. The abundant population of large prawns in the Ba River as they are caught by nearby villagers for food.
2. Dragonfly and damselfly nymphs (most are endemic) are one of the important predators in streams. They spend 2–3 years growing in the water before they hatch into adults. They spend only a few days as adults during this time they fly in search of mates and before she dies the female lay eggs on rocks or water weed.

4.2 POTENTIAL IMPACTS

All freshwater invertebrates are adversely affected by silt and grit that covers stream bottoms during forest logging, road making and dam building. Haynes (1994) found that after the forest in the Nabukavesi valley was logged in 1989–1990, the Nabukavesi Ck was discoloured and a thick layer of mud and grit covered the stony bottom. In 1991, when most of the mud had been washed away, net building caddis larvae, mayfly nymphs and moth larvae were the first invertebrates to recolonise the stream. By 1992, seven invertebrate species had returned and by 1993, 12 species were present. Over the three year period 1992–1995, 34 species of invertebrates were identified from the Nabukavesi Ck, while 38 were identified from nearby Wainikovu Ck where no logging had occurred (Haynes, 1999). After 5 years, the abundance of invertebrates in the two streams was the same but the Nabukavesi Ck lacked species that had originally been present in patchy or sparse populations before logging occurred.

The Nanuku Ck had 19 invertebrate species living in it before the construction of the Monasavu dam in 1977 (INR, 1977). When the Monasavu Lake was monitored for the FEA in 1987 it had 9 species of invertebrates, in 1989 and 1990 it had 6 species. Only *Melanoides tuberculata* was found in 1992, in 1994 a brown sponge, *Spongilla alba*, possibly introduced with fish, was found as well as *M. tuberculata*.

The building of the dam, the power house and the construction of roads in the Sigatoka–Ba catchment area will cause a lot of siltation of the streams. The populations of gastropods and prawns below the Power House are likely to disappear. This includes the endemic gastropod *F. maculata*. However, as *F. maculata* reproduces by parthenogenesis, i.e. their eggs hatch into young snails without being fertilized, it should be possible to transfer them to other similar streams in the region and thus establish new populations.

All invertebrates (with the possible exception of *M. tuberculata*) living in the part of the Nadala and Qaliwana creeks that will be flooded by the construction of the dam, will eventually disappear. They are invertebrates that live in oxygen saturated fast flowing water. Lakewater, especially that near the lake bottom, is low in oxygen and invertebrates can only survive in the shallower parts near the edge. Hydrogen sulphide produced by anaerobic bacteria on the lake bottom is also lethal to invertebrates.

Over time most invertebrates should become re-established in the streams that have been affected by the construction of the hydropower scheme once the silt and grit is washed away however as in the case of the Nabukavesi Ck between 1989-1994, some rare species may be lost.

Table 3. Invertebrates present in the streams affected by the Sigatoka–Ba Hydropower Scheme, at sites 1–8 between 25-31 August 2004. The letter **a** indicates the species found on the stones and rocks and **b** the species found on plants in the stream. p = present; A = abundant, - = absent

	Sampling sites														
	Nukunuku Ck.						Nadala Ck.		Qaliwana Ck.						Ba R.
Invertebrate taxa	1		2		3		4		5		6		7		8
	a	b	a	b	a	b	a	b	a	b	a	b	a	b	
TURBELLARIA															
Black flat worm	-	-	-	-	p	-	-	-	-	p	-	-	-	-	-
HIRUDINEA															
Predatory leech	-	-	p	-	-	-	-	-	-	-	A	-	-	-	-
GASTROPODA (snails)															
Melanoides tuberculata	p	-	A	p	p	-	-	p	p	p	p	A	p	p	A
Melanoides lutosa(sici waidrana)	p	-	-	p	p	-	-	-	-	-	-	p	-	-	p
Fijidoma maculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	p
Physastra nasuta (sici sewa)	-	-	-	-	-	-	-	-	A	A	-	p	p	-	-
Fluviopupa pupoidea	-	-	-	-	-	-	-	-	-	p	-	p	-	-	-
Neritina pulligera (tabia)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	p
CRUSTACEA (prawns)															
Caridina sp. A (small atyid)	-	p	-	-	-	p	-	A	-	p	-	p	-	p	A
Caridina fijiana " "	-	-	-	-	-	-	-	-	-	p	-	-	-	-	-
Atoida pilipes (Sagai)	-	p	-	-	-	-	-	-	-	-	-	-	-	-	A
Atyopsis spinipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A
*Macrobrachium equidens (*ura sa)	-	p	-	-	-	-	-	-	-	-	-	-	-	-	A
Macrobrachium rosenbergii (ura tokoi)		p	-	-	-	p	-	-	-	-	-	-	-	-	A
Macrobrachium latimanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	A
INSECTA															
EPHEMEROPTERA (mayflies)															
Pseudocleon sp.	p	-	A	-	p	-	p	-	p	-	p	-	-	-	p
Cleon sp. A	-	p	-	p	-	p	p	p	-	-	-	p	-	-	-
Cleon sp. B	-	-	-	-	-	-	p	p	p	-	-	-	-	-	-
ODONATA															
Dragonfly nymph (large green)	-	-	-	-	-	-	-	-	-	-	-	p	-	-	-
Nesobasis sp. A (damselfly nymph)	-	p	-	-	p	-	p	-	p	p	p	-	-	p	-
Nesobasis sp. B " "	-	-	-	-	-	-	p	-	-	-	-	-	p	-	-
TRICHOPTERA (caddis fly larvae)															
Abacaria fijiana (net building)	P	-	A	-	P	-	-	-	A	-	-	-	p	-	-
Hydrobiosis sp. (free living)	p	-	p	-	p	-	-	-	-	-	-	-	-	-	-
Oxyethira sp. (small clear case)	-	-	-	-	-	-	-	-	p	-	-	-	-	-	-
Calamoceratidae (leaf case)	-	-	-	-	-	-	-	p	-	p	-	p	-	-	-
Leptoceridae (stalk case)	-	-	-	-	-	-	-	-	-	-	-	p	-	-	-
Philorheithridae (small stone case)	-	-	-	-	-	-	-	-	-	p	p	-	-	-	p
LEPIDOPTERA (moth larvae)															
Nymphula sp.	-	-	p	-	p	-	-	-	p	-	-	-	p	-	-
DIPTERA (fly larvae)															
Chironomidae (midge larvae)	-	-	-	-	p	-	p	p	A	-	-	-	-	-	-
COLEOPTERA (beetles)															
Small gray beetles	-	-	-	-	-	-	-	-	-	-	-	-	-	-	p
Number of species	5	6	6	3	8	3	6	6	9	9	5	9	5	3	12
Number of species at each site	9		7		12		9		15		13		7		12

FRESHWATER FISH

David Boseto

1.0 INTRODUCTION

1.1 FRESHWATER FISH OF FIJI

Ryan (1980, 1991) listed 75 species of fresh water fish of which the *Gobiidae* (23 spp) and *Eleotridae* (9 spp) families are the largest. Today there are at least 125 recognised species of freshwater fish (Boseto pers comm.). Twenty-four species of freshwater fish have been introduced to Fiji, 15 of which are now established in the wild (Andrews 1985, Lewis and Pring 1986, Jenkins 2001). Few, if any of the freshwater fish introduced for sport appear to have become adventive in Fiji.

1.2 PREVIOUS FISH SURVEYS IN MONASAVU AREA

In 1977 the proposed river intakes to the planned Monasavu Dam were surveyed for freshwater fish. This survey included the Wainivodi Creek, Wainisavulevu River, Wainimala River and the Wailoa River. A total of six fish species were recorded in the area (INR 1977). In 1994, a fish survey was carried out in the Nadarivatu area and identified two goby species common to the area, *Awaous guamensis* and *Sicyopterus hicklingi* (Australian Museum 1994). A recent fish survey by John Pogonoski in August 2003, in the Qaliwana River, Navai River, Nadala River, Nukunuku River and the head waters of the Ba River recorded six fish species similar to those reported by INR in 1977 (Jenkins 2003). A survey of the Wabu Forest Reserve in November 2003 only recorded one species of eel fish (Morrison et al. 2003).

Due to these previous studies, the freshwater fish in the area of the proposed Sigatoka–Ba hydro project have been well documented. Unfavourable conditions due to heavy rain and high water levels in the rivers made fish surveys during the time of the current survey difficult. Consequently, this report is compiled based on past reports of fish surveys in the proposed water intake and surrounding areas in combination with hand-line fishing at Nukunuku River and interviews made from the surrounding villages. This study highlights the need to have a holistic view of freshwater fish biodiversity of the proposed sites of the hydropower project.

2.0 METHODS

2.1 PHYSICAL PARAMETERS

A YSI meter 85 (model # 85/10 FT) was used to measure the dissolved oxygen, conductivity and temperature of the water. pH was not measured in the field during this survey. Turbidity was measured by estimating the water clarity ranging from 0-100%, with 100 % denoting pristine freshwater. A 100 m tape measure was used to measure the length, width and depth of the sampling site.

2.2 FISHING METHODS

A combination of previous fish reports, visual observations, night gleaning, hand line and hook methods and interviews with surrounding villages were used to compile the fish list of the Tabunabeka Creek, Ba River, the Nukunuku River, the Nadala River and the Qaliwana River. The five rivers were surveyed between August 23rd and September 2nd 2004.

Fish were identified to family level using the Gestalt Method (Shape/location). Taxonomic keys by Allen (1991), Watson (1992), Allen et al. (2000) and Marquet et al. (2003) were used to identify specimens to the genus and species levels.

3.0 RESULTS

3.1 PHYSICAL PARAMETERS

The five rivers can be classified as productive based on the physical parameters (Table 2, water quality section) with the water condition being conducive for fish and other aquatic organisms. Water temperature appears to be stable at 20.9 – 21.7^{o}C. Dissolved oxygen is readily available with a range of 6.7 mg/l above Ba power house to 7.13 mg/l at Nadala River. The water conductivity is well within the suitable habitat range for fish ranging from 54.7 µS at Qaliwana intake to 85.6 µS below the Ba powerhouse.

3.2 FISH SPECIES DIVERSITY

A total of six species of freshwater fish were recorded from the five rivers and creeks (Table 4). These were a species of freshwater eel fish (*Anguilla marmorata*), a species of flagtail (*Kuhlia rupestris*), two species of gobies (*Awaous guamensis* and *Sicyopterus caeruleus*) and two introduced species, tilapia (*Oreochromis mossambicus*) and eastern mosquito fish (*Gambusia holbrooki*). Four of the six species *(Anguilla marmorata*, *K. rupestris*, *Awaous guamensis* and

Sicyopterus caeruleus) are all native and are widely distributed throughout the freshwater system of Fiji (Ryan 1980/91, Lewis and Pring 1986 and Jenkins 2003).

Village interviews resulted in an additional eight fish species (Table 5) present in the water systems that have never been recorded by past researchers. Seven of these species are native and the other an introduced species. Most are common and widely distributed in Fiji. Combining these data results in a total of 14 fish species present in head waters of the Sigatoka and Ba Rivers.

As fish and prawns represent an important part of the diet of village people in the area, villagers are constantly aware of the abundance of fish in the water systems. Interviews of the villagers of Navai, Nadala, Lewa, Buyabuya and Marou villages revealed that there have been no obvious changes to fish abundance in the rivers.

4.0 DISCUSSION

4.1 PHYSICAL AND BIOLOGICAL IMPACTS OF DAM CONSTRUCTION

The major environmental changes that the project construction may bring about generally include the altering and blocking of the natural flow of the river subsequently interfering with fish migration and destroying native fish populations. Other changes include high water temperature, poor water quality and damage to riparian plants and other freshwater fauna (Grossman 1997). More specifically, the negative impacts of the hydro project on the freshwater ecosystem are:

1. Disturb the fish life cycle.

Most of the fish are amphidromous species i.e. they spawn in the freshwater and their larvae are washed down to the sea to spend at least four to six weeks after which time they swim back into to the river and upstream to complete their lifecycle (Keith 2003, McDowall 2004). Freshwater eel fish are known as catadromous i.e. they swim downstream to spawn in the sea with juveniles making their way back into the rivers and swimming upstream where they will complete their life cycle (Allen et al. 2002).

In order to move up and down streams to and from the ocean, some amphidromous species like the *Sicyopterus caeruleus* gobies (McDowall 2004) have the ability to climb vertical barriers like the steep rocks and spillways of dams using their mouths and pelvic fins while eel fish have the ability to reach the headwaters by using their bodies to slither up the rapids, waterfalls and spillways of dams (Allen 1991). The majority of fish species, however, are unable to overcome these obstacles. Therefore, blocking the Qaliwana and the Nukunuku Rivers will reduce the fish stock above the intake areas as most of the fish fauna will not be able to migrate upstream.

2. Reduce River Flow

River outlets can enrich freshwater ecosystem with constant water volume and nutrient supply. The water level below the intake areas however, will be greatly reduced during dry periods resulting in reductions in fish and other freshwater fauna population in these downstream areas.

3. Anoxic conditions

The large decomposition of organic materials and detritus at each catchment area will certainly result in anoxic conditions and in the production of hydrogen sulphide in the bottom water strata potentially lasting for five to ten years (Balon and Coche 1974). Subsequently, these conditions will pose a severe threat to fish stocks and other organisms downstream during dry periods.

4. Water diversion

The diversion of water from Qaliwana, Nadala and Nukunuku Rivers into Ba River may affect stream productivity due to increased turbidity. However, the constant spillage of water into the Ba River will have stabilizing effect and reduce seasonal variations in flow. Stabilized flow might increase abundance of some species while exacerbating the loss of others. The increased volumes of water coming down the Ba River will also make it difficult for some species to swim back upstream to complete their lifecycles.

4.2 SOCIO-ECONOMIC IMPACTS OF CONSTRUCTION

Most of the villagers reported having fish and prawns once a week as part of their diet. The fish consumption by these villagers is very low, however, due to limited and inadequate alternative protein sources which are available, fish and prawns represent a very important dietary component of these people and as such, the few resources available to them should be preserved.

5.0 RECOMMENDATIONS AND CONCLUSIONS

5.1 RECOMMENDATIONS

1. Fish passages structure such as fish ladders or fish ways can be built to allow water flow downstream and also the amphidromous and catadromous fish species to migrate downstream and upstream to complete their life cycle.

2. In terms of likely changes in the fish and other freshwater fauna stocks in the Qaliwana, Nadala and Nukunuku Rivers during or after the construction period, a detailed assessment be made of the year round status of the fish and other freshwater fauna populations and in the local villages diet.

3. A freshwater fish and fauna monitoring should be put in place so that the freshwater fauna can be monitored annually.

5.2 CONCLUSIONS

As there are no endemic and critical endangered fish species in the area, there is no biological reason as to why the project should not go ahead. However, the above recommendations must be considered for sustaining the fish populations in the affected area above where the water intake is sealed off to maintain the fish species and populations of the head waters of the Sigatoka and Ba Rivers to limit the socioeconomic effect on nearby villages.

Table 4. Fish species check-list of the proposed project area.

River /Creek	Fish collected/ observed	Local names	No. individuals	Fish status	Fishing method
Tabunabeka Creek	*Anguilla marmorata*	Duna	1	Native	Night gleaning
Ba River	*Anguilla marmorata*	Duna	common	Native	Past reports Pers. Obs. Interview
	Gambusia holbrooki	Tiatia	highly abundant	Introduced	
	Kuhlia rupestris	Ika droka	abundant	Native	
	Oreochromis mossambicus	Malea	abundant	Introduced	
Nukunuku Creek	*Anguilla marmorata*	Duna	common	Native	Past reports Pers. Obs. Handline fishing Interview
	Gambusia affinis	Tiatia	highly abundant	Introduced	
	Kuhlia rupestris	Ika droka	abundant	Native	
	Oreochromis mossambicus	Malea	abundant	Introduced	
	Awaous guamensis	Vo	Abundant	Native	Handline
	Sicyopterus caeruleus	Beli	abundant	Native	
Nadala Creek	*Anguilla marmorata*	Duna	common	Native	Past reports Pers. Obs. Interview
	Gambusia hoolbrooki	Tiatia	highly abundant	Introduced	
	Oreochromis mossambicus	Malea	abundant	Introduced	
	Awaous guamensis	Vo	abundant	Native	

Table 4 Continued

River/Creek	Fish collected/ observed	Local names	No. individuals	Fish status	Fishing method
Nadala	*Sicyopterus caeruleus*	Beli	abundant	Native	
Qaliwana	*Anguilla marmorata*	Duna	common	Native	Past reports Pers. Obs. Interview
	Gambusia hoolbrooki	Tiatia	highly abundant	Introduced	
	Oreochromis mossambicus	Malea	abundant	Introduced	
	Awaous guamensis	Vo	abundant	Native	
	Sicyopterus caeruleus	Beli	abundant	Native	

Table 5. Fish reported from Interview. Neither reported from past fish reports of the area or observed or caught from the current survey.

River	Fish Reported	Scientific Name	No. of individuals present	Fish status
Ba River	Babani	*Gymnothorax polyuranodon*	Common	Native
	Bura		Common	Native
	Duna dina			Native
	Malavu	*Moringua abbreviata*	Common	Native
	Rovula		Common	Native
	Tuna balavu		Common	Native
Nukunuku Creek	Bura		Common	Native
	Malavu	*Moringua abbreviata*	Common	Native
	Rovula		Common	Native
	Tuna Dina			Native
	Sakelo	*Kuhlia marginata*	Common	Native
	Isreali	*Oeochromis niloticus*	Common	Introduced
	Deke		Common	Native
	Savene		Common	Native
Nadala Creek	Bura			Native
	Duna dina		Common	Native
	Isireli	*Oeochromis niloticus*	Common	Introduced
Navai/ Qaliwana Ck	Duna dina			Native
	Malavu	*Moringua abbreviata*	Common	Native
	Rovula		Common	Native
	Tuna balavu			Native
	Isreali	*Oeochromis niloticus*	Common	Introduced

HERPETOFAUNA

Nunia Thomas

1.0 AIMS

1. To provide baseline data on the herpetofauna area within the proposed Sigatoka-Ba Hydropower Project site on Viti Levu.
2. More specifically, to provide an annotated checklist of all herpetofauna found in the Nadala-Qaliwana river dams, with particular attention to rare and endemic species.

2.0 INTRODUCTION

2.1 GENERAL BACKGROUND

Herpetofauna is the collective term for the members of two vertebrate classes, the amphibians (salamanders and frogs) and reptiles (turtles, crocodilians, lizards and snakes). Fiji's known terrestrial herpetofauna consists of 30 species: 3 frogs, 2 iguanas, 3 snakes, 10 geckoes and 12 skinks. Of these, 12 (forty percent) are endemic to Fiji. All the herpetofauna of Fiji are widely distributed, with the exception of three locally endemic species (*Emoia mokosariniveikau,* Fiji Forest Skink – Saivou (Vanua Levu); *Leiolopisma alazon,* Lauan Ground Skink – Yanuya Island (Ono-I- Lau); and *Lepidodactylus gardineri,* Rotuman Forest Gecko - Rotuma (Morrison, 2003).

2.2. PREVIOUS SURVEYS IN THE MONASAVU AREA

Nine herpetofauna species have been recorded from the Rairaimatuku Plateau and its vicinity during previous surveys. These include five endemic species - *Platymantis vitiensis*, Fiji Tree Frog; *Emoia campbelli,* Montane Tree Skink; *E. nigra,* Pacific Black Skink; *E. parkeri,* Fijian Copper-head Skink; *Lepidodactylus manii,* Mann's Forest Gecko; two native species - *E. trossula,* Barred Tree Skink; *Nactus pelagicus,* Skink-toed Gecko; and two introduced species - *Hemidactylus frenatus,* House Gecko; and *L. lugubris,* Mourning Gecko (see Morrison 2003 for review). The majority of these surveys were conducted prior to 1990 and there have been no surveys conducted in the area since these observations were made.

3.0 METHODS

Diurnal surveys were conducted for skinks and nocturnal surveys for frogs and geckoes in eight sites between the 25th August and 1st September 2004:

Nukunuku Creek - around the Lewa intake (Butoni) and Lewa village,

Tubunabeka Creek /Ba River - the Ba outlet (Tabanacici and Tuba Bariya Creek), Marou Settlement, Vunasole Stream, Tuvuya pool, Buyabuya village,

Qaliwana/Nadala Creeks - Qaliwana Creek and Delainavunitokalau.

Only one nocturnal survey was conducted for frogs after the day trips revealed that the proposed sites did not show ideal habitats or if a frog was found during the day. The searches were conducted in both very forested and open habitats for the duration of one to two hours per site. They were concentrated in known microhabitats: in epiphytes, under loose bark, at the base of buttressed trees, under and inside logs, under rocks, in rock crevices and accumulated leaf litter. Habitat details, weather conditions, time of day and the number of searchers were recorded for each survey.

4.0 RESULTS

Five species were found including one frog, two geckoes and two skinks (Table 6). Of these, two are endemics (Fiji tree frog, *Platymantis vitiensis,* Pygmy snake-eyed skink, *Cryptoblepharus eximus*), two native (Barred tree skink, *Emoia trossula* and the Skink-toed gecko, *Nactus pelagicus*) and one introduced (House gecko *Hemidactylus frenatus*). All were uncommon.

Table 6. Sites surveyed for herpetofauna and species found

Site	Area surveyed	Date	Species Found
Nukunuku Creek	Butoni (Lewa intake)	25/08/04	None
	Lewa Village (Nukunuku River)	29/05/04	*Hemidactylus frenatus*
Tubunakeba Creek/Ba River	Tabanacici (along the Ba river)	25/08/04	None
	Tuba Bariya Creek	25/08/04	None
	Marou Settlement	26/08/04	*Cryptoblepharus eximus*
Qaliwana/Nadala Creeks	Nadala Village to Tuvuya Pool (along Vunasole Creek)	30/08/04	*Platymantis vitiensis*
	Lower Qaliwana to Upper Qaliwana	31/08/04	*Nactus pelagicus, H. frenatus*
FEA Access Road	Delainavunitokalau	01/09/04	*Emoia trossula*

There were also reports by the guides from Nadala Village of the *Gehyra vorax* (Giant Forest Gecko).

5.0 DISCUSSION

5.1 SIGNIFICANT FINDINGS

1. *Platymantis vitiensis,* the endemic Fiji Tree Frog

This frog is recorded from Viti Levu, Vanua Levu, Taveuni and Ovalau. They have been found in lowland rainforest, upland rainforest and agricultural land. Mostly inhabiting pandanus, banana trees, birds' nest ferns and the common montane lily, *Collospernum montanum* during the day, this nocturnal species can be found on streamside vegetation at night (Morrison 2003). Only one frog was found during a day survey along Vunasole Creek, in a banana tree at 50cm above the ground.

2. *Cryptoblepharus eximus*, Pygmy-eyed Skink.

To date this skink has only been recorded as a coastal species. This is the first confirmed inland record.

5.2 SIGNIFICANT ABSENCES

1. *Emoia campbelli*, endemic Montane Tree Skink

Emoia campbelli has only been recorded from pristine cloud forest and highland rainforest in the Monasavu area. This species was one of the target species of this survey but was not found in several days of searching. This is probably due to the relatively disturbed nature of the forest.

2. *Emoia nigra*, Pacific Black Skink

Emoia nigra is a large skink that was originally found over much of Viti Levu, Vanua Levu, Taveuni and several of the smaller islands. The introduction of the mongoose to Fiji has seen the extirpation of this species in areas where the distribution of the two species overlapped. Although recorded from the Monasavu area some time ago, this species is now believed to be extinct in the area.

3. *Lepidodactylus manni*, endemic Mann's Forest Gecko

Lepidodactylus manni is a small gecko endemic to lowland and highland rainforest in Fiji. It is sensitive to habitat disturbance and often disappears from logged forests. The absence of *L. manni* in the area surveyed indicates forest disturbance.

It is important to note that the weather throughout the duration of the survey was unfavourable for herpetofauna other than frogs. It was overcast and raining prior to and during the survey. A survey should be conducted under more favourable weather conditions for a more reliable indication of the herpetofauna in the area. There should also be a survey conducted in the warmer, summer months when herpetofauna are most active in order to get a better estimate of the abundance of these taxa in the area. The disturbed nature of most of the area surveyed however would most likely preclude the findings of some of these species regardless of weather conditions.

6.0 RECOMMENDATIONS

The absence of rare or threatened endemic species in the area and the relatively low abundance of herpetofauna recorded suggest that the area surveyed has been fairly disturbed in recent times (and in some cases is undergoing continuing disturbance). As such, construction of the project and subsequent flooding of selected areas is not likely to have a severe negative impact on the herpetofauna species in the area. If time permits, another survey in more favorable conditions should be conducted to confirm these findings.

FLORA AND VEGETATION REPORT

Marika Tuiwawa

1.0 INTRODUCTION

This report is the result of a preliminary survey of the flora and vegetation of the two proposed dams and two power stations along the headwaters of the Ba and Sigatoka Rivers. One aim of the survey was to compile an annotated checklist of native plants found in the impacted area-

i. immediately down stream of the junction between Nadala and Qaliwana Creeks,

ii. at the Nukunuku Creek dam and Lewa power house and

iii. a power house near the junction where the Tubunabeka Creek enters the Ba River.

The emphasis of the survey was on the rare and endangered endemic plant species found in the proposed impacted areas with their conservation status assessed. Possible impact of the hydropower project on these special plants would be assessed and appropriate mitigation measures proposed. Also during the survey the presence of invasive plants would be documented. The survey was carried out on behalf of Sustainable Energy Limited (SEL) in its commitment to protect and minimise the damages and loss of Fiji's biodiversity in the proposed area of development. The group members of the flora and vegetation ecology survey included Marika Tuiwawa (Curator – SPRH) and Alivereti Naikatini (Snr. Technician – SPRH). The field survey was carried out from the 24th August to 3rd September and on the 29th September 2004.

1.1 BACKGROUND

1.1.1 UNIQUENESS OF FIJI'S FLORA

Endemism of vascular plants species has been estimated to range from 23% by Ash (1992) to 60% by Tuiwawa (1999). Speciation for some groups of plants is very high where Fuller (1997) noted that the native palm flora (28 spp.) has 100% endemism. The same is also true for the genera *Elaeocarpus* (23 spp.) (Smith 1981) and *Cyrtandra* (39 spp.) (Smith 1991) i.e. genera with more than 20 species. In the family Rubiaceae, the genus *Psychotria* recorded 74 endemic species of a total of 76 native species (Smith 1988). Special plant groups for Fiji include the family Degeneriaceae, a primitive angiosperm family endemic to Fiji with two species (Smith 1981).

1.1.2 OVERALL RICHNESS

A review of the current state of knowledge about Fiji's flora based on Brownlie (1977), and Watkins (1994) recorded approximately 2530 species of vascular plants. Of these, 63% (1592 species) are considered native, of which 56% (892 species) are endemic to Fiji. The remaining 37% (936 species) consist of introduced exotics, of which 34% (319 species) have become naturalised.

According to Tuiwawa (1999) on the review of Smith's Flora, central Viti Levu and in particular the Nadarivatu area recorded Fiji's highest botanical diversity. A total of 599 plant species (Watkins 1994) was recorded for the area. Endemism for central Viti Levu may be as high as that for the natural forests in the province of Serua and in particular Namosi, which is as high as 60%. A total of 270 native vascular plants species are considered rare and endangered for Fiji (Fiji NBSAP -Botanical Technical Report (TG 3) 1998).

1.1.3 PRINCIPAL VEGETATION TYPES

According to Mueller-Dombois and Fosberg (1998), nine principal vegetation types are recognized for Fiji. Three of these vegetation types are present in the proposed sites to be assessed. The vegetation types of interest for this project are:

1.1.3a Upland Freshwater Swamp

The Nadrau Swamps is located in the upper drainage of the Rewa River at an elevation of more than 950m asl. Very little is biologically known about this montane peat bog except that the vegetation would be dominated by the moss *Sphagnum* spp. and the sedges *Eleocharis dulcis* and *Lepironia articulata*. A noteworthy fact is the unconfirmed report of the endangered Barred-winged Rail (*Nesoclopeus poecilopterus*) seen in the area in 1973 (Holyoak (1979). The swamp is currently threatened from agricultural activities that take place on the slopes next to it.

1.1.3b Transition Dry Forest and Grassland

The transition dry forest system here is mostly composed of gymnosperms. This include *Podocarpus affinis, Podocarpus neriifolius, Decussocarpus imbricatus, Agathis macrophyllum* and *Dacrydium nidulum.* Also common in this forest type are *Alphitonia* spp. *Turrillia* spp., *Metrosideros colina* and *Garcinia.* Most of the dry forest has been destroyed through continuous burning, grazing and shifting cultivation. These activities over the years have resulted in the conversion of this forest type to grassland. The grassland is dominated by *Pennisetum polystachyon* and on its fringes the invasive *Piper aduncum*.

1.1.4 PREVIOUS STUDIES

No previous published studies were carried out in the proposed hydropower project sites. Although sporadic collection trips were carried out in the area more detailed studies were carried elsewhere in the neighbouring forest system. This included a report on the "Biological studies conducted in the area around the proposed Monasavu Hydroelectric Dam" commissioned by Sir Alexander Gibbs and Partners in 1977. Other lesser detailed but more recent studies included compilation of unpublished checklist of plants around Mt. Tomaniivi by various authors including, Games 1997, Tuiwawa 1998-2000, Thaman & Whistler 1999, 2000.

2.0 METHODOLOGY

2.1 FLORA

A literature review to compile a list of important endemic species (rare and endangered) found within the area to be impacted and in the surrounding forest systems was carried out. References used included Smith 1979-1991; Lear 1991; Fuller 1997; Fiji NBSAP -Botanical Technical Report (TG 3) 1998, and Tuiwawa 1999. Other native plant species not in the literature but known (amongst foresters and conservation personnel) to be scarce and threatened (from habitat loss) were also included in the list.

For the three sites, the survey involved the documentation of native vascular plants found in the area accessed. A preliminary annotated checklist was compiled based on field observations conducted during the survey whilst trekking through the area. Plant names are those used by Smith (1979-1991) for the higher vascular plants and by Brownlie (1977) for ferns and their allies. The survey to document the presence or absence of the important rare and threatened endemic plant species was carried out by accessing most roads and tracks in the area with a vehicle or trekking through selected sections of creeks and adjacent slopes and ridges to be impacted. The process is selective because for some of these species their habitat preference is known. The locality of rare or endangered species located is recorded using a GPS and also entered onto a 1:50000 topography map and a herbarium specimen collected (if deemed necessary). The immediate surrounding forest was rapidly surveyed to determine how widespread and viable (if it is regenerating i.e. the presence of seedlings and saplings) the population is.

Assessment was carried out in similar habitats or sub-forest types especially in nearby relatively intact forests (if easily accessible). The latter not only serve to determine its local range extension but also identify possible refugia or relocation sites.

2.2 VEGETATION ECOLOGY

A general overview of the current status of the vegetation in the three creek systems was carried out. In sections of the forest that looked relatively intact a more detailed qualitative assessment was carried out.

3.0 RESULTS

3.1 FLORISTIC REVIEW

3.1.1 Rare and Endangered Flora

The results of the literature review to compile a list of rare and threatened plants recorded a total of 42 vascular plant species for central Viti Levu which for the purpose of this survey included the Naqarabuluta Reserve, Nadarivatu, Mt Tomaniivi Reserve and the Monasavu catchment. The species list was extracted from a list of vascular plant species submitted for the Fiji National Biodiversity Strategy and Action Plan (BSAP) (1998) as a list of plants that need immediate conservation measures by the national government to ensure their protection (BSAP – Technical Group 3 Report, 1998). All 42 vascular plant species are native with 28 species endemic. Five endemic species were reported from the immediate vicinity of the proposed impacted area which included Nadala, Navai, and Nadrau. The plants are listed in Table 1 of Appendix B. Only two plant species from this list (Appendix C) considered rare and endangered were seen during the survey and they are:

Meryta tenuifolia – A rare (Smith 1985) Araliaceae (same family as the umbrella tree) known only in the world to be found on slopes of upland forest on the leeward side or transition forest near Naga (also known as Savusavu) village. For this project it is most likely to be found along the Qaliwana and Nadala Creeks from were the dam is likely to be constructed. A walk through survey into the area failed to find this tree.

Cyphosperma tanga – A Critically Edangered (IUCN red listing) rare and endemic palm currently known to be restricted to a small ridge in a mahogany plantation near Navai village. The palm population is restricted to slopes whose surfaces are literally strewn with rocky rubbles. It is most likely to be found along slopes of hills adjacent to the Qaliwana Creek downstream from Navai village. A brief visit to the area failed to find the palm.

Similar vegetation systems where the above plants are found were also observed upstream and downstream from the impacted areas along the Nadala and Qaliwana Creeks. The same was also noticed south of Naga village. Thus the likelihood of these rare and threatened plants being found elsewhere outside the impacted area was highly likely. According to local informants the forest south of Naga Village has never been logged before. This augers well for the project as the area can be a potential sites for the ex situ conservation of "special plants" that may be later found in the impacted area. These areas can also be used as seed bank source to increase and maintain the overall biodiversity of the area and seedling supply source for any future forest rehabilitation program that may be required.

Overall the results of the general preliminary flora assessment indicated that the plant species composition for each site is different, and that it would increase as we progress from the proposed power station site on the Ba River to the dam at the Qaliwana Creek on the Sigatoka River. Here an increase in terms of plant species diversity, number of native and especially endemic species would be expected. From the data collated in Appendix B, the following floristic results were obtained for the various sites.

3.1.2 Ba Power Station - Junction of the Tubunabeka Creek and Ba River.

The site was situated on Grid Map Coordinate 113,265 (Fiji map Series M27, Figure 1). Here a total of 70 vascular plants were recorded for the area; 66% (46 species) of all vascular plants collected from the area were native plants out of which only 37% (17 species) were endemic. Most of the native plants were found along the creek edge and flat land along the Tabunabeka Creek where the only "good" forest was found for the entire area. As typical of such forest systems (gully forest surrounded by grassland) the forested area was restricted to gullies along seasonal dry creek-beds. The other adjacent landscapes were dominated with grassland. Most of the naturalised and invasive plant species were found on the grassland and they included the weedy *Wedelia biflora, Vernonia cinerea, Stachytarpheta urticaefolia, Nephrolepis biserrata, Sporobolus diander* and the dominant *Pennisetum polystachyon*; the noxious *Psidium guajava, Lantana camara, Vitex trifoliata*; and the invasive *Piper aduncum*.

3.1.3 Lewa Power Station and Weir - Nukunuku Creek

The site was situated on Grid Map Coordinate 139,269 (Fiji map Series M27, Figure 1). A total of 154 vascular plants were recorded from the area. The native plants made up 78% (120 species) of the flora out of which 54% (65 species) were endemic. The site has the highest recorded number of naturalized and invasive plant species where 22% (34 species) of its flora comprised these groups of plants. This was not suprising as a lot of farming and livestock husbandry activities were done in the immediate area and upstream. Plants of economic importance that were of concern due to their weediness included *Wedelia biflora, Cyperus rotundas* and *Hedychium gardnerianum*; the noxious *Psidium guajava* and *Lantana camara*; and the invasive *Spathodea campunulata, Piper aduncum, Mikania micrantha* and *Clidemia hirta*.

3.1.4 Qaliwana Dam - Nadala Creek

The site was situated on Grid Map Coordinate 159,283 **(**Fiji map Series M27, Figure 1). Here a total of 162 vascular plants were recorded from the area. The native plants made up 87% (141 species) of the flora out of which only 60% (84 species) were endemic; 13% (21 species) of the flora comprised of naturalized and invasive plant species. Plants of economic concern include the invasive *Spathodea campunulata* and *Piper aduncum* and the noxious weeds *Psidium guajava* and *Lantana camara* were plentiful. The relatively high incidence of the undesirable plants were the result of extensive vegetable farming and grazing of domesticated livestock that was taking place upstream.

3.1.5 Qaliwana Dam – Qaliwana Creek

The site was situated on Grid Map Coordinate 160275 (Fiji map Series M27, Figure 1). A total of 176 vascular plants were recorded from the area. The native plants made up 89% (156 species) of the flora out of which only 61% (95 species) were endemic. The site recorded the least number of naturalized and invasive species (11% (20 species)). All plants in the latter group were restricted to the forest edges, which included creek banks, and patches along slopes and ridge top recently disturbed or where succession process has proceeded at a slower rate. Here the invasive *Piper aduncum* dominated the landscape. On the creek bank especially where it is prone to flooding the introduced exotic ornamental ginger, *Hedychium gardnerianum*, dominated and in some areas it forms a continuous mass along the creek bank.

The overall diversity of the native flora for the proposed hydropower sites were relatively low compared to similar intact forest systems elsewhere. The flora of the Nadala and Qaliwana Creek systems were floristically more significant due to the high number of native plants and especially the endemic plant species observed in the area. The most common family was Euphorbiaceae with thirteen species. Myrtaceae, Poaceae and Rubiaceae followed with ten species each. The most common genus was Syzygium with six species. On average for both sites 88% of their flora was native. Endemism was also high with both sites having on average 60% of their flora being endemic. Such high endemism is only comparable to few sites in Fiji like Waisoi in Namosi (Tuiwawa 1999) and Mt Korobaba (Kirkpatrick and Hassal 1985) whose flora were known.

For Nadala and Qaliwana Creeks the remaining 12% of their flora was made of a few exotics, invasive and some common weeds. These "undesirable" plants were restricted to the forest edges and gaps like the creeks, dirt tracks and roads and rocky logged over areas. Very few or none of these plants were found in intact sections of the forest especially along the slopes and ridges west of the Qaliwana Creek.

3.2 VEGETATION

3.2.1 Ba Power Station: Junction of the Tubunabeka Creek and Ba River.

There are two sub-forest types observed in and around the area proposed to be developed. Along ridge tops and slopes the landscape is mainly grassland. The grassland is dominated by the common and widespread grasses, ferns and herbs like *Pennisetum polystachyon, Sporobolus diander, Blechnum orientale, Nephrolepis biserrata* and *Pteris tripartita*; shrubs like the noxious weed *Psidium guajava, Lantana camara*,; and trees like *Glochidion spp., Mangifera indica*.

The other vegetation type observed in the area are those restricted to gullies with seasonal dry creeks. Dominant plants found in such system include the tree *Aleurites mollucannus, Intsia bijuga, Samanea saman, Albizia labbeck* and *Gyrocarpus americanus*. In all the area surveyed grazing of livestock (goats, horses, and cattle) is common.

3.2.2 Lewa Power Station and Weir - Nukunuku Creek

The vegetation and flora in and around the area to be inundated was greatly disturbed from human induced activities. These activities included grazing and farming were carried on slopes on either side of the Nukunuku Creek. As such the vegetation on the slopes especially the slopes towards Lewa village (left facing upstream) was dominated by plants commonly observed in pastures and they include: *Pennisetum polystachyon, Sporobolus diander, Paspalum spp., Chloris spp., Blechnum orientale, Nephrolepis biserrata* and *Pteris tripartita*; shrubs like the *Sida rhombifolia, Xanthium occidentale, Psidium guajava, Lantana camara*,; and trees like *Glochidion spp., Mangifera indica, Piper aduncum, Wikstromia foetida.*

On the other slope the vegetation system tends to be more forested although grazing is currently carried out in the area. The forest was dominated by the trees *Metrosideros collina, Trichospermum richii, Rhus* spp.*, Rapanea* spp. and *Geissois ternata.* Other common plant species included *Bambusa vulgaris, Erythrina* spp.

The only endemic plants spacious found in the area included *Amoraria soulemeiode, Saurauia rubicunda, Pittosporum rhytidocarpum, Rhus* spp.*, Rapanea* spp.*, Plerandra seemaniun, Macaranga* spp. and *Geiosis ternata.*

3.2.3 Qaliwana Dam – Nadala Creek

The upper section of the Nadala Creek from Nadala village to the first series of water falls was briefly assessed by trekking along the creek edge and adjacent ridges. Overall the vegetation is typical of that that had undergone intensive logging operations. Lots of logging tracks were noticed in the area and the absence of very large trees greater than 50cm dbh was evident as this was usually indicative of areas previously logged over. A few large (60cm dbh) unlogged *Pinus caribaea* trees were noticed on the ridge top and slopes. This indicated that the area was once planted over with this conifer after the initial logging of the native forest, it had matured, logged and now the forest is left unmanaged to recover from this process. Logging began in the area about 60 to 70 yrs ago and the harvesting of matured pine in the area took place in 1994 (pers. comm. local informants).

The forest here now is generally dominated by the native *Metrosideros collina, Neonauclea fosteri, Trichospermum* spp.*, Alphitonia* spp.*, Dillenia biflora* and *Garcinia* spp. most of which on average has a dbh of around 35 cm. Along the creek edges the vegetation was comprised mainly of the endemic *Syzygium seemannii* and *Acalypha rivularis,* and the native *Podocarpus neriifolius*. Also along the creek flats were the invasive *Piper aduncum, Hedychium gardnerianum*, *Kyllinga polymorpha,* and the weedy *Arundo donax*, all of which were relatively very common. Along the slopes, above the flood line, there tend to be more native species and the most commonly found plants were *Podocarpus neriifolius, Ficus vitiensis, Macaranga graeffeana, Premna serratifolia, Calophyllum cerasiferum, Myristica castaneifolia* and *Syzygium effusum.*

Major logging of pine had taken place along the adjacent slopes and ridges about 10yrs ago (pers. comm. local guide). Some large trees that that survived the logging operations had dbh of up to 100cm and these were *Metrosideros collina* 110cm. *Calophyllum* spp. (95 cm). These trees were found near the stream edges that drain into the Nadala Creek.

The presence of some serious noxious and invasive species like *Psidium guajava, Solanum torvum, Lantana camara, Piper aduncum* and *Spathodea campunulata* is indicative of how degraded (floristically) the area is.

3.2.4 Qaliwana Dam – Qaliwana Creek

The Qaliwana Creek was the most vegetated forest of the three creek systems assessed. The forest cover along the slope was closed and two distinctive canopies were noticed (see Figure 2). The forest looked intact and in selected segments of the forest visited a good representation of the native tree species were encountered. Overall the tree sizes were small with most attaining dbhs ranging from 30cm to 40cm. Occasionally larger trees like *Calophyllum* spp. (50cm), *Dysoxylum* spp. (80cm), *Neonauclea fosteri* (100cm) were encountered.

The most common and important timber tree species observed along the slopes, towards the Qaliwana Creek from the FEA dirt track to the Hydrology Station in Bulu, included the emergent *Neonauclea fosteri, Macaranga* spp.*, Calophyllum vitiensis, Calophyllum* spp.*, Myristica* spp.*, Garcinia* spp.*, Syzygium* spp.*,* and *Turrillia vitiensis*. The common subcanopy plants included *Girroniera celtidifolia, Dysoxylum* spp.*, Dillenia biflora, Bischofia javanica, Aglaia archboldiana, Citrus grandis, Amoraria soulameoides, Cerbera manghas* and *Trichospermum richii.* The shrub *Elastoma australe* that in most areas formed a "monoculture" ground cover dominated the understorey.

Along the creek edges the vegetation was comprised mainly of the endemic shrubs/trees *Syzygium seemannii* and *Acalypha rivularis,* and the native *Podocarpus neriifolius*. Also along the creek flats the invasive *Piper aduncum, Hedychium gardnerianum*, *Kyllinga polymorpha,* and the weedy *Arundo donax* and *Wedelia biflora* were found and all of which were relatively very common. A few *Metrosideros collina* trees were found along this strip of vegetation. Found amongst these shrubs and small trees are weeds that can be commonly found in gardens, pastures and villages.

Immediately above the flood line the vegetation was comprised of only native plant species like *Premna serratifolia, Dillenia biflora*, and *Syzygium* spp.*, Planchonella* spp. *Calophyllum* spp. and *Ficus vitiense*.

On disturbed slopes, especially on the ridge that separates the Qaliwana and Nadala Creeks, patches of *Miscanthus floribundus* and *Piper aduncum* were noticed. On the edge of this patch pioneer plant species associated with succession were noticed and this included *Moutia australis, Commersonia batramia, Trichospermum richii* and *Cyathea lunulata.*

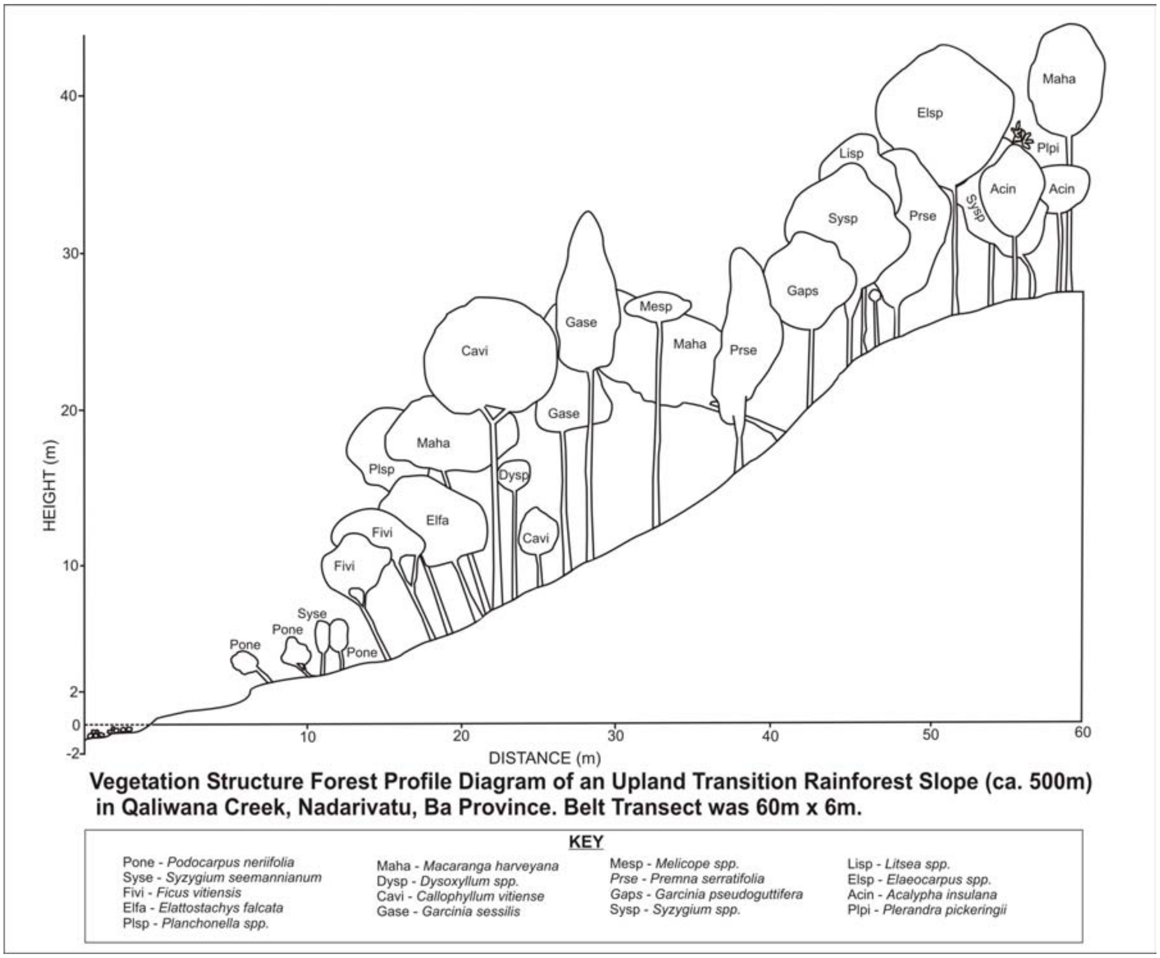


Figure 2. Vegetation structure profile diagram of upland transition rainforest slope, Qaliwana

3.2.5 General floristic and vegetation overview

The overall diversity of the native flora for the surveyed area was relatively low even if only the Nadala and Qaliwana flora was considered compared to similar intact forest systems elsewhere. From the preliminary checklist of native plants collated (see Appendix 2 a total of only 170 native taxa were recorded for the surveyed compared to 360 native taxa recorded for a simillar sized area in Namosi (Tuiwawa 1999) and 420 native taxa for Nadarivatu. (It should be noted that the survey work in the latter areas was intensive and conducted over a much longer period). These figures should only be used to qualitatively determine the relative diversity of native plant species in the surveyed area, as the checklist is NOT a complete listing.

3.3 INVASIVE SPECIES

A survey of currently recognised invasive plant species for Fiji and other Pacific Island countries revealed the presence of the following species listed in Table 7**.**

Table 7. List of invasive plant species found along the Tubunabeka Creek (Tub), Nukunuku Creek (Nuk), Nadala Creek (Nad) and Qaliwana Creek (Qal) with their common name, growth form and the plantation they are found in. The cross (X) denotes the presence of the plant.

Botanical Name	**Common Name**	**Form/Habit**	**Plantation**			
			Tab	**Nuk**	**Nad**	**Qal**
Spathodea campunulata	African tulip	Tree	X	X	X	
Samanea saman	Raintree	Tree	X	X		
Swietenia macrophylla	Mahogany	Tree				X
Piper aduncum	Onalulu	Small tree	X	X	X	X
Wedelia biflora		Creeper		X	X	X
Lantana camara	Lantana	Shrub	X	X	X	
Solanum torvum	Prickly solanum	Shrub	X	X	X	
Mikania micrantha	Mile a minute	Creeper	X	X	X	X
Psidium guajava	Guava	Small tree	X	X	X	
Hedychium gardnerianum,	Cevuga	Herbaceous		X	X	X
Kyllinga polymorpha	Navua sedge	Grass	X	X	X	X

The incursion of alien plant species into the proposed development sites and the surrounding forest will always exist. This is because further upstream and downstream along the creeks large human settlements including villages are found. Domestic activities that include gardening, subsistence farming, livestock husbandry all contribute to the introduction of these alien species and water that flows along the creeks become an ideal dispersal agents.

Of immediate concern due to its current negative impact on the environment is *Spathodea campunulata*. Currently it is restricted to disturbed areas along the Nadala, Nukunuku and Tubunabeka Creeks. As noticed elsewhere in the lowland forests of Tailevu and Naitasiri province (Sawani, Naqali, Waibau, and Wainibuka) it can form very thick stands in areas recently left fallow. Thus eradication of the plant is of paramount importance. Of similar concern is *Lantana camara* and *Psidium guajava*. For most of these invasive plants, physical, chemical and biological control mechanism are available and expert advice can be obtained from the Department of Agriculture or the Pacific Secretariat (SPC) – Plant Protection Unit in Nabua. The most commonly used physical approach is through controlled cultivation and harvesting of mahogany. Here over exposure of the ground is to be avoided or minimised as this creates ideal conditions for the establishment of weeds and pests. Also the cutting down or uprooting then burning of invasive plants is a sure way of eradicating this pest. Eradication of saplings is more advantageous than the matured plants. Chemically the preferred and effective chemicals used are the herbicide glyphosphate and 2,4-D. For biological controls, specialists in SPC in Nabua should be consulted.

4.0 RECOMMENDATIONS AND MITIGATION MEASURES

Recommendations include:

- A complete botanical and vegetation survey needs to be conducted in the area especially in the Nadala and Qaliwana Creek and catchment area. The study is necessary if a complete biological inventory of the area is required and also if monitoring work on the impact of the operations on the flora and vegetation needs to be known.

- If the operation is to proceed then the likelihood of the catchment being declared a protection forest because of its significance as a catchment area is highly likely. This then would make the area ideal for ex situ conservation of some of the rare and threatened plants and animals found in the surrounding areas. This is especially true for plants like *Cyphosperma tanga, Meryta tenuifolia*; and fauna like the pink billed parrot finch, the Long Legged Warbler and the Peregrine Falcon and lorikeet. Thus this option should be pursued as this would augur well for an institution like FEA or similar organisation supporting conservation work in Fiji.

- Some rare species previously reported from the area were not seen during the survey. They may have become locally extinct. For this reason a long term survey to assess other habitats in the proposed development area and its immediate surrounding forest system be carried out on a collaborative basis with institutions like IAS/USP or other relevant NGOs.

- Because of the general low botanical diversity of the native flora within the three areas earmarked for development, the introduction of seeds and seedlings of native plants deemed "rare" from neighbouring forests be encouraged. Patches of grassland noticed on the slopes and ridges between the Qaliwana and Nadala and Nukunuku creeks would be ideal rehabilitation sites. For the Tubunabeka Creek the forested gully should be fenced off from livestock. This should encourage the return of native plants to the area.

- The creek banks along the Qaliwana and Nadala Creeks that are likely to be flooded are relatively steep in some areas, erosion would be a problem. In such areas an erosion barrier should be established. Vetiver grass can be used as an erosion barrier along these steep escapements. This material is locally available.

BIRDS

Alivereti Naikatini

1.0 INTRODUCTION

This report is of a preliminary baseline survey of the land birds and mammal fauna of part of the upper Sigatoka and Ba River catchments, Ba province and is provided to SEL in accordance with a contractual agreement with the Institute of Applied Science, University of the South Pacific.

The report provides observations and comments on the above mentioned fauna as well as those known from literature and informal interviews with local guides. The study area comprised old logging and hunting tracks as marked on Figure 1.

2.0 METHODOLOGY

An annotated checklist of native birds and mammals observed during the survey at the three core sites (and the surrounding forest system) namely the Tubunabeka Creek,/Ba River junction; the Nukunuku Creek, and the Nadala/Qaliwana Creeks, was compiled. Emphasis was on the rare and threatened native birds species identified during the scoping exercise in the proposed development area. The surveys were carried out early in the morning whilst walking along trails and old logging tracks and using opportunistic method of documenting every species seen or heard. The survey was conducted from the 25th September to 1st October 2004.

The routes were pre-selected to cover representative vegetation types in each of the proposed development sites. After every 100m to150m a pause of up to 10 minutes was carried out to ensure the detection of shyer birds and mammals. Where possible (weather permitting) observations were conducted between 5.00am and 8.00am and between 4.00 and 7.00pm. During the day (11.00am to 3.00pm) observations were continued while joining the vegetation and flora survey group. Special efforts were made to observe certain target species, including the Red-throated Lorikeet, Red-billed Parrot Finch, Long Legged Warbler and any other IUCN listed bird species, by listening to their distinctive calls at dawn and dusk from viewing points overlooking large areas of the forest or a forest break.

Interviews were carried out with the locals (especially guides) on their local knowledge about some of the rare and threatened species. Mammals observed during the survey were also recorded.

3.0 RESULTS

The literature review covering the general area of Nadarivatu, Mt Tomaniivi, Monasavu catchment, Wabu Forest Reserve and Nadrau recorded a total of ca. 29 native bird species and this included fourteen bird species endemic to Fiji. Those bird species considered threatened by IUCN standard found in the area included *Prosopeia personata, Trichocichla rufa, Clytorhynchus nigrogularis, Erythrura kleischmidti, Charmosyna amabilis, Nesoclopeus poecilopterus* and *Gymnomyza viridis.*

The assessment survey was focused on the immediate vicinity of the proposed hydro electricity development sites and adjacent forest systems. Fieldwork effort is summarized in Table 8.

Table 8. Fieldwork effort summary for the three core sites.

Date	Site/Place	Observation from Viewpoints (hr))	Observation along tracks (hr)
26, 30th Sept.	Tubunabeka/Ba	3	10
28,29th Sept.	Nukunuku/Lewa	4	12
31, 1st Oct.	Nadala/Qaliwana	4	10
Total		11	32

i). Tubunabeka Creek/Ba River – Power Station

The vegetation type was that of open grassland in upland transition forest (between the dry and wet zone). Gully forests were observed along seasonal dry creeks especially along the Tubunabeka Creek. Tree vegetation along the Ba River was disturbed.

Regular burning especially on slopes, farming, and grazing are common activities carried out in and around the proposed area of development. These activities and especially the vast openness of the grassland limited the free movement of birds and mammals to other better nearby forested areas. The gully forest provided the best habitat for both the residential and migrating birds and native mammals for the area.

A total of fifteen native bird species were recorded for the area. Of these six were endemic to Fiji (see Table 1 of Appendix D). The most common birds found were the Vanikoro Broadbill, Wattled Honey Eater and Polynesian Triller. The only native mammal recorded for the area was Pacific Flying Fox (*Pteropus tonganus*). All other mammals recorded in the area were introduced.

ii). Nukunuku Creek - Weir & powerhouse

The vegetation type was grassland and secondary transition forest. Human activity prevalent in the area includes grazing and farming (commercial & subsistence), burning and expanding settlement away from the traditional village set up. The abundance of the flowering plant *Erythrina* spp. and *Metrosideros collina* being favorite feeding trees would attract most fructivores and nectarvorus birds. This is further enhanced in that a relatively intact forest occurs higher up along the slopes of a ridge that separates the Nukunuku and Nadala Creeks.

A total of 27 native bird species was recorded of which eleven species were endemic (see Table 1 of Appendix D). Like the previous site the most common native birds observed were the Wattled Honey Eater, Fiji White-eye, Fiji Silver Eye, the Collared Lory and Fiji Parrot-Finch. All mammals observed during the survey (see Table 2 of Appendix D) were recorded which included the two native mammals – *Pteropus tonganus* and *P. samoensis* (flying foxes).

iii). Nadala/Qaliwana Creeks – Dam

The general locality of the survey area was depicted by a dotted line on Figure 1. The forest was well vegetated and in comparison to the other two surveyed areas had the best "intact" forest. This forest system also formed a continuous system to the more luxurious and pristine Mt Tomaniivi, Wabu and Monasavu forest systems.

A total of 30 native birds was recorded of these thirteen species were endemic to Fiji (see Table 1 of Appendix D). The area recorded the highest number of native birds. The density tended to be greater as well as evident in the regular cries of larger birds like the Masked Shining Parrot, Barking Pigeon and Giant Forest Honey Eater. The more common birds were the Wattled Honey Eater, Fiji White-eye and Fiji Silver Eye.

The only mammal not found in the surveyed area was the introduced *Capra hircus*. All other domesticated mammals observed in the area were found further upstream from the proposed dam site and its impacted area. Most of these mammals access the area through old logging trails along the Nadala Creek.

For the three sites, More bird species were recorded from Lewa and Qaliwana areas due to the greater forested area compared to Buyabuya where the majority of the forest remaining was found in the gully forest along the Tubunabeka Creek.

A total of 35 species of birds was recorded (see Table 1 of Appendix D) and of these thirteen were endemic to Fiji and eighteen species native to the region. Only two of the seven IUCN threatened species were found in the area were recorded. They were:

i. Giant Forest Honeyeater – Sovau

The species is considered vulnerable which means that it is facing very high risk of extinction in the wild in the near future. It is common in the Nukunuku (Lewa) Creek and especially in the Nadala/Qaliwana Creek area.

ii. Masked-shining Parrot - kaka

The species is considered vulnerable with a high risk of extinction in the near future. It is uncommon in Nukunuku (Lewa) and very common in the Nadala/Qaliwana Creek area.

The other species like the Pink-billed Parrot Finch, Black-faced Shrikebill, Long-legged Warbler, Friendly-ground Dove, Red-throated Lorikeet, Barred-winged Rail and Peregrine Falcon were not recorded. According to local informants both the Red-throated Lorikeet and Peregrine Falcon had been observed in the area.

As for the mammals a total of eight species (see Table 2 of Appendix D) was recorded. Only two species were native. Of the two native species, *Pteropus samoensis* (the Samoan Flying Fox) is listed as vulnerable in the IUCN Listing. There was no record of any caves and any other native bat species in any of the three areas surveyed.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The weather conditions on the first four days were not favorable for early morning and late afternoon fieldwork. Visibility was very poor due to heavy mist. The weather gradually improved towards the end of the survey period. These overall climatic conditions greatly affected the results of the survey.

Despite the above conditions the results of the survey are in line with expectations of an area with disturbance adjacent to an intact forest system. Most of the species recorded are those common in Fiji's forest. The actual sighting of the Giant Forest Honeyeater and Masked-shining Parrot and reported sighting of the Red-throated Lorikeet and Peregrine Falcon by the local guides – four IUCN threatened species was significant. Thus the area could be a potential important bird area for Viti Levu .

4.2 RECOMMENDATIONS

- Extensive survey in the catchment over a longer period to include good weather conditions and at different seasons throughout the year estimate densities and distribution of birds of conservation importance especially the Giant Forest Honeyeater, Masked-shining Parrot, Red-throated Lorikeet and Peregrine Falcon.
- To verify that certain other birds of conservation significance are absent from the area. These include the Red-throated Lorikeet, Peregrine Falcon, Pink-billed Parrot Finch, Long-legged Warbler, Black-faced Shrikebill, Friendly Ground Dove and Barred-winged Rail.
- More intensive surveys including the use of mist netting to verify the presence or absence of other native mammals especially the bats.

RECOMMENDATIONS

The following recommendations are made for the various surveys

Water quality

- Undertake monitoring of current sites during construction of dam and intakes and during operation to determine whether the dam construction and operation are having an impact on surface water quality and thus measures could be taken to mitigate.
- To minimise impact on water quality in downstream areas from Qaliwana and Lewa intakes ensure appropriate volume of water is allowed to overflow.
- To minimise impact on water quality at Ba powerstation outflow ensure water is withdrawn from reservoir at optimal depth to avoid high nutrient levels at surface and anaerobic bottom waters.
- Once in operation, monitor addition sites within the dam to determine if erosion is causing an increase in silt.

Freshwater invertebrates

- The building of the dam, the power house and the construction of roads in the Sigatoka–Ba catchment area will cause a lot of siltation of the streams. The populations of gastropods and prawns below the Power House are likely to disappear. This includes the endemic gastropod *F. maculata*. However, as *F. maculata* reproduces by parthenogenesis, i.e. their eggs hatch into young snails without being fertilized, it should be possible to transfer them to other similar streams in the region and thus establish new populations.

Freshwater Fish

- Fish passages structure such as fish ladders or fish ways can be built to allow water flow downstream and also the amphidromous and catadromous fish species to migrate downstream and upstream to complete their life cycle.
- In terms of likely changes in the fish and other freshwater fauna stocks in the Qaliwana, Nadala and Nukunuku Rivers during or after the construction period, a detailed assessment be made of the year round status of the fish and other freshwater fauna populations and in the local villages diet.
- A freshwater fish and fauna monitoring should be put in place so that the freshwater fauna can be monitored annually.

Herpetofauna

- The weather throughout the duration of the survey was unfavourable for herpetofauna other than frogs. It was overcast and raining prior to and during the survey. A survey should be conducted under more favourable weather conditions for a more reliable indication of the herpetofauna in the area. There should also be a survey conducted in the warmer, summer months when herpetofauna are most active in order to get a better estimate of the abundance of these taxa in the area.

Flora and vegetation

- A complete botanical and vegetation survey needs to be conducted in the area along the slopes and ridges that separates the Nadala and Qaliwana Creeks and the adjacent catchment area. The study is necessary if a complete botanical inventory of the area is required and also if monitoring work on the impact of the operations on the flora and vegetation needs to be undertaken.
- Detailed assessments of the areas potential of becoming an ex situ conservation site for some of the rare and threatened plants (and also animals) found in the surrounding areas. This is especially true for plants like *Cyphosperma tanga, Meryta tenuifolia*; and fauna like the pink billed parrot finch, the Long Legged Warbler and the Peregrine Falcon and lorikeet.
- Because of the general low botanical diversity of the native flora within the three areas earmarked for development, the introduction of seeds and seedlings of native plants deemed “rare” from neighbouring forests be encouraged. Patches of grassland noticed on the slopes and ridges between the Qaliwana and Nadala and Nukunuku creeks would be ideal rehabilitation sites. For the Tubunabeka Creek the forested gully should be fenced off from livestock. This should encourage the return of native plants to the area.
- The creek banks along the Qaliwana and Nadala Creeks that are likely to be flooded are relatively steep and in such areas, erosion would be a problem. In such areas an erosion barrier should be established. Vetiver grass can be used as an erosion barrier along these steep escapements. This material is locally available.

Birds

- Further surveys should be conducted under good weather conditions as well as over a longer period of time to gather data on seasonal variation in density and distributions of birds in the area. Special attention should be paid to birds of conservation importance including the Giant Forest Honeyeater, Masked-shining Parrot, Red-throated Lorikeet and Peregrine Falcon.

- Further surveys for important species not found during this survey should be conducted including the Red-throated Lorikeet, Peregrine Falcon, Pink-billed Parrot Finch, Long-legged Warbler, Black-faced Shrikebill, Friendly Ground Dove and Barred-winged Rail.
- More intensive surveys including the use of mist netting should be conducted to verify the presence or absence of other native mammals especially the bats.

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APPENDIX A

SELECTED FRESHWATER INVERTEBRATES FOUND DURING SURVEYS

(a) Stony case caddisfly larva (*Melanoides lutosa*)

(b) Damselfly nymph

(c) *Melanoides tuberculata*

(d) Green dragonfly nymph (55mm)

(e) *Macrobrachium latimanus*

(f) *Atyopsis spinipes*

APPENDIX A CONTINUED

(g) *Caridina* sp.

(h) Leaf case caddisfly larva

APPENDIX B.

Preliminary annotated checklist of vascular plants recorded from the likely areas to be impacted around the Tubunabeka (Tub), Nukunuku (Nuk), Nadala (Nad) and Qaliwana (Qal) creeks

Family	**Botanical Name**	**Origin**	**Local Name**	**Plantation**			
				Tub	Nuk	Nad	Qal
Acantaceae	*Blechum pyramidatum*	Nat		X	X	X	X
Acanthaceae	*Cordia myxa*	Exo		X	X		
Agavaceae	*Cordyline fruticosa*	Ind	Qai	X	X	X	X
Alangiaceae	*Alangium vitiense*	End	(ula ni sau			X	X
Anacardiaceae	*Mangifera indica*	Exo	maqo	X	X	X	
Anacardiaceae	*Semecarpus vitiensis*	End	(kaukaro)		X	X	X
Anacardiaceae	*Spondias dulcis*	Abo. Int	wi		X		
Annonaceae	*Annona muricata*	Ext/Inv	uto	X	X		
Annonaceae	*Cananga odorata*	Ind	Makosoi	X	X		
Annonaceae	*Cyathocalyx insularis*	End	Makosoi ni veikau	X	X	X	X
Annonaceae	*Xylopia pacifica*	End	Dulewa		X	X	X
Apidiaceae	*Tectaria latifolia*	Ind	ota loa			X	X
Apocynaceae	*Alstonia montana*	End	Sorua draulailai			X	X
Apocynaceae	*Alstonia pacifica*	Ind	Sorua		X	X	X
Apocynaceae	*Alstonia vitiensis*	End	Sorua levu		X	X	X
Apocynaceae	*Cerbera manghas*	Ind	Vasa ni veikau	X	X	X	X
Apocynaceae	*Ervatamia obtusiuscula*	Ind	Vueti naitasiri		X	X	X
Apocynaceae	*Pagiantha thurstonii*	End	tadano	X	X	X	X
Araceae	*Epipremnum pinnatum*	Ind	yalu	X	X	X	X
Araliaceae	*Plerandra insolita*	End	Sole		X	X	X
Araliaceae	*Plerandra vitiensis*	End	sole			X	X
Araliaceae	*Polyscias multijuga*	Ind	Danuidani ni veikau		X	X	X
Araliaceae	*Schefflera vitiensis*	End	Sole lewa			X	X
Araucariaceae	*Agathis macrophylla*	Ind	dakua makadre			X	X
Aspidiaceae	*Tectaria latifolia*	ind				X	X
Aspleniaceae	*Asplenium amboinense*	Ind				X	X
Aspleniaceae	*Asplenium australicium*	Ind			X	X	X
Asteraceae	*Vernonia cinerea*	Nat	kaukamea	X	X	X	X
Asteraceae	*Wedelia trilobata*	Inv	kovekove		X		X
Barringtoniaceae	*Barringtonia edulis*	End	Vutu kana	X	X	X	X
Bignoniaceae	*Spathodea campanulata*	Nat/Inv	pasi		X	X	
Blechaceae	*Blechnum orientale*	Ind			X		
Blechnaceae	*Blechnum milnei*	Ind			X	X	X
Blechnaceae	*Blechnum orientale*	ind			X	X	X
Burseraceae	*Canarium harveyi*	Ind	Kaunigai/kaunicina		X	X	X
Burseraceae	*Canarium vanikoroense*	End	kaunisiga				X
Caesalpiniaceae	*Cynometra insularis*	End	moivi		X	X	X
Caesalpiniaceae	*Intsia bijuga*	Ind	Vesi	X	X		
Caesalpiniaceae	*Kingiodendron platycarpum*	End	Moivi/cibicibi	X	X		
Caesalpiniaceae	*Maniltoa grandiflora*	End	Moivi levu	X	X		X

Caricaceae	*Carica papaya*	Abo. Int	maweli	X	X		
Casuarinaceae	*Gymnostoma vitiense*	End	velau		X		
Chrysobalanaceae	*Atuna racemosa*	Ind	makita			X	X
Chrysobalanaceae	*Parinari insularum*	End	sa	X	X	X	X
Clusiaceae	*Calophyllum cerasiferum*	End	damanu draulailai			X	X
Clusiaceae	*Calophyllum vitiense*	End	damanu dilodilo		X	X	X
Clusiaceae	*Garcinia myrtifolia*	Ind	laubu	X	X	X	X
Clusiaceae	*Garcinia pseudoguttifera*	Ind	Bulu M	X	X	X	X
Combretaceae	*Terminalia vitiensis*	End	tivi			X	X
Comelinaceae	*Commelina diffusa*	Nat	co bulabula	X	X	X	X
Connaraceae	*Connarus pickeringii*	End	wa tele		X	X	X
Convulvolaceae	*Ipomoea micrantha*	Ind			X		
Cucurbitaceae	*Coccinia grandis*	Nat/Inv		X	X		
Cucurbitaceae	*Mommordica charantia*	Exo	kerala		X	X	
Cunoniaceae	*Geissois ternata*	End	Vure	X	X	X	X
Cyathaceae	*Dicksonia brackenridgei*	Ind				X	X
Cyatheaceae	*Cyathea lunulata*	Ind	balabala		X	X	X
Cyperaceae	*Cyperus papyrus*	Nat.	papyrus		X	X	X
Cyperaceae	*Cyperus rotundus*	Ind			X	X	X
Cyperaceae	*Kyllinga polyphylla*	Nat	Navua sedge	X	X	X	X
Davalliaceae	*Nephrolepis biserrata*	Ind		X	X	X	X
Degeneriaceae	*Degeneria vitiensis*	End	Masiratu			X	X
Dilleniaceae	*Dillenia biflora*	Ind	Kuluva	X	X	X	X
Euphorbiaceae	*Acalypha rivularis*	End	Kalabuci ni wai		X	X	X
Euphorbiaceae	*Baccaurea pulvinata*	End	Midra		X	X	X
Euphorbiaceae	*Baccaurea stylaris*	End	Midra			X	X
Euphorbiaceae	*Bischofia javanica*	Ind	Koka	X	X	X	X
Euphorbiaceae	*Endospermum macrophyllum*	End	Kauvula			X	X
Euphorbiaceae	*Glochidion seemannii*	End	Molau		X	X	X
Euphorbiaceae	*Jatropha curcas*	Exo			X		
Euphorbiaceae	*Macaranga harveyana*	Ind	Mavu	X	X	X	X
Euphorbiaceae	*Macaranga magna*	End	Davo levu			X	X
Euphorbiaceae	*Macaranga vitiensis*	End	Davo			X	X
Euphorbiaceae	*Manihot esculenta*	Abo. Int	tavioka		X		
Euphorbiaceae	*Mikania micrantha*	Nat/Inv	wabosucu	X	X	X	X
Euphorbiaceae	*Omalanthus nutans*	Ind	Tadano	X	X	X	X
Fabaceae	*Albizia saman*	Nat/Inv	seremaia	X	X		
Fabaceae	*Cynometra insularis*	Ind	moivi		X	X	X
Fabaceae	*Entada phaseoloides*	Ind	Walai			X	
Fabaceae	*Erythrina variegata*	Exo	drala	X	X		
Fabaceae	*Leucaena leucocephala*	Nat/Inv	vaivai	X	X		
Fabaceae	*Mimosa pudica*	Nat	co gadrogadro	X	X	X	X
Flacourtiaceae	*Homalium vitiense*	End	Molaca			X	X
Flagellariaceae	*Flagellaria gigantea*	Ind	Waulo levu			X	X
Flagellariaceae	*Flagellaria indica*	Ind	Waulo				X
Gesneriaceae	*Cyrtandra jugalis.*	End				X	X
Gnetaceae	*Gnetum gnemon*	ind	Sukau		X	X	X
Gonystylaceae	*Gonystylus punctatus*	end	Mavota			X	X
Goodinaceae	*Scaevola floribunda*	End	Durubi			X	X
Heliconiaceae	*Hedychium coronarium*	Intr		X	X	X	X
Heliconiaceae	*Heliconia paka*	Ind	Vava		X	X	X

Hernandiaceae	*Gyrocarpus americanus*	Ind	wiriwiri		X		
Hernandiaceae	*Hernandia olivacea*	End	Dalovoci			X	X
Icacinaceae	*Citronella vitiensis*	end	nuqa			X	X
Joinvilleaceae	*Joinvillea plicata*	Ind	Gasau ni veikau		X	X	X
Labiatae	*Hyptis pectinata*	Nat		X	X	X	X
Lauraceae	*Cryptocarya fusca*	end	Lidi			X	X
Lauraceae	*Cryptocarya hornei*	End	diriniu		X	X	X
Lauraceae	*Endiandra gillespiei*	end	damabi			X	X
Lecythidaceae	*Barringtonia edulis*	End	Vutu gaga	X	X	X	X
Loganiaceae	*Fagraea berteroana*	Ind	Bua ni viti		X	X	X
Loganiaceae	*Geniostoma rupestre*	Ind	Boiboida		X	X	X
Loganiaceae	*Neuburgia corynocarpa*	Ind	Bo loa	X	X	X	X
Lycopodiaceae	*Lycopodium cernuum*	Ind	Lewa ninini			X	X
Malvaceae	*Hibiscus tiliaceus*	Ind	Vau	X	X	X	X
Malvaceae	*Sida rhombifolia*	Nat	deni me	X	X	X	X
Marattiaceae	*Angiopteris evecta*	Ind	Basovi			X	X
Marattiaceae	*Angiopteris opaca*	End	Basovi			X	X
Marattiaceae	*Marratia smithii*	ind				X	X
Melastomataceae	*Astronidium confertiflorum*	end	Dava	X	X	X	X
Melastomataceae	*Astronidium robustum*	End	Dava			X	X
Melastomataceae	*Clidemia hirta*	Nat/Inv		X	X	X	X
Meliaceae	*Aglaia archboldiana*	End				X	X
Meliaceae	*Aglaia elegans*	End	kautoa		X	X	X
Meliaceae	*Dysoxylum richii*	End	tarawau kei rakaka	X	X	X	X
Meliaceae	*Vavaea harveyi*	End	sevua			X	X
Mimosaceae	*Serianthes vitiensis*	End	vaivai ni veikau		X	X	X
Moraceae	*Artocarpus altilis*	Abo. Int				X	X
Moraceae	*Ficus barclayana*	End				X	X
Moraceae	*Ficus masonii*	End	Nunu			X	X
Moraceae	*Ficus sp.*					X	
Moraceae	*Ficus storckii*	End	ai masi		X	X	X
Moraceae	*Ficus theophrastoides*	Ind	lolo tagane		X	X	X
Moraceae	*Ficus vitiense*	End	Lolo	X	X	X	X
Musaceae	*Musa sp.*		jaina		X		
Myristicaceae	*Myristica castaneifolia*	End	Male			X	X
Myristicaceae	*Myristica chartacea*	End	Male (draulailai		X	X	X
Myristicaceae	*Myristica grandifolia*	End	kaudamu			X	X
Myrsinaceae	*Maesa tabacifolia*	Ind	matameragigi		X	X	X
Myrsinaceae	*Rapanea myricifolia*		Doi nio vosa	X	X	X	X
Myrsinaceae	*Tapeinosperma megaphyllum*	End	Dasia			X	X
Myrtaceae	*Cleistocalyx decussatus*	End	yasimoli		X	X	X
Myrtaceae	*Decaspermum vitiense*	End	nuqanuqa	X	X	X	X
Myrtaceae	*Metrosideros collina*	Ind	vuga	X	X	X	X
Myrtaceae	*Psidium guajava*	Ext/Nox	quwawa	X	X	X	
Myrtaceae	*Syzygium amplifolium*	End				X	X
Myrtaceae	*Syzygium cf. malaccense*	Abo. Int	kavika	X	X	X	
Myrtaceae	*Syzygium fijiense*	End	yasidravu		X	X	X
Myrtaceae	*Syzygium gracilipes*	End				X	X
Myrtaceae	*Syzygium grayi*	End	Yasi leba			X	X
Myrtaceae	*Syzygium seemannii*	End	Yasi wai		X	X	X
Orchidaceae	*Bulbophyllum sp.*				X		X
Orchidaceae	*Calanthe sp.*					X	X
Orchidaceae	*Dendrobium sp.*				X	X	
Orchidaceae	*Oberonia equitans*	Ind		X			
Orchidaceae	*Taeniophyllum fasciola*	Ind	De ni caucau			X	X
Oxalidaceae	*Oxalis corniculata*	Nat	toto wiwi	X	X	X	X

Pandanaceae	*Freycinetia caudata*	End	Wa me				X
Pandanaceae	*Freycinetia hombronii*	Ind	Wa me			X	
Pandanaceae	*Freycinetia urvilleana*	Ind	Wa me		X	X	X
Pandanaceae	*Pandanus thurstonii*	End				X	
Passifloraceae	*Passiflora suberosa*	Nat		X	X	X	X
Piperaceae	*Piper aduncum*	Nat/Inv	yaqoyaqona	X	X	X	X
Pittosporaceae	*Pittosporum pickeringii*	End	duva kalou		X	X	X
Pittosporaceae	*Pittosporum rhytidocarpum*	End	duva kalou		X	X	X
Poaceae	*Arundo donax*	Intro	Gasau ni vavalagi		X	X	X
Poaceae	*Brachiaria mutica*	Nat	para		X	X	
Poaceae	*Eleusine indica*	Nat	co vatu	X	X	X	X
Poaceae	*Ischaemum indicum*	Nat		X	X	X	X
Poaceae	*Miscanthus floribundus*	Ind	gasau	X	X	X	X
Poaceae	*Paspalum conjugatum*	Nat		X	X	X	X
Poaceae	*Pennisetum polystachyon*	Nat		X	X	X	
Poaceae	*Schizostachyum glaucifolium*	Ind	Bitu dina	X	X		
Poaceae	*Sporobolus diander*	Nat		X	X	X	X
Podocarpaceae	*Dacrycarpus imbricatus*	Ind	Amunu			X	X
Podocarpaceae	*Dacrydium nidulum*	Ind	Yaka				X
Podocarpaceae	*Podocarpus neriifolius*	Ind	kuasi		X	X	X
Podocarpaceae	*Retrophyllum vitiense*	Ind	dakua salusalu			X	X
Polygadaceae	*Polygala paniculata*	Nat		X	X	X	
Proteaceae	*Turrillia ferruginea*	End	kauceuti		X	X	X
Proteaceae	*Turrillia vitiensis*	End	kauceuti			X	X
Pteridaceae	*Culcita straminea*	Ind		X	X	X	
Rhamnaceae	*Alphitonia zizyphoides*	Ind	Doi	X	X	X	X
Rhamnaceae	*Emmenospermum micropetalum*	End	tomanu				X
Rhizophoraceae	*Crossostylis pendunculata*	End					X
Rhizophoraceae	*Crossostylis seemannii*	End	tiri vanua			X	X
Rubiaceae	*Decaspermum vitiense*	End	nuqanuqa		X	X	X
Rubiaceae	*Dolicholobium latifolium*	End	Soso ni ura		X	X	X
Rubiaceae	*Dolicholobium macgregorii*	End	sogasoga			X	X
Rubiaceae	*Gardenia c.f gordonii*	End	drega		X		X
Rubiaceae	*Gardenia c.f storckii*	End	bolovatu			X	X
Rubiaceae	*Ixora sp.*					X	X
Rubiaceae	*Melicope cucullata*	End	drautolu			X	X
Rubiaceae	*Neonauclea forsteri*		Vacea	X	X	X	X
Rubiaceae	*Psychotria confertiloba*	End	deqedeqe			X	X
Rubiaceae	*Timonius timonius*	Ind	dogo ni vanua		X	X	X
Rutaceae	*Citrus grandis*	Ind	moli kania		X	X	X
Rutaceae	*Citrus limon*	Ind	moli karo	X	X		
Rutaceae	*Morinda citrifolia*	Ind	kura	X	X	X	
Sapindaceae	*Elattostachys falcata*		masamasa	X	X	X	X
Sapotaceae	*Burckella parviflora*	End	baumika		X	X	X
Sapotaceae	*Palaquium fidjiense*	End	bausauwalu		X		X
Sapotaceae	*Palaquium hornei*	End	sacau			X	X
Sapotaceae	*Palaquium porphyreum*	End	bauvudi	X			X
Sapotaceae	*Palaquium vitilevuense*	End	(bau)		X		X
Saurauiaceae	*Saurauia rubicunda*	End	mimila		X	X	X

Simaroubaceae	*Amaroria soulameoides*	End	vasa ni veikau	X	X	X	X
Smilacaceae	*Smilax vitiensis*	End	warusi	X	X	X	X
Sterculiaceae	*Heritiera ornithocephala*	End	rosarosa)		X	X	X
Thelypteridaceae	*Christella harveyi*	Ind		X	X	X	
Thymeleaceae	*Gonystylus punctatus*	End	mavota			X	X
Tiliaceae	*Trichospermum calycatum*	End	mako loa			X	X
Tiliaceae	*Trichospermum richii*	Ind	mako		X	X	X
Ulmaceae	*Gironniera celtidifolia*	Ind	sisisi		X	X	X
Urticaceae	*Dendrocnide harveyi*	Ind	salato	X		X	X
Urticaceae	*Procris sp.*						X
Verbanaceae	*Stachytarpheta urticaefolia*	Nat		X	X	X	X
Verbenaceae	*Faradaya ovalifolia*	End	Wavudi		X	X	X
Verbenaceae	*Lantana camara*	Inv/Nox	Lantana	X	X	X	X
Verbenaceae	*Premna serratifolia*	Ind	yaro	X	X	X	X
Zingiberaceae	*Alpinia boia*	End	Boica			X	X
Zingiberaceae	*Alpinia macrocephala*	End				X	X

APPENDIX C

Threatened plants of central Viti Levu and specifically within the vicinity of the Navai and Nadala , Lewa and Nadarau villages and upper reaches of the Ba River, Qaliwana, Nadala and Nukunuku Creeks.

Checklist Legend:

Distribution Status: E=endemic; Conservation Status and its Basis (CSB):

CE=critically endangered; TH=threatened; DD=data defficient; R=Rare; TC=plant known from type collection and holotype collection; TL= known only from the type locality;1L= one locality;2C=two collections.

Species	**Endemic**	**CSB**		**Locality and Habitat**
Calanthe imthurnii Kores	E	DD	2C	Navai south road to Nadrau.
Cyphosperma tanga (H.E. Moore) H.E Moore	E	CE	1L	Navai
Dendrobium carnicarinum Kores	E	DD	TC	Navai - Nadarivatu
Drypetes pacifica A.C. Smith	E	TH	TC	Galiwana creek - Navai
Psychotria gracilior A. C. Smith	E	TH	TC	Nadala and Nukunuku Creek, trail from Nadala to Lewa
Meryta tenuifolia	E	R	TL	Naga - Nadrau

APPENDIX D

Table 1. Checklist of birds recorded from Lewa (L), Buyabuya (B) and Qaliwana (Q) Areas.)

Common Name	Scientific Name	L	B	Q	Local Name	Status
Barking Pigeon	*Ducula latrans*	*	*	*	Ruve driu	Endemic
Barn Owl	*Tyto alba*	*			Lulu	Native
Blues-crested Broadbill	*Myiagra azureocapilla*		*	*		Endemic
Collared Lory	*Phigys solitarius*	*		*	Kula	Endemic
Common Mynah	*Acridotheres tristis*	*	*	*	Maina	Introduced
Eastern Reef Heron	*Egretta sacra*	*	*	*	Belo	Native
Fiji bush warbler	*Cettia ruficapilla*	*		*	Jikivili	Endemic
Fiji Goshawk	*Accipiter rufitorques*	*		*	Reba	Endemic
Fiji parrotfinch	*Erythrura cyanovirens*	*	*	*	Qiliyago	Endemic
Fiji white-eye	*Zosterops explorator*	*	*	*		Endemic
Fiji silver-eye	*Zosterops lateralis*	*	*	*		Native
Fiji Woodswallow	*Artamus mentalis*	*		*	Sikorere	Endemic
Giant forest honey eater	*Gymnomyza viridis*	*		*	Sovau	Endemic
Gloden Dove	*Ptilinopus luteovirens*	*	*	*	Bune	Endemic
Golden whistler	*Pachycephala pectoralis*	*		*	Diriqwala	Native
Island thrush	*Turaus poliocephalus*	*		*	Sasare	Native
Jungle mynah	*Acridotheres fuscus*	*	*	*	Maina ni viji	Introduced
Lesser Shrikebill	*Clytorhynchus vitiensis*	*	*	*		Native
Many-coloured Fruit-dove	*Ptilinopus perousii*			*		Native
Masked Shining Parrot	*Prosopeia personata*	*		*	Ka	Endemic
Orange breasted myzomela	*Myzomela jugularis*	*	*	*	Maji	Endemic
Pacific Black Duck	*Anas superciliosa*	*	*	*	Ga ni viti	Native
Pacific Harrier	*Circus approximans*	*		*	Takubu	Native
Polynesian Starling	*Apolonis tabuensis*			*		Native
Polynesian triller	*Lalage maculosa*	*	*	*	Sea	Native
Red-vented Bulbul	*Pycnonotus cafer*	*	*	*	Ulurua	Introduced
Scarlet Robin	*Petroica multicolor*	*		*	Diriqwala	Native
Spotted turtle dove	*Streptopelia chinensis*	*			Kukuru	Introduced
Slaty monarch	*Mayrornis lessoni*			*		Endemic
Streaked fantail	*Rhipidura spilodera*	*		*		Native
Vanikoro broadbill	*Myiagra vanikorensis*	*	*	*	Diriqwala	Native
Wattled honey eater	*Foulehaio carunculata*	*	*	*	kitou	Native
White-collared kingfisher	*Todiramphus chloris*	*	*	*	Lele	Native
White-rumped swiftlet	*Aerodramus spodiopygius*	*	*	*	Kakalaba	Native
White throated pigeon	*Columba vitiensis*	*		*	Ruve lo	Native

Table 2 Checklist of Mammals recorded from Lewa (L), Buyabuya (B) and Qaliwana (Q) Areas.)

Common Name	**Scientific Name**	**L**	**B**	**Q**	**Local Name**	**Status**
Cow	*Bos sp.*	*	*	*	Bulumakau	Introduced
Feral Cats	*Felis catus*	*	*	*	Vusi	Introduced
Pacific Flying Fox	*Pteropus tonganus*	*	*	*	Bekwa	Native
Goat	*Capra hircus*	*	*		Me	Introduced
Horse	*Equus caballus*	*	*	*	Ose	Introduced
Mongoose	*Herpestes auropunctatus*	*	*	*	Manivusi	Introduced
Rats	*Rattus sp.*	*	*	*	Kucuve	Introduced
Samoan Flying Fox	*Pteropus samoensis*	*		*	Bekwa	Native