Data Book-14

Result of Environmental and Social Survey

SCoPE PACIFIC LIMITED
STRATEGIC CONSULTANTS IN PLANNING & ENGINEERING

JICA Study Team
Planning of the Nadi River Flood Control Structures Project

Environmental Field Survey

FRESHWATER ECOLOGICAL ASSESSMENT

Final Issue
November 2015

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1. Background

The Government of Fiji and Japan have signed a Memorandum of Agreement in late 2014 for the study of the Planning of the Nadi Flood Control Structure Project to address flooding management along the Nadi River catchment area and the Region.
The JICA Study Team will work together with the Ministry of Agriculture namely, the Land and Water Resource Management (LRWM) Division to carry out the study in **3 stages**: 1) Basic Study; 2) Master Plan; and 3) Feasibility Study.
SCOPE Pacific has been engaged by the JICA Study Team to assist with the basic data gathering and legislative reviews together with identifying the environmental and social considerations required under the EIA Process, examples of recent EIAs, as well as the review of the land acquisition and involuntary resettlement process in Fiji together with any recent case studies.
The basic study stage also requires the examination of all environmental and social considerations whereby initial field environmental assessments are required to be undertaken to evaluate the effects of the potential flood control measures in order for JICA to prepare an evaluation method.
The environment field assessments that SCOPE was engaged to assist with includes the following:

1) Terrestrial Flora and Fauna Assessment
2) Water Quality Sampling and Analysis
3) Freshwater Ecological Assessment (the subject of this report)
4) Sediment Sampling & Descriptive Assessment of the Sample Sites

2. Introduction

2.1. Scope of Work

The scope of works for the freshwater biological field survey of the Nadi River flood study area required by JICA includes the following:

- Description of the freshwater ecological environment;
- Sampling of representative habitats across the stream as well as stream profiling;
- Aquatic fauna of commercial/recreational value and migratory fish species along with their spawning ground;
- Habitat including breeding ground and access corridor for food and shelter;
- Fish assemblages and population determining the abundance, species diversity and distribution frequency for each sampling location;
- Identification and recording of macro-invertebrates species, algae and aquatic macrophyte communities;
- Sediment composition;
- Water quality assessment, surface water quantity and flows;

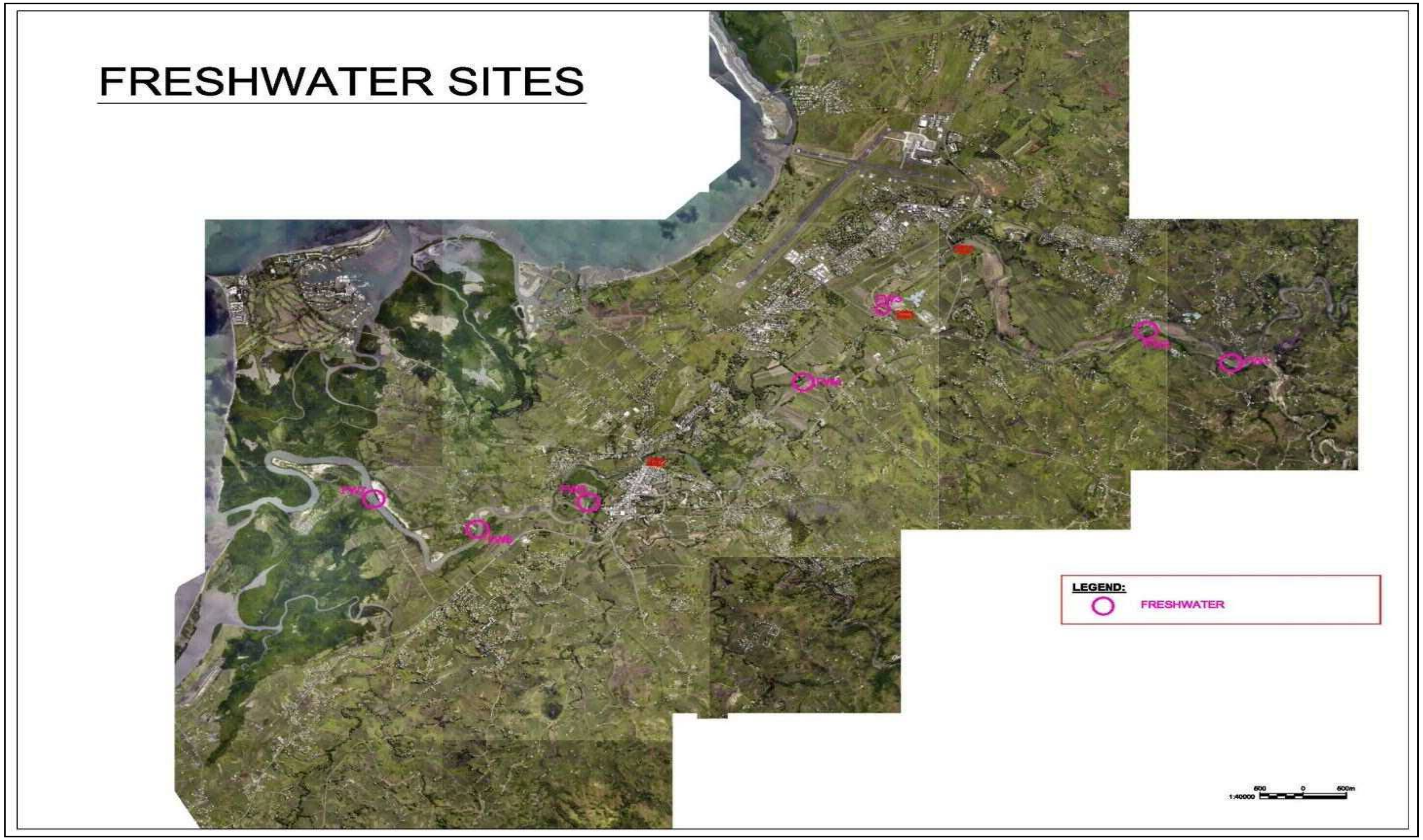
2.2. Methodology

A variety of collection techniques and methodology were used for this freshwater flora and fauna assessment at the seven (7) selected sites as shown in Figure 1 along Nadi River, in order to gain a thorough understanding of species presence and absence including stream flows, stream width and general health of the stream. The field survey was carried out on the 29th September, 2015 in dry weather conditions.

The following are some equipment and techniques used during the survey:

- A large *seine net* (2 m x 7 m, 0.4 cm2 meshes) was used during the assessments. The net was pulled forward at the top floating edge of the net in a rough circle, with the bottom edge down as close as possible to the substrate. This technique was executed before anyone set foot in the water body to minimize the number of fleeing fishes and was generally used in minor tributaries with slow moving or still waters.

- **Figure 1 Freshwater Sample Sites along Nadi River**



- *A medium pole seine net* (1.2 m x 0.8 m, 1mm 2 mesh) was used in a variety of ways. Firstly, it was held firmly downstream while fielder workers walk, kick and dislodge rubble upstream. This is a useful method for collecting small, bottom dwelling/feeding fish. On vegetated banks, the net was thrust under submerged vegetation dislodging fishes into the net. Also, it was used to "scoop" (bottom edge held forward and run along substrate for a few seconds then lifted) any accessible shallow body of water.
- *Small hand nets* (15cm x 10cm + 10 cm x 8 cm, 1mm 2 mesh) were used to "scoop" the underside of overhanging rocks and in small crevices and also to collect fauna when in still water bodies.
- Specimens were fixed with 20% ethanol and 80% for preservation in a jar were labeled with site location, date and contents before taken to the USP laboratory for identification.
- A 10 meter tape was laid out parallel to the length of the stream. An estimated average width and depth of the sampling area was assumed and recorded. The habitat type, bank vegetation, algae and size of sampling area was noted and recorded. The recording of physical water quality parameters: pH, conductivity, DO, temperature and turbidity was undertaken using Horiba Multi-meter.
- Stream flow was measured using a tennis ball. A tennis ball was placed into the water and the distance it travelled was also timed in order to obtain a rate of meters per second. A measuring tape was used to obtain the depth, width and length of the stream at the four sampling point.

3. The Existing Environment

3.1. Sampling Sites

A total of seven sites were selected for freshwater fisheries and macro-invertebrates. These were selected based on the extent of the project works within the Nadi River. There were two (2) upper catchment sites, three (3) middle catchments and two (2) lower catchments sampling sites. The field survey began from upstream then continued downstream ending close to the river mouth.

3.1.1. *Site 1 Upper Catchment*

The first site surveyed was located on the top end of the tributary river. The site was dominated with sand and gravel, although soil could be located on both the sides of the River. The riverbed is estimated to have 60% gravel, 30% sand and 10% soil.

▪ **Figure 2 Upper Catchment of Site 1**

The riparian vegetation consisted of grassland and shrubs. The forest cover was estimated to be around 10% (very low) as most riparian vegetation has been removed for farming and mostly exotic and invasive grass dominate the riparian vegetation, thus resulting in high turbidity from runoff during heavy rain as shown in Figure 2. Also evident on site was the high degree of disturbance arising from gravel extraction operations upstream.

▪ **Table 1 Measurement recorded at Site 1**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 1	6	15	1.2	0.37

The active width of the site was around 6 meters whilst the flood plain width recorded up to 15 meters. With the impacts of gravel extraction; altering the nature of the flow and depth, the average depth was around 1.2 meters with the velocity recorded at 0.37 m/s.

3.1.2. *Site 2: Upper Catchment*

The second site surveyed as shown in Figure 3 was located on the upper catchment of the river tributary. The substrate was dominated with sand, gravel and pebbles. An estimated riverbed percentage falls at 50% gravel, 30% sand and 20% pebble.

- **Figure 3 Upper Catchment of Site 2**

The riparian vegetation consisted of grassland and exotic plants with evidence of old farms. Also evident on site was the gravel extraction disturbances in the river. Household waste was also found to be scattered along the river bank indicating that residence living nearby disposed their rubbish into the river. This was obvious and the need to promote waste management with these residents is crucial in order to improve river conditions as well as to support aquatic life and livelihoods for the local community.

- **Table 2 Measurement for Site 2**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 2	15.5	22.3	1.5	0.39

The active width of the river was 15.5 meters which would increase to 22.2 meters by with the flood plain areas. Average depth was 1.5 meters with the average velocity at 0.39m/s.

3.1.3. *Site 3: Middle Catchment*

The 3rd site surveyed was located below the old Queens Road bridge with Metromix (cement factory) located upstream. The river system was found to be very highly disturbed from the cement factory discharging waste water directly to the river causing significant impacts downstream as shown in Figure 4. It appears that habitats have been lost due to the amount of siltation covering the river system.

- **Figure 4 Middle Catchment showing runoff from Metromix and siltation in the river**

Sand is estimated to be around 30% as substrate was observed at around five meters off the bridge on one side of the river only and beyond that, was all silt which was around 80-90% of the substrate cover. Riparian vegetation was mainly grassland and shrubs estimated to be around 30-40%. The upper part of the bridge upstream of the outlet of the run-off was also surveyed and despite the disposal of household waste from local communities, it appeared that overhanging grass on the sides of the river seem to be providing home to some aquatic fauna which included an amphidromous fish from the Gobiidae family that was observed.

- **Table 3 Measurement on Middle Catchment**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 3	20.5	40	0.5	0.23

The active width of the River at Site 3 was 20.5 (m) with an average depth of 0.5 (m) and a velocity of 0.23 (m/s).

3.1.4. *Site 4: Middle Catchment*

The location of Site 4 was further downstream from the third site towards Nadi Town with the substrates consisting of 40% mud and 60% gravel.

- **Figure 5 Middle Catchment as Site 4**

The river bank vegetation was mainly covered with shrubs, grassland and exotic plants and 20 meters off the river bank were garden vegetables & tobacco farm shown in

Figure 5. Signs of disturbance could still be obvious as this was the continuation of the downstream impacts of the stormwater and sediment run-off from upstream. The impacts of were obvious with the low count of abundance and diversity of both macro-invertebrates and fish. The flow rate was slow and tidal change was experienced at this site considering its close proximity to where the river joins up with other main tributaries.

- Table 4 Measurement of middle catchment

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 4	23.5	24.0	1.5m	0.16

The water velocity recorded at Site 4 was 0.16m/sec with an active width of 23.5m.

3.1.5. *Site 5: Lower Catchment*

Site 5 was located much closer to where a tributary merges with the Nadi River. Tidal change was more obvious at this site and substrate was predominately mud (90%) and 10% sand particularly on the sides of the river tributary.

- Figure 6 Lower Catchment at Site 5

The site lined with riparian vegetation mainly grassland with a few mango trees on either the side as shown in Figure 6. The high degree of disturbance from upstream could be found downstream as the survey team had to wade knee deep in mud and silts as a result of the upstream activities.

Table 5 Measurement at lower catchment

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 5	3	30	0.5	0.21

Table 5 shows that the active width including the flood plain area was 30 metres wide and average depth of the river was less than ½ metre. Water velocity was also measured at 0.21 metres per second.

3.1.6. *Site 6 Lower Nadi River*

The main substrate for Site 6 was mud and sand; with around 80% of mud and 20% sand. Riparian vegetation was mainly grassland and exotic trees with no forest cover as shown in Figure 7.

Figure 7 Lower Nadi River

The site has undergone extensive dredging in order to deepen the Nadi River and this was obvious on site. One side of the river bank was covered with grass, growing on the deposited sand or spoil (as a result of dredging) while on the other side of the river bank comprised mainly of shrubs with few trees holding the bank together therefore preventing soil erosion. Tidal change was more obvious and flow could still be experienced during low tide. The only threat appeared to be the Navakai Sewerage Plant outfall shown in Figure 8 discharging directly into the River upstream from this sampling site.

Figure 8 Navakai STP Discharge Point into Nadi River

The velocity of water was 0.27m/sec with the active width recorded at 50m as shown in Table 6 below.

- Table 6 Measurement on the Lower Nadi River

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 6	50	50	2	0.27

3.1.7. *Site 7: Lower Nadi River*

Similar to Site 6, the substrate at Site 7 as shown in Figure 9 was mainly mud (90%) and the other 10% was sand particles. Forest cover was noted as 30% comprising of riparian vegetation mainly grassland and native trees. A high degree of disturbance from sedimentation and siltation was evident downstream and this could be attributed to upstream activities such as farming, logging, gravel extraction operations and stormwater run-off. This area is also largely affected by the dredging that took place in the Nadi Town area a few years ago, as the banks of Site 7 was used to dump the dredged spoil which over time is being washed back into the Nadi River as the banks were not bunded to contain the spoil.

- Figure 9 Site 7 Lower Nadi River

The width of the river at this point was 60 metres inclusive of the flood plain area, with average depths of 2.5 metres and water velocity of 0.29m/sec as shown in Table 7 below.

- Table 7 Measurement on the Lower Nadi River (Site 7)

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 7	60	60	2.5	0.29

4. Field Results and Findings

4.1. Water Quality Physical Parameters

A comparative summary of the environmental and physical parameters recorded for each site is shown in Table 8 below.

- **Table 8 Water Quality Results**

Parameters	Site 1	Site 2	Site 3	Site 4	Site 5
Temperature (°C)	26.3	26.9	27	27.3	27.4
pH	9.9	10.3	8.2	8.3	8.4
Conductivity (mS/cm)	45.4	35.6	0.7	0.2	0.2
Turbidity (NTU)	14.6	8	41.3	19	34.4
Dissolved Oxygen (mg/L)	8.4	8.2	8.7	8.8	8.9
TDS (g/L)	27.7	21.7	0.5	0.15	0.14
Salinity (ppt)	28.9	21.5	0.2	0	0

Note: Site 1 (downstream) to Site 5 (upstream)

Measuring water temperature is very simple and is a very important factor in water quality. Several things determine the rise and fall of water temperature in a stream but the most important are weather and season. Many of the physical, chemical and biological characteristics of streams are directly affected by temperature. Water temperature influences the amount of oxygen that can be dissolved.

The temperature recorded ranged between 26 and 27°C and is considered high for many sensitive aquatic invertebrates. Macro-invertebrates can only survive temperature not exceeding 19°C and temperatures above that are lethal to the river system. However, fish are susceptible to rapid temperature changes. Some species have different temperature needs at different stages of life.

The high temperature would often cause environmental damage over time as a result of human activities. In the case of Nadi River, it could be attributed to runoffs from the nearby industrial operations, factories, the Navakai STP, agricultural farms, etc. Also, the clearing of riparian vegetation on both sides of banks allows the sun to shine directly into the water thus increasing the water temperature.

The value of pH for all sites ranged between 8 and 10 indicating the alkalinity of Nadi River. The pH level of freshwater is usually 6.5 to 9, although wide variation can occur because of catchment geology. Site 2 was found to be outside the normal range when compared to the other four sites and this could be attributed to the direct discharge of sewerage outfall into the receiving water body causing nutrient level to increase, thus increasing the growth of algae and other plants. Animals and plants in streams can adapted to certain ranges of pH though changes in pH levels outside the normal range of the water body can cause more sensitive species to die.

Conductivity is one way to measure the amount of substances like calcium, bicarbonate, nitrogen, phosphorus, iron or sulphur dissolve in water. Raised levels of dissolved minerals may affect how suitable the stream water is in protecting ecosystems. Site 1 value is above the recommended guideline because of its location being close to the river mouth where salt water content is high and Site 2 is mainly due to the STP discharge. Site 4 and Site 5 were found to be within the trigger value, despite the many changes in the geology of the area with the river conductivity remaining normal upstream.

Turbidity values were high in the upper catchment to mid river when compared to the mid and lower catchment sites and this was directly related to gravel extraction activities and sediment run-off into and along the Nadi River. It is also due to erosion which occurs within the catchment whereby tiny particles of clay, silt or small organic particles are washed into the river particularly in areas where vegetation has been striped or cleared by cultivation too close to the stream's edge, livestock crossing the streams, unstable banks, etc. Further downstream where the river widens and deepens, the turbidity value dropped due to sediment settling on the substrate clearing the surface water. One way to control water turbidity is by keeping vegetation along stream margins to stabilize banks and to have proper upper catchment management in terms of landuse and practices.

Dissolved oxygen is the small amount of oxygen gas dissolved in water. This oxygen is vital to fish and other aquatic animals, micro-organisms and plants which depend on it for the process of respiration. The level of DO is a useful indicator of water quality. It indicates the presence of certain pollutants particularly organic matter. The dissolved oxygen level at all sites ranged between 8mg/L and 9mg/L which was above the trigger value indicating the presence of sewage effluent, decaying aquatic vegetation and animal manure which reduces DO levels through decomposition by micro-organisms. DO levels in natural waters depend on four factors such as how quickly oxygen is absorbed into the water from air, how quickly oxygen is used up by organisms in the water, photosynthesis of plants and algae and flow variation.

Increased salinity levels have been observed in the lower reaches of Nadi River particularly at Site 1 and Site 2. Salinity poses major threat to freshwater river systems since organisms thriving in such river can tolerate certain ranges of water salinity. However, much greater species diversity can be found in low salinity river.

4.2. Biological Parameters

4.2.1. *Macro-invertebrates*

Table 9 Macro-invertebrates Observed along the 7 sites

Scientific order	Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Total
Trichoptera (Caddisflies)	*Triaenodes fijianus*	2	1	-	1	-	-	-	4
Decapoda	*Macrobrachium equidens*	5	10	12	6	-	-	-	33
	Macrobrachium lar	3	2	4	2	-	-	-	11
Sorbeoconcha									
Thiaridae (Family)	*Melanoides tuberculata*	-	-	10	5	-	-	-	15
Total		10	13	26	14				**63**

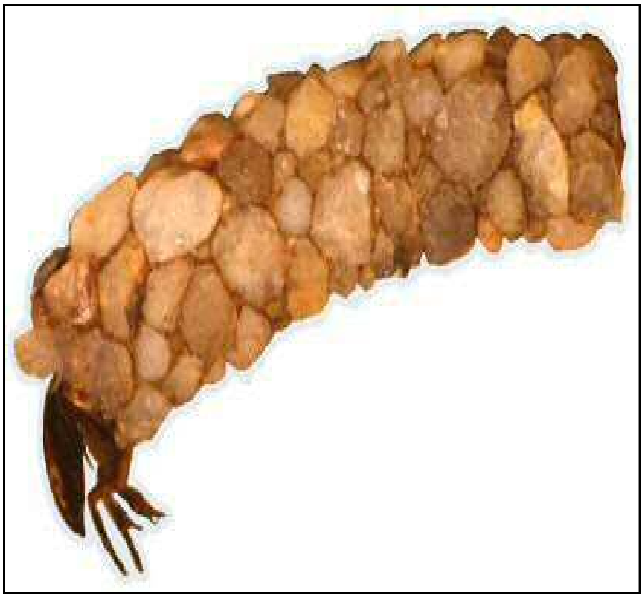
*Note: Site 7 (river mouth) to Site 1 (upstream)

A total of four species from three orders were observed during the field survey (refer Table 9). Note that from Site 5 to Site 7 showed no presence of macro-invertebrate as the three locations are situated downstream where there is salt content due to this area of the Nadi River being tidal. The species present proved to be low in terms of species abundance and diversity. Although the quality of water was not preferable, the species counts proved otherwise. Even with low numbers, the presence of native and endemic species was a good indication of fauna being resilient and adaptive in a degraded environment like the Nadi River. It also demonstrates how the river system is able to withstand changes and in the process restore the fauna at any given time particularly during favourable weather conditions.

4.2.1.1. Caddisfly

Caddisfly as shown in Figure 10 was observed to be present upstream where water quality is moderately disturbed and proved to be low in number during the survey indicating the river quality. Caddisfly is known to mate during flight and one female can lay up to several hundred eggs. Eggs are enclosed in a gelatinous mass either on or near the water. The larvae are aquatic and have a sclerotised head and thorax and well developed legs. They have a soft body which sheath into casing made from silk that are covered in various materials such as sand or plant debris to provide protection and camouflage.

Figure 10 Photographs of Caddisfly Larvae and Casing



Caddisfly do not feed, however the larvae have a wide variety of feeding methods and diets. The larvae may either be herbivorous or predatory. They are predominately found near water bodies as observed in Site 1, Site 2 and Site 4 of Nadi River since their young are aquatic. Water conditions such as oxygen, temperature, chemicals and particulate matter are important to different caddisfly species which often directly correspond to the presence or absence of certain species in an area. Their larvae are sometimes used as environmental indicators of water quality.

4.2.1.2. Decapoda

Macrobrachium equidens species shown in Figure 11 recorded the highest species present in the Nadi River. They are able to adapt to a wide range of salinities (euryhaline) and were found in the middle and lower reaches of estuaries, occasionally upstream to the limit of tidal influence as in the case of Nadi River. The organisms are euryhaline because their life cycle involves migration between freshwater and marine environment.

- **Figure 11 Macrobrachium equidens species**

- **Figure 12 Macrobrachium lar**

The Tahitian prawn *Macrobrachium lar* shown in Figure 12 was sighted at Site 1 to Site 4 and are an introduced species to Fiji. The Tahitian prawns like shaded deep pools and sheltered parts of the stream. They eat almost anything ranging from algae and plant matter to fish and snails and they harm native stream species through predation.

4.2.1.3. Thiaridae

- **Figure 13 Red-rimmed melania**

Red-rimmed melania or *Melanoides tuberculata* shown in Figure 13 was observed at Site 3 and Site 4. The species has a worldwide distribution with no specific threats affecting it. Their population can reach extremely high densities in sandy or gravel sediments where snails do not only live upon the surface but also in the top layer. They are found in all types of permanent waters and from oligotrophic to eutrophic waters. It browsers over microalgae, they are detritrivore (feeding on detritus, plant leaves and dead animals) and are able to survive in relatively alkaline and saline waters. It is parthenogenetic and is spread by birds and is the intermediate host of several trematodes.

4.2.2. *Functional Feeding Groups*

Overall, the macro-invertebrates identified were mixture of three broad categories of macro-invertebrate feeding groups which help describe their role in an aquatic system. These are collectors, shredders and predators.

4.2.3. *Fisheries Observed*

A total of 11 different species from 9 different families shown in Table 10 were observed during the survey. Out of the 11 different species observed, 8 were natives while 3 were introduced. Out of the seven sites surveyed, Site 1 to Site 4 was heavily invaded with introduced species. The introduced species can dominate the entire ecosystem at an alarming rate in future if not controlled.

- **Table 10 Fisheries Observed**

Family	Species	Status	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Total
Gobiidae	*Stenogobius genivitattus*	Native	-	1	-	-	-	-	-	1
	Glossogobius aureus	Native	-	-	-	-	3	-	-	3
Anguillidae (eels)	*Anguilla marmorata*	Native	2	1	1	-	-	-	-	4
Syngnathidae (Ragged tail pipe-fish)	*Microphis retzi*	Native	2	-	-	-	-	-	-	2
Ambassidae	*Ambasis miops*	Native	-	-	-	-	8	-	-	8
Hemiramphidae	*Zenarchopterus dispar*	Native	-	-	-	1	-	-	-	1
Leiognathidae	*Leiognathus equlus*	Native	-	-	-	-	-	1	-	1
Carangidae	*Caranx papuensis*	Native	-	-	-	-	-	1	-	1
Cichlidae	*Oreochromis mossambicus*	Introduced	4	3	2	1	-	-	-	10
	Oreochromis niloticus	Introduced	2	3	1	2	-	-	-	8
				5	4	3	-	-	-	18

4.2.3.1. Gobiidae

- **Figure 14 Stenogobius genivitattus**

Chinstripe goby or *Stenogobius genivitattus* shown in Figure 14 was observed to be present in Site 2. The species is found in freshwater and inhabits clear to turbid freshwater streams and river.

■ Figure 15 Glossogobius aureus

Glossogobius aureus shown in Figure 15 was found inhabiting Site 5. It is a widely distributed and common species known from a range of sites. It is found in a range of freshwater habitats including Nadi River as well as in other protected areas. The species inhabits clear to turbid freshwater streams and river with mud, sand or gravel substrate usually in depths less than 1m. Although it does have a marine larval stage but some land-locked populations are known. There are no known major threats to this species but they may be affected by habitat destruction or deterioration, and sometimes as a result of natural disasters.

4.2.3.2. Anguillidae (Giant Long-finned Eel)

■ Figure 16 Giant long-finned Eel

The giant long-finned eel also known as marbled eel shown in Figure 16 has the widest distribution in rivers and streams. The species was recorded sighted at Site 1, Site 2 and Site 3 of the Nadi River and their size can increase up to 2m and weigh 20kg. Anguillid eels spend their adult life in freshwater or estuarine habitats, and then migrate to the ocean to reproduce. The species is long-lived and may reach up to 40 years in age. Anguilla marmorata is nocturnal and feed on a wide range of prey especially crabs, fish and frogs.

4.2.3.3. Syngnathidae (Ragged Pipe-fish)

■ Figure 17 Ragged pipe-fish

The ragged pipe-fish shown in Figure 17 is classified under the family of Syngnathidae and was sighted at Site 7. The pipefish is classified in same family as the seahorses and sea dragons. Site 7 is located downstream close to the river mouth where the species was found. It is known to be present in temperate and tropical seas across the world. Most species inhabit shallow, coastal waters but few are also known to be present in open ocean conditions near associated sargassum mats.

4.2.3.4. Ambassidae (Flagged-tail Glass Perchlet)

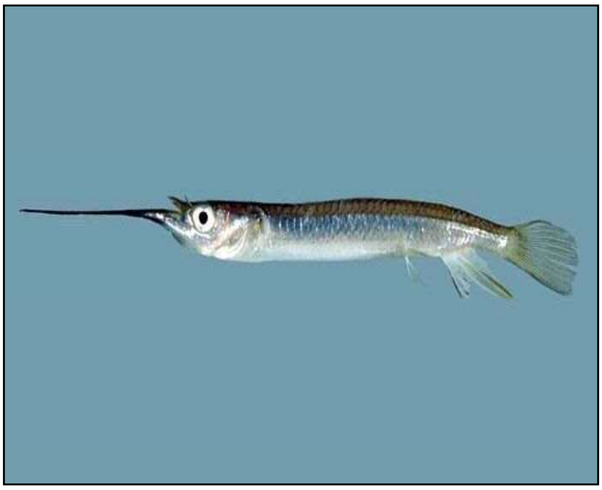
Flagged-tail glass fish shown in Figure 18 was mostly observed populating Site 5 and due to the species wide distribution and lack of any known threats, is considered least of concern. The widespread species can be locally common but not seemed to be abundant.
The species can be found in clear freshwater streams within 20km of the sea and or in the lower reaches of rivers and streams. Its food habitats may depend upon habitat with this species taking more crustaceans and small fish in estuaries than in freshwater where terrestrial insects and their larvae are dominant.

- **Figure 18 Ambassidae *Ambasis miops***

4.2.3.5. Hemiramphidae

Zenarchopterus dispar shown in Figure 19 is a naturally rare species, however it is very widespread and there are currently no known threat acting upon its global population. This is a brackish water species occurring in the lower reaches of Nadi River and ecotone between rivers and estuaries. A number of potential threats to the species include land reclamation, siltation, pollution (pesticide and organic), invasive weeds and fishing.

■ Figure 19 Hemiramphidae



4.2.3.6. Cichlidae

Oreochromis mossambicus (Mozambique Tilapia) and *Oreochromis niloticus* (Nile Tilapia) shown in Figure 20 were both introduced to Fiji's rivers and streams 50 years ago and both were observed to be heavily populating Site 1 to Site 4. Tilapia was generally considered an easy species to culture and a good source of animal proteins for protein-deficient inland communities. Mozambique Tilapia was introduced first and later came the Nile Tilapia with the strain originating from Israel. It was introduced owing to its better growth rate compared to Mozambique Tilapia.

Mozambique Tilapia is threatened by hybridization with the rapidly spreading Nile Tilapia and is being spread by anglers and for aquaculture. Given the rapid spread of Nile Tilapia, it is anticipated that this species will qualify as threatened due to rapid population decline through hybridization. Mozambique Tilapia inhabits all but fast-flowing waters; and thrives in standing waters. It is most common in blind estuaries where it tolerates brackish and marine environments. Their source of food are algae especially diatoms, detritus, large individuals also take insects and other invertebrates.

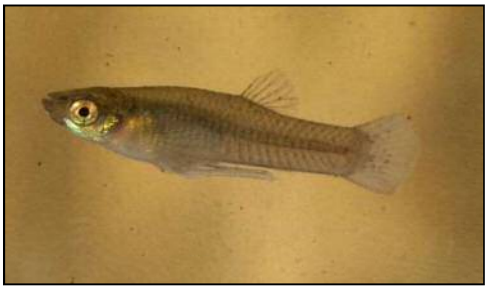
The Nile Tilapia exists in a variety of freshwater and brackish habitats and is a diurnal species. Its preferred temperature is 31-36 degree celcius hence its presence in the Nadi River. It prefers shallow water and is omnivorous. It feeds on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna and detritus.

- **Figure 20 Cichlidae - *Oreochromis mossambicus & Oreochromis niloticus***

4.2.3.7. Poeciliidae

Gambusia affinis or mosquitofish shown in Figure 21 is also another introduced species to Fiji and were found to be highly populating Site 1 to Site 4. It is a widespread and common species with no major threats to the global population. It is a species of freshwater fish and is small in size in comparison to many other freshwater fish. The name "mosquito fish" was given because at times their diets consist of large numbers of mosquito larvae, relative to body size. They typically feed on zooplankton, beetles, mayflies, caddisflies, mites and other invertebrates and mosquito larvae make up only a small portion of their diet.

- **Figure 21 Female and male mosquitofish**



4.2.3.8. Pony fish

Leiognathus equulus shown in Figure 22 is commonly known as Ponyfish. It exists in brackish and marine waters. It is native to Fiji and was found to be present at Site 6 where the site has a mixture of salt and freshwater. It is often found in mangrove areas too. Adults are coastal inhabitants found on soft bottoms and juveniles are commonly found in mangrove estuaries and tidal creeks and sometimes entering the lower reaches of freshwater streams. The species are active by day and they feed on polychaetes, small crustaceans, small fishes and worms. It is also an important food fish in the tropics.

- **Figure 22 Pony fish (*Leiognathus equulus)***

4.2.3.9. Carangidae

Caranx papuensis as shown in Figure 23 is also known as Brassy Trevally and is a native species. It was observed at Site 6 where there is presence of salt water. The species is of a large marine fish classified in the jack family, Carangidae. It grows to a known maximum length of 88cm and can weigh up to at least 6.4kg. It predominantly inhabits both coastal and offshore reefs as well as inshore lagoons, bays and even estuarine waters when juvenile. It is a predatory species and is of great importance to commercial fisheries.

- **Figure 23 Brassy Trevally**

4.2.4. Algae

Filamentous Algae: Due to high proportion of sediments there were not much visible signs of Algae. However the common Filamentous Algae as shown in Figure 24 which are thread-like algae was observed as floating in huge green masses on the water surface.

- **Figure 24 Filamentous Algae**

They form dense mats in stagnant water and can also be found attached to any logs or debris along the river bed. Its filaments consist of series of cells being joined end to end giving a thread-like appearance. This form begins growing on the bottom or substrate and then lifts to the surface as buoyancy grows due to its production of oxygen. This form of algae may seem cottony, slimy, or coarse in texture (refer to Figure 24).

4.2.5. Aquatic Macrophyte

The most common macrophyte observed was *Potamogeton perfoliatus* also known as clasping leaf pondweed as shown in Figure 25. The macrophytes observed were growing largely from Site 4 to Site 7 indicating the presence of freshwater. It is a perennial aquatic plant occurring in both standing and flowing freshwater habitats and does not tolerate drying out. It is the most robust plants which tend to occur >1m water depth. At high nutrient concentrations, it is vulnerable to shading from phytoplankton and epiphytic algae as well as filamentous algae. It can also be found inhabiting brackish or estuarine habitats, however, elevated salt concentration have a negative effect on both growth and flowering. Waterbirds, fish, water beetles and caddis larvae can all be important grazers of perfoliate pond weed, reducing its biomass or even eliminating it locally.

- **Figure 25 Aquatic Macrophyte Present along Nadi River**

5. Discussion

5.1. Overall River Health

The area surveyed within the Nadi River consists mainly of sand, gravel and mud. The landuse on either sides of the river bank were found to be mostly agricultural farms where runoff and erosion easily came from into the receiving environment due to large areas of land clearance and stripping of vegetation close to the river's edge. There are also other activities occurring upstream such as gravel extraction and damming contributing highly to the siltation downstream. Along the surveyed sites downstream from the Navakai Sewerage Treatment Plant and Metromix cement factory, high turbidity and nutrient levels were also recorded.

The riparian vegetation observed was mainly shrubs, grasslands which are not good at filtering sediments from entering the river. Also present along some sites are few large trees that shade parts of the river at certain times of the day. The presence of grassland along the river bank that hangs over the water also provides good habitats for fishes and other freshwater organisms. The river banks throughout the study site increases in width as you go downstream though the river depth varies depending on the water flows, obstructions and river alignment. The recorded velocity and flow rate is normal for a river though in some areas, the river appeared stagnant and dry.

The Nadi River is not a good habitat for most freshwater fish and other living organisms and it is likely that the proposed flood control project within the river will have both positive long and negative impacts on the existing fishes and macro-invertebrates, if not managed appropriately.

5.1.1. Water Quality Physical parameters

The overall quality of water is highly disturbed due to factors such gravel extraction, agricultural farming, animal grazing near river banks, dumping of household waste into the river and most importantly, the Navakai STP discharges and the cement factory wastewater discharge.

5.1.2. Macro-invertebrates

As a result of these unmanaged activities; the river cannot support aquatic life to its full potential. Ecosystem processes have been hindered and thus resulting in loss of biodiversity. Aquatic organisms cannot play their role due to the degraded state of the river. The physical parameters may have produced appropriate results to support life, but the actual counts proved otherwise.

5.1.3. Fisheries

The native fish present were found to be low in abundance and diversity. The entire catchment had only 11 different species and this is approximately 18% from the total species that are found in Fiji. However, the high numbers of species identified to be highly populating Nadi River were the introduced species. The characteristics of the system suites them well.

They can survive in areas with high temperature, low turbidity, low dissolve oxygen as well as stagnant waters.

5.1.4. Algae & Macrophytes

The common algae and macrophyte plant observed during the survey were the common ones which can grow without oxygen. This is a clear indication to the real situation under water. Filamentous algae are the first to survive at any place which shows how resilient they are to any condition.

6. Conclusion

The current status of Nadi River is highly disturbed as indicated by the results of survey throughout the river. This was obvious due to the low counts in species abundance and diversity. The general decline of these rivers is due to poor management of logging, subsistence farming, and human settlement waste and minimal centralized management capacity. Catchment level-management and rehabilitation should be undertaken to restore some of the ecosystem function of these rivers and in turn bring benefit to the near-shore marine areas. Some potential options for assisting in catchment rehabilitation are:

- community-based replanting of riparian trees as buffer zones particularly in mid-catchment areas adjacent to subsistence agriculture and logging areas
- strict enforcement of logging code of practice for buffer zones
- minimize gravel extraction upstream
- village waste and water management plans (e.g. construction of ecological or compost toilets, livestock waste areas, minimize livestock traversing waterways, rainwater harvesting mechanisms for human usage or solar water purification, integrating irrigation with aquaculture of native species (e.g. *Macrobrachium lar.*)
- review of industrial waste discharge policy
- review of the treatment process and performance of the Navakai Treatment Plant to improve the quality of the discharge waste water into the receiving Nadi River

Tilapia introduction in these rivers is not a sound long term economic option as it will only serve to further erode the ecosystem function, most of which are already dominated by invasive species in mid-reaches and depauperate in size and number. Investment in restoration of ecosystem function will enhance productivity naturally and also benefit near-shore reefs. Stocking of native species (e.g. Gudgeons) should be considered as well as integrated irrigation/aquaculture of prawns (Macrobrachium sp.).

With regards to flood mitigation, the proposed project by JICA will help maintain a constant river flow in which the water volume is evenly distributed across the river width as oppose to breaking the banks during long periods of high rain events. The current status of the river proves that due to human activities such as gravel extraction and deforestation upstream causing erosion, the width changes according to the extent of the activity. The river can have 20 meters width on one end; and a few meters down the stream it diminishes in size to 10 meters. This type of river width variation alters the flow that increases flow velocity on narrow waterways. It would be a good idea not only to work on the river banks stabilization but engineers should also design a flow to which the water body reaches the entire width of the river to avoid overtopping and flooding. Only then can flow be controlled and during heavy periods of rain as well as during extreme events or natural disasters, the design of work will help water bodies adapt to the environment surrounding them thus minimizing floods.

7. Reference

1. Allen, G.R. 1991. Field Guide to the Freshwater Fishes of New Guinea. Christensen Research Institute. 268pp
2. Argent and Carline, 2004, Fish assemblage changes in relation to land use disturbance. Aquatic Ecosystem Health & Management, 7(1):101–114
3. Atherton, J.,Olson, D.,Farley L. & I. Qauqau. 2005. Fiji watersheds at risk: watershed assessment for healthy reefs and fisheries. Wildlife Conservation Society.42ppgs
4. Jenkins, A.P., Boseto, D., Mailautoka, K. 2006. Aquatic fauna and water quality of five river catchments in Macuata Province (Vanua Levu, Fiji). Wetlands International – Oceania, Canberra. 21 pgs.
5. Jenkins, A.P., Jenkins, C.L., Reynolds, J.B. 2005. Successes and challenges of managing coral reefs in Papua New Guinea through locally managed marine areas. Proceedings of the 10th International Coral Reef Symposium, Okinawa, Japan. 4: 1524 - 1530.
6. Jenkins, A.P. 2005. A preliminary study of freshwater fauna and water quality of Kubuna River and tributaries with recommendations for conservation action. Wetlands International – Oceania. John Gorton Building, Canberra, ACT 2601. 14 pgs.
7. Jenkins, A.P. and D. Boseto 2003. A preliminary investigation of priority Ichthyofauna and watershed ecosystem services for assessing representation in Fiji's forest reserve network. Report to Wildlife
8. McDowell, R. M. 2004. Ancestry and amphidromy in island freshwater fish faunas. Fish and fisheries. 5, 75-85
9. Russ GR, Alcala AC (1996ª) Marine reserves: rates and patterns of recovery and decline of large predatory fish. *Ecological Applications* 6:947-961.
10. Gore, J.A. and Hamilton, S.W. (1996). Comparison of flow-related habitat evaluations downstream of low-head weirs on small and large fluvial ecosystems. *Regulated Rivers:Research and Management,* 12, 459-469.
11. Comiti, F., Mao, L., Lenzi, M.A. and Siligardi, M. (2009). Artificial steps to stabilize Mountain Rivers: A post-project ecological assessment. *River Research and Application*, 25, 639-659.
12. Gore, J.A. and Hamilton, S.W. (1996). Comparison of flow-related habitat evaluations downstream of low-head weirs on small and large fluvial ecosystems. *Regulated Rivers:Research and Management,* 12, 459-469.
13. Pethebridge, R., Lugg, A., and Harris, J. (1998). Obstructions to fish passage in New South Wales south coast streams. Final Report Series 4, Cooperative Research Centre for Freshwater Ecology and NSW Fisheries, Cronulla, NSW
14. Litvan, M.E., Stewart, T.W., Pierce, C.L. and Larson, C.J. (2008). The effect of grade control structures on the macro invertebrate assemblages of an agriculturally impacted stream. *River Research and Applications*, 24, 218-233

Nadi River Flood Study – Environmental Surveys

The environmental surveys undertaken for the Nadi River Flood Study comprised a terrestrial ecological assessment, a freshwater ecology assessment, water quality assessment and sediment sampling and analysis.

1. Sediment Sampling – Background Information

Sediment sampling was undertaken on Tuesday, 29th September 2015. A total of five (5) sediment samples were collected at specific sites along the Nadi River, within JICA's intended area of work which covers a distance of approximately 25km, from the river mouth to the upper Votualevu area approximately 8km northeast of Nadi town. The five sites are indicated in Figure 1.

The samples were collected and sent via courier to Hills Labs in Hamilton, New Zealand for analyses under the following physical and chemical parameters:

- Organic matter content;
- Dry matter content;
- Ash content;
- Moisture content;
- Total recoverable Manganese (Mn);
- Total recoverable Phosphorous (K);
- pH;
- Nitrites;
- Nitrates
- Heavy metals trace
    - Arsenic (As)
    - Cadmium (Cd)
    - Chromium (Cr)
    - Copper (Cu)
    - Nickel (Ni)
    - Lead (Pb)
    - Zinc (Zn)
    - Mercury (Hg)

JICA Study Team
Planning of the Nadi River Flood Control Structures Project

Environmental Field Survey

TERRESTRIAL ASSESSMENT

- Final Issue
- October 2015

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Contents

Background

The Government of Fiji and Japan have signed a Memorandum of Agreement in late 2014 for the study of the Planning of the Nadi Flood Control Structure Project to address flooding management along the Nadi River catchment area and the Region.

The JICA Study Team will work together with the Ministry of Agriculture namely, the Land and Water Resource Management (LRWM) Division to carry out the study in **3 stages**: 1) Basic Study; 2) Master Plan; and 3) Feasibility Study.

The JICA Study Team has engaged SCOPE Pacific to assist with the basic data gathering and legislative reviews together with identifying the environmental and social considerations required under the EIA Process, examples of recent EIAs, as well as the review of the land acquisition and involuntary resettlement process in Fiji together with any recent case studies.

The basic study stage also requires the examination of all environmental and social considerations whereby initial field environmental assessments are required to be undertaken to evaluatethe effects of the potential flood control measures in order for JICA to prepare an evaluation method.

The environment field assessments that SCOPE was engaged to assist with includes the following:

1) Terrestrial Flora and Fauna Assessment (the subject of this report)
2) Water Quality Sampling and Analysis
3) Freshwater Ecological Assessment
4) Sediment Sampling & Descriptive Assessment of the Sample Sites

Introduction

A terrestrial flora and fauna assessment was undertaken as part of Stage 1 Basic Study. The terrestrial assessment was carried out along the banks of the Nadi River over a five-day period, from 28th November to 2nd October 2015 over approximately 20 kilometres of riverbank, within JICA's intended study area.

The distance of each transect varied according to the type of vegetation and physical terrain observed in each area as well as surrounding land uses with transects covering distances between 279 metres to 3.3 kilometres in total; visual observation, analysis and inventory-taking were carried out within each transect to record the types of vegetation (flora), animals (fauna) and birds (avifauna) present on-site.

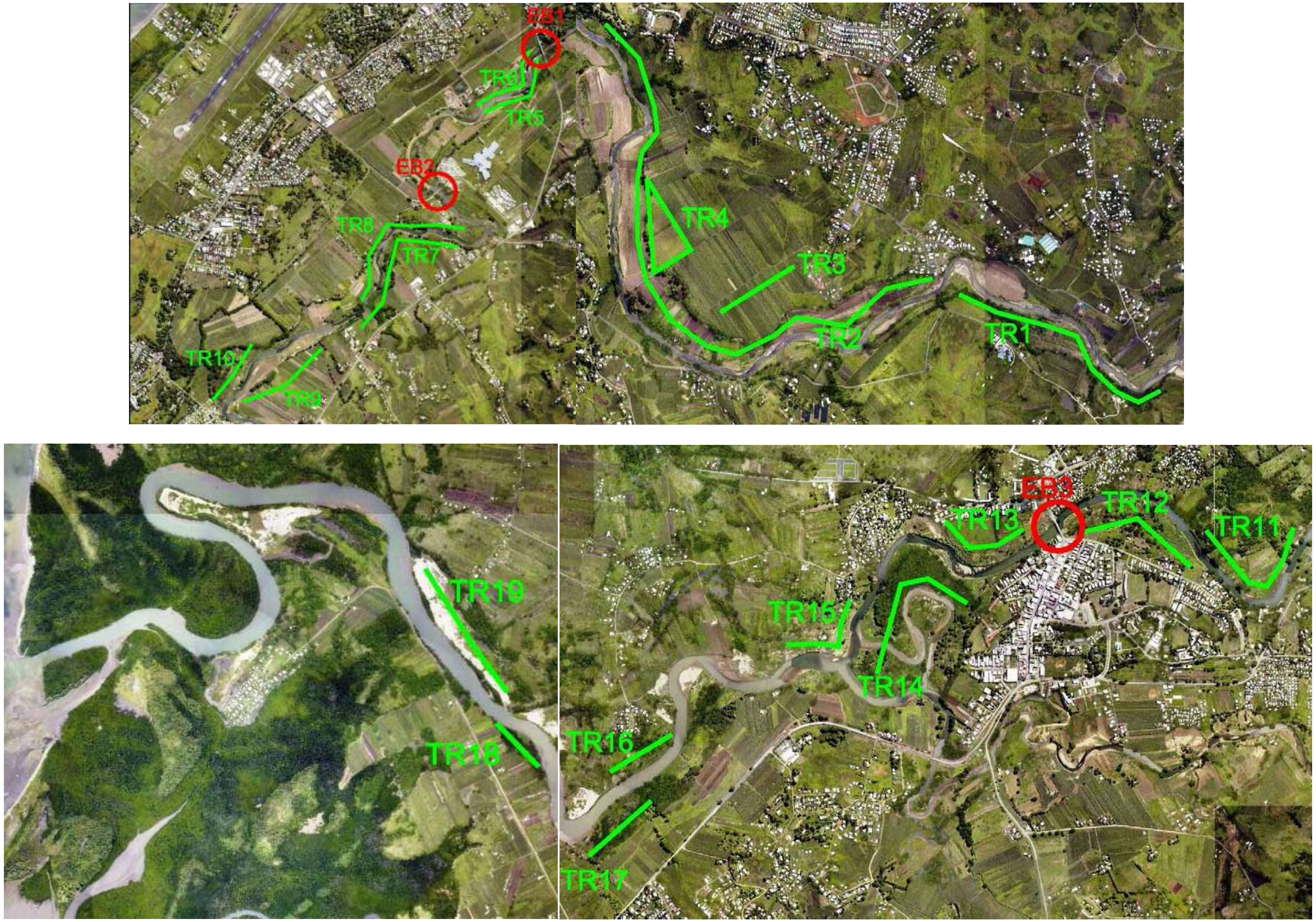
Methodology

The terrestrial ecological assessment was undertaken on differing sides of the Nadi River and aerial photograph was used to randomly identify and select different types of vegetation cover along the Nadi River bank within the study area. A total of 19 transects were plotted andGPS coordinates were taken at the beginning and end of each transect. The 14 transacts are depicted in Figure 1 below.

Methodology for the longest transects (TR 1, 2, 7 & 8) involved plotting 100m and 200m points along eachof these transect recording all vegetation, animals and birds observed at each point.

The methodology adopted for the remaining transects involved walking the entire length of each transect and recording the vegetation, animals and birds observed along the way.

■ **Figure 1 Rough map showing the location of the Transects**



Description of the Existing Environment

Vegetation

Vegetation remained uniform for the most part along both banks of the Nadi River, with certain species present in all transects. Land use within the entire study area comprised of mainly bushland and grassy areas, vegetable and root crop plantations, and sugarcane fields. There were also some residential properties and farms near transect areas.

Tobacco fields were dominant within the upper Votualevu area (TR1 & TR2) as well as in several areas along the Nadi Back Road (TR 5 & TR7). Several tobacco plantation owners that were consulted during the field study in Votualevu explained that their tobacco leaves were collected for processing by British American Tobacco Fiji which has a leaf-processing factory in Votualevu.

The transects along the Nadi Back River (TR6 – TR8) covered areas that were situated next to a local garage, a sand and gravel aggregates supply company (MetroMix Ltd) and ran alongside a local hardware manufacture & supplies company (Vinod Patel) and a primary school (International Primary School). Other transects ran near the villages of Saunaka, Nakavu and Yavusania (TR10, TR11 & TR16) and near Nadi Town (TR 12 – TR14).

Transects further downriver and closest to the river mouth mostly comprised bushland and mangrove areas and were situated next to sugarcane fields (TR 17 – TR19).

- **Table 1 Categories of vegetation and number of species recorded in each category**

Vegetation Type	No. of species recorded
Shrub	43
Food/Fruit	38
Medicine	16
Domestic use	6
Weed	6
Ornamental value	4
Commercial use	2
Timber value	1
Total no of species	**107**

Shrubs and grasses

A total of 43 shrubs and grasses were recorded; majority of the species are aboriginal introductions to the region and are common within woodland areas.

The Castor-oil plant (*Ricinuscommunis*) was the most abundant vegetation species recorded in all transects, particularly in TR1 & TR2 where they grew thick alongside paragrass along the riverbank and inland areas as well. It is native to Africa but is now widely naturalized and cultivated in tropical countries and was first recorded in the Pacific in 1819. Commercial castor oil is extracted from the castor beans and the leaves have medicinal properties as well and are used in indigenous Fijian and Indian remedies.

- **Picture 1 Left – Castor oil plant (*Ricinuscommunis*); Right – Fern (*Leptopterisspp*); Bottom – Fireweed (*Crassocephalumcrepidoides*)**



Paragrass (*Brachiariamutica*) was also abundant and was observed in all transects; thick paragrass fields exist along the riverbanks in the upper Votualevu area and along the stretch of river all along the Nadi Back Road. Thick paragrass areas were also observed on the small island and along the riverbank adjacent to Nadi Town (TR14). Paragrass is an aboriginal introduction that has become naturalized and is common in all areas. Other naturalized grass species observed within the study area include Goose grass (*Eleusineindica*), Jungle rice (*Echinochloacolona*), Feathery pennisetum (*Pennisetumpolystachion*), Henry's crabgrass (*Digitariaciliaris*) and Swollen fingergrass (*Chloris barbata*). The origins of another grass species that was recorded within the study area, Beach wiregrass (*Dactylocteniumaegyptium*) is uncertain; however the species may be native to Fiji.

Other shrubs that were aboriginal introductions and have become naturalized over time include the Coral berry (*Rivinahumilis*), Spiny amaranth (*Amaranthusspinosus*), Prickly solanum (*Solanum torvum*), Ivy gourd (*Cocciniagrandis*), the Black nightshade (*Solanum americanum*), Primrose willow (*Ludwigiaoctovalvis*) and countless others. A complete inventory of the different shrubs, grasses and sedges observed on-site is found within Appendix A.

Edible fruits and plants

A total of 38 species of edible fruits and plants were recorded within the study area; the most abundant of these was the Pawpaw (*Carica papaya*) or **'weleti'**, whether it was grown in plantations or growing wild. Many of the recorded vegetables and some fruits were grown in plantations, as were root crops; however some were found to also grow in the wild. These are outlined in Table 2.

- **Table 2 Cultivated vegetables, fruits and yams (*also growing wildly in some areas)**

Cultivated Vegetables & Fruits		
Local Name	**English Name**	**Scientific Name**
*Weleti	Pawpaw	*Carica papaya*
Tomata	Tomato	*Solanum lycopersicum*
Papukeni	Pumpkin	*Curcubita spp.*
-	Coriander/Dhania	*Coriandrum sativum*
Baigani	Eggplant	*Solanum melongena*
-	Yardlong bean	*Vigna unguiculata* subsp. *sesquipedalis*
-	Zucchini	*Cucurbita pepo var. cylindrica*
Dovu	Sugarcane	*Saccharum officinarum*
Letisi	Lettuce	*Lactuca sativa*
Meleni	Watermelon	*Citrullus lanatus*
-	Capsicum	*Capsicum annuum*
Vudi	Plantain	*Musa sapientum* subsp. *paradisiaca*
Sila nivavalagi	Maize/ Indian Corn	*Zea mays*
Kaveji/Kapeji	Chinese cabbage	*Brassica rapa* subsp. *pekinensis*
Moli	Kumquat	*Citrus japonica*
Painapiu	Pineapple	*Ananas comosus*
*Rokete	Chillies	*Capsicum frutescens*
*Jaina	Banana	*Musa acuminata*
*Bele	Aibika/ Hibiscus manihot/	*Abelmoschus manihot*
*Molikarokaro	Lemon	*Citrus limon*
*Wi	Ambarella/ Golden Apple	*Spondias dulcis*
Cultivated Root Crops		
Local Name	**English Name**	**Scientific Name**
Dalo	Taro	*Colocasia esculenta*
Kumala	Sweet potato	*Ipomoea batatas*
Tavioka	Cassava	*Manihot esculenta*
Uvi	Yam	*Dioscorea alata*
*Via	Giant swamp taro	*Cyrtosperma chamissonis*

- **Picture 2 Top left – Zucchini; Top right – Cassava plantation; Bottom left – Yam plantation; Bottom right – Eggplant plantation**

Some fruit species and edible plants were found growing only in the wild; these are outlined in Table 3.

- **Table 3 Fruits and edible plants growing wild**

Cultivated Vegetables & Fruits		
Local Name	**English Name**	**Scientific Name**
Quwawa	Guava	*Psidiumguajava*
Ivi	Tahitian chestnut	*Inocarpusfagifer/ Inocarpus edulis*
-	Bitter gourd	*Momordicacharantia*
Maqo	Mango	*Mangiferaindica*
Tamarini	Tamarind	*Tamarindusindica*
Niu	Coconut	*Cocos nucifera*
-	Curry tree	*Murrayakoenigii*
Molibatiri	Wild orange	*Citrus macroptera*
Uto	Breadfruit	*Artocarpusaltilis*
Boronidia	Horse-radish tree/ Moringa	*Moringaoleifera*
Kavika	Malay apple	*Syzygiummalaccense*

A complete inventory of the different fruits, vegetables and root crops observed on-site is found within

Appendix A.

Medicinal Trees & Plants

Many of the shrubs and herbs and some ornamental plants and trees observed have high medicinal value for local communities. A total of 16 medicinal species were identified; these included the Noni or Indian Mulberry (*Morindacitrifolia*), known locally as '**kura**', the Snake Plant (*Sansevieriatrifasciata*) or '**yame-ni-laione**', the Mile-a-minute vine (*Mikaniamicrantha*) or '**wabosucu**', the Copperleaf (*Acalypha wilkesiana*) or '**kalabucidamu**', Nodeweed (*Synedrellanodiflora*) or '**sugusuguvanua**' and the Wild Cape-gooseberry (*Physalisangulata*) or '**tukitukiyadre**'.

The Noni, or '**kura**' as it is locally known, is a native species that has is used to treat numerous sicknesses and ailments including joint pain and swelling, backaches, headaches, muscle pain, arthritis, sprains and strokes. It is also used as a general elixir and poultice to treat skin infections and inflammation, and the fruit juice has become a major export for the South Pacific region to Europe and North America; in addition, secondary products such as shampoos, soaps, skin creams, herbal tea and tablets have been manufactured and marketed (Pande et al., 2005). Local communities also utilize the bark and roots of the Noni tree as natural dyes.

The leaves of the Mile-a-minute creeper vine (**wabosucu**) are rubbed on to cuts and wounds to staunch bleeding, the leaves of the Snake Plant (**yame-ni-laione**) are used to treat ear-aches, the leaves of the Nodeweed (**sugusuguvanua**) are used to treat haemorrhoids and diarrhoea and as a poultice to heal wounds.

The leaves of the Copperleaf (**kalabucidamu**) are used to treat gastric problems while the leaves of the Wild Cape Gooseberry (**tukitukiyadre**) are used to treat illnesses associated with coldness.

A complete inventory of the many plants of medicinal value found at all sites is found within Appendix A.

Timber Trees and Plants of Important Domestic Use

- **Picture 3 Left – Line of Raintrees; Right – Bamboo growing along riverbank**


The only tree of timber value observed within the study area was the Raintree (*Samaneasaman*) or '**vaivai-ni-vavalagi**', which was the dominant tree species in the upper Votualevu area (TR2) and was recorded in every transect. The Raintree is an introduced species whose wood can be used in timber production and whose fruit is edible.

Screwpine (**balawa**) plays an important role within Fijian society because its leaves are used to weave mats that can be found in all Fijian households, as well as thatches, sails, baskets, hats, etc. Mats also play an important role in Fijians' traditional structure because they are commonly presented as gifts during weddings, funerals, farewell ceremonies, and all other Fijian social ceremonies. In addition the edible fruit and prop roots are a source of food and native medicines in various parts of the Pacific.

Bamboo (**bitu**) wood is commonly used to make water rafts and is also used as water containers and fishing poles. It is also used by the people of the Naitasiri province of Viti Levu as a type of cooking vessel or 'pot' for cooking a Fijian dish that utilizes Taro leaves (**rourou**).

The fruit of the Fish-poison tree (**vutu-gaga**) is commonly used by *iTaukei* fishermen as a natural fish poison during fishing activities as the fruit releases a toxin that stuns the fish.
Mangroves (**tiri** and **dogo**) are vital in coastal areas as they protect shorelines from the eroding activities of waves and from potential damage to coastal areas during storm surges and high wave events. In addition, they are vital nurseries and breeding grounds for many important fish species as well as invertebrates and other aquatic organisms. Mangrove wood is also used by local communities for firewood, and the bark of the Red Mangrove (**tiri**) is used by local women to produce the brown dye used in printing tapa.
Wild tamarind (*Leucaenaleucocephala*) is an introduced species that has become naturalized over time; its wood is used as firewood by local communities.

Pests and Invasive Species

A total of 6 species that are considered pests and invasive species were recorded within the study area; these included the African tulip (*Spathodeacampanulata*), Swamp apple (*Annona glabra*) or '**uto-ni-bulumakau**', Cocklebur (*Xanthium strumarium*), Wild passionfruit (*Passiflorafoetida*), Koster's curse (*Clidemiahirta*) or '**sovusovu**', and Sensitive grass (*Mimosa pudica*) or '**co gadrogadro**'.
The African Tulip is an introduced species that has very quickly become an invasive pest and noxious weed in many of the forested areas of Viti Levu. The flowers of the African Tulip attract fruit bats and various birds. The African tulip was recorded in 10 of the 19 transects.

- **Picture 4 Left – Swamp apple (*Annona glabra*); Right – Cocklebur (*Xanthium strumarium*)**

The Koster's curse plant (**sovusovu**) is also an introduced, invasive species that has become a serious pest in native forest areas.

Ornamental Plants & Flowers

Ornamental trees, plants and flowers were also observed within the study area; a total of 4 species were recorded within transect areas which is not surprising considering the main land uses along the Nadi River banks were agricultural use and some areas remained as bush land and grassland.
The recorded species comprised the Snake Plant (*Sansevieriatrifasciata*) or '**yame-ni-laione**', Royal palm (*Roystonearegia*), Marigold (*Calendula officinalis*) and Bouganvillea (*Bougainvillea spectabilis*), all of which are introduced species.

▪ **Picture 5 Royal palm (*Roystonearegia*)**

Plants of Important Commercial Value

Plants of important commercial value that were recorded within the study area were the Tobacco plant (*Nicotianatabacum*) or '**tavako**' and Sugarcane (*Saccharumofficinarum*) or '**dovu**'.

Vast fields of tobacco were recorded within the Votualevu area (TR1 – TR2) and smaller fields were recorded along the stretch of river within the Nadi Back Road. As mentioned earlier, tobacco field growers sell their bales of tobacco to British American Tobacco Fiji which has a leaf-processing plant in Votualevu; the tobacco company picks up the bales of tobacco directly from the farms and transports them to the leaf-processing plant.

▪ **Picture 6 Tobacco field (left) and sugarcane field (right)**

Large-scale sugarcane production is common in the western region of Viti Levu where Nadi is located and it is one of the oldest and most vital primary industries in Fiji. The stem of the sugarcane is commercially processed for the production of brown sugar which is a major export commodity of the Fiji economy and which is also sold locally.

Local edible vegetables also observed in market gardens are also considered to have some commercial value in the local market for local consumption and may even have some export market values that will need to be further investigated as part of the social consultation process.

A complete inventory of the types of vegetation found on-site as well as their uses is attached as Appendix A.

Fauna and Avifauna

Animals and insects (fauna) observed in their natural habitats within the study area comprised five (5) species of animals, fourteen (14) species of insects including seven (7) species of butterflies, and twelve (12) species of birds.

Animals and Insects

Animals recorded comprised locally common species including the Horse (*Equusferuscaballus*) or **'ose'**, Cow (*Bostaurus*) or **'bulumakau'**, Pig (*Sus scrofadomesticus*) or **'vuaka'**, Goat (*Capra aegagrushircus*) or **'me'**, and the Small Indian Mongoose (*Herpestesjavanicus*) or **'manivusi/manipusi'**. All are introduced species; horses, cows, pigs and goats have become important domestic farm animals while the Mongoose is considered a pest due to its destructive predation of native birds, animals and insects.
Insects included the Skink (*Emoiaspp.*) or **'moko'**, Millipede (*Diplopoda*) or **'oliva'**, Red dragonfly (*Diplacodesbipunctata*), Wasp (*Polistesolivaceus*) or **'pi'**, Honeybee (*Apismellifera*) or **'oni'**, Bluebottle fly (*Calliphoravomitoria*) or **'lago'**, the Ladybug (*Coccinellidae*), and seven (7) species of butterfly which are outlined in
Table 4. The skink and the Red dragonfly are native to Fiji.
Of the seven recorded species of butterflies, four species are endemic to Fiji – the Common Crow, Blue Moon, Common Fijian Ringlet, and Capper White.

- **Table 4 Butterflies recorded within the study area along the Nadi River**

Butterflies		
English Name	**Scientific Name**	**Status**
Common Blue	*Zizinaotis*	Introduced, naturalized, common
Small Grass Yellow	*Euremabrigittaaustralis*	Introduced, naturalized, common
Common Crow	*Euploealewinii sub.*	Endemic
Blue Moon	*Hypolimnasbolina sub. pallescens*	Endemic
Common Fijian Ringlet	*Xoissesara*	Endemic
Capper White	*Belenois java sub. clarissa*	Endemic
Monarch	*Danausplexippus*	Common

- **Picture 7 Left – Blue Moon butterfly (*Hypolimnasbolina sub. Pallescens*); Right – Bluebottle fly (*Calliphoravomitoria*)**


Birds

Twelve species of birds were recorded within the study area; of these, one (1) species is endemic to Fiji and four (4) species are native to Fiji. Details of these species are highlighted below Table 5.

Table 5 Birds recorded within the study area along the Nadi River

Local Name	English Name	Scientific Name	Status
Maina	Common Mynah	*Acridotherestristis*	Introduced
Mainaloa	Jungle Mynah	*Acridotheresfuscus*	Introduced
Ulurua/ Uluribi	Red-vented Bulbul	*Pycnonotuscafer*	Introduced
Levecagi	Fiji Woodswallow	*Artamus mentalis*	Endemic
Ruve	Feral Pigeon	*Columba livia*	Introduced
Matayalo	Vanikoro Broadbill	*Myiagravanikorensis*	Native
Qiqi	Silvereye	*Zosteropslateralis*	Introduced
Siti	Red Avadavat	*Amandavaamandava*	Introduced
Seasea	Polynesian Triller	*Lalage maculosapumila*	Native
Kukuru	Spotted Dove	*Streptopeliachinensis*	Introduced; In the region, found only in Fiji
Belo	Eastern Reef Heron	*Egretta sacra*	Native
ManumanuniDoa	Pacific Swallow	*Hirundotahitica*	Native

The Fiji Woodswallow is common in open habitats, particularly on the drier western sides of the larger islands. It was recorded within the open habitats in the upper Votualevu area. The Fiji Woodswallow is insectivorous and catches large insects on the wing or pounces on them from the air. This species is considered endemic in Fiji.

The Vanikoro Broadbill is considered a regionally near-endemic species. It is a native species that has adapted to man-modified habitats and is distributed from montane forests to mangroves. It feeds on insects and is an avid 'leaf-snatching fly-catcher' that is able to take insects from the underside of leaves on short aerial sallies. The Vanikoro Broadbill also persistently harasses predatory bird species that enter the vicinity of its nest.

The Polynesian Triller is widespread throughout the region and several other Pacific island countries. It is a conspicuously noisy bird that feeds on insects and fruit and is common in most areas, although it is more likely to be found in immature secondary habitats.

The Eastern Reef Heron is a common species in Fiji and the region. It is found in any aquatic habitat from an exposed reef to a small inland stream in thick forest. The heron's diet comprises fish, crustacean and molluscs, and sometimes also includes insects and lizards.

Pacific Swallow is found throughout Fiji and is an aerial feeder of flying insects and is commonly found in coastal and estuarine habitats, as well as along rivers inland.

A complete inventory of the types of animals, insects and birds found on-site is attached as Appendix B.

References

1. https://www.spc.int/phs/pphsn/Publications/PHDSurveillance/Surveillance-pages85-93.pdf [accessed 28 October 2015]

2. https://books.google.com.fj/books?id=jxvMfprugfAC&pg=PA328&lpg=PA328&dq=Synedrella+nodiflora+fijian+name&source=bl&ots=KEfPJAYylx&sig=3qS29tId5jPpYsQ0N23VtkJ-T5s&hl=en&sa=X&redir_esc=y#v=onepage&q=Synedrella%20nodiflora%20fijian%20name&f=false

[accessed 28 October 2015]

3. Patrick, B. & Patrick, H. 2012. *Butterflies of the South Pacific*. Otago University Press. Dunedin, New Zealand.

4. Watling, D. 2004. *A Guide to the Birds of Fiji & Western Polynesia*. Environment Consultants (Fiji) Ltd.

5. Whistler, W. 1994. *Wayside Plants of the Islands – A Guide to the Lowland Flora of the Pacific Islands*. Everbest Printing Company Ltd. Hong Kong.

6. Marinov, M. & Waqa-Sakiti, H. 2013. *An Illustrated Guide to Dragonflies of Viti Levu, Fiji*. USP Press. Suva, Fiji.

SCoPE PACIFIC LIMITED
STRATEGIC CONSULTANTS IN PLANNING & ENGINEERING

JICA Study Team
Planning of the Nadi River Flood Control Structures Project

Additional Environmental Field Survey – Malakua & Nawaka Rivers

WATER QUALITY ASSESSMENT

Final Issue
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Environmental Field Survey

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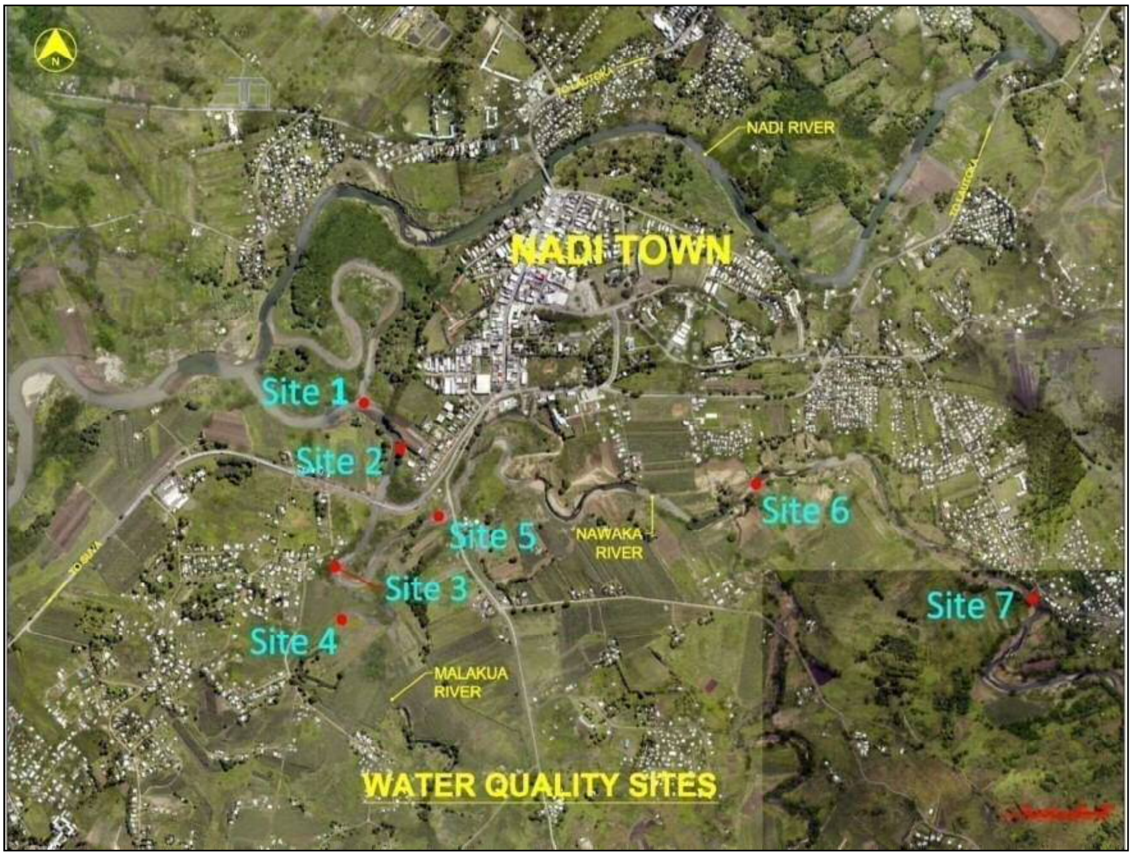
▪ Figure 1 Location of River Water Quality Sampling Points at Malakua & Nawaka River



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A Horiba Multimeter was also used on site for measuring the physical parameters. For chemical analysis, water samples were collected in plastic bottles and once collected; they were placed in an ice chilled esky to the appropriate temperature and were transported by air to the laboratory within the 24 hour timeframe. Analysis of the samples was conducted by the Chemical Laboratory of the Institute of Applied Science (IAS) at the University of the South Pacific in Suva.

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It should be noted that the water quality results analysed and shown below are a result of a 'one-off water quality sampling' event. Therefore, the results obtained will only reflect the river quality during the sampling event and could differ in other weather conditions or times of the day and year.

The water quality guidelines used in this report for comparison of data are designed to help users assess whether the quality of surface water resource is good enough for human use, food production or for an aquatic ecosystem. It is also necessary to ensure the protection of waters used for recreational activities such as swimming and boating and to preserve the aesthetic appeal of water bodies.

The Australia and New Zealand Conservation Council provide comprehensive guidelines on water quality (ANZECC 2000 & 1999) guidelines which have been applied to the results displayed in the **Table 1**. The values outlined in the National Liquid Waste Standards of Schedule 3 (Concentration standards for significant/general ecological zone) under the Environment Management (Waste Disposal & Recycling)

Regulations (2007) were also used. Levels identified to be above these values may lead to adverse effects on the aquatic ecosystem.

2.2. Water Quality Analysis of Results

Results outlined in **Table 1** indicate that for Malakua and Nawaka River, the physical parameters such as temperature, pH, salinity, dissolved oxygen and total dissolved solids are within the appropriate guidelines[1] as recognized by the Department of Environment with the exception of turbidity and conductivity levels which exceeds the recommended values. It should be noted that water sampling was undertaken the week after Tropical Cyclone Winston and hence significant changes in the parameters value is expected.

Temperature is one of the most important characteristics of an aquatic system affecting dissolved oxygen levels, chemical and biological processes, and specific composition of the aquatic ecosystem, water density and stratification and environmental cues for life-history stages for aquatic organisms. The river water temperatures at all sites were measured at an average of 27°C.

Water temperature fluctuates between day and night and over longer periods of time and varies along the length of a river with latitude and elevation, however can also vary between small sections only meters apart depending on local conditions. At a higher temperature, plants grow and die faster, leaving behind matter that requires oxygen for decomposition. Some plants and animals become dormant if water temperatures drop very low but will grow extremely quickly in warmer waters. Shade is important to the health of water body as it reduces warming effect of direct sunlight which is only provided in some areas along the two rivers where there are big rain trees but otherwise lacks shade as most river banks are lined with para grass and plantations which do not provide any shade at all. Human activities also affect water temperature in many ways and quite often, waste discharged into receiving environments like rivers and streams increases temperature which affect fish and bugs.

- **Table 1 Malakua & Nawaka River Water Quality Analysis Result**

Water Quality Parameters	Unit	1	2	3	4	5	6	7	Guidelines
Temperature	°C	27.21	26.58	27.39	26.34	28.02	27.23	27.21	15-35*
pH	unit	8.32	8.33	8.4	8.17	8.11	8.2	8.34	6.0-9.0*
Salinity	ppt	0.1	0.1	0.1	0.1	0	0	0	0.0128-0.16*
Dissolved Oxygen	mg/L	7.89	8.15	7.83	8.76	8.83	9.55	9.27	<6*
Turbidity	NTU	16	15.5	17	7.4	25.9	9.9	6.6	2-15*
Conductivity	mS/cm	0.354	0.356	0.288	0.29	0.196	0.164	0.157	0.02-0.25*
Total Dissolved	mg/L	0.23	0.232	0.187	0.188	0.127	0.107	0.102	1000**

[1] Guidelines: ANZECC, 2000, National Liquid Concentration Standards and Schedule 3,Environmental Management (Waste Disposal & Recycling Regulations)

Water Quality Parameters	Unit	1	2	3	4	5	6	7	Guidelines
Solids									
Total Suspended Solids	mg/L	11	10	24	6	16	19	<1	30**
Total Phosphorus	mg/L	0.05	0.04	0.05	0.03	0.05	<0.013	<0.013	0.01-0.1*
Nitrate	mg/L	0.82	0.83	0.93	0.51	1.05	0.85	0.47	0.15*
BOD	mg/L	<18	<18	<18	<18	<18	<18	<18	40**
COD	mg/L	28	<28	<28	<28	<28	<28	<28	

*ANZECC (1992 & 2000) guidelines for Upland River. Levels above these values may lead to adverse effects on the ecosystem
** Concentration Standard for General Ecological Zone, National Liquid Waste Standards, Schedule 3, Waste Disposal & Recycling Regulations (2007)
a – Guideline for recreational water quality and aesthetics (ANZECC 2000)

Dissolved Oxygen (DO) levels at all sites were within the ANZECC's recommended guidelines of <6 mg/L with levels ranging between 7.83-9.55 mg/L. The higher levels are an indication of an adequate supply of oxygen present in the river. This gas is essential for the survival of aquatic organisms including fish, invertebrates, bacteria and plants. Aquatic organisms use oxygen in respiration, similar to organisms found on land, or terrestrial organisms. The atmosphere is a major source of dissolved oxygen in river water. Waves and tumbling water mixes atmospheric oxygen with the river water and it is also produced by rooted aquatic plants and algae as a product of photosynthesis. Most healthy water bodies generally record high levels of DO; however certain water bodies naturally have lower levels of DO. A deficiency in this area is a sign of an unhealthy river with variety of factors affecting levels of dissolved oxygen.

A stable measuring tool used in analyzing the acidity or alkalinity of any surface water is pH. It responds to changes in dissolved carbon dioxide (CO2) concentrations, alkalinity and in a small way to temperature. ANZECC guidelines state that the pH of river should fall within pH 6.0 – 9.0 and sample results indicate that the pH level at all seven sites were well within the recommended guidelines. The water pH determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. The greatest natural cause for change in pH in surface water is seasonal and daily variation in photosynthesis.

Respiration and decomposition process lowers the pH levels. For this reason, pH is higher during daylight hours and during the growing season when photosynthesis is at its peak. The more common concern in pH changes is caused by discharge of municipal or industrial effluents. Small changes in pH can have many indirect impacts on surface water. Polluted conditions typically correspond with increased photosynthesis in surface water; pollution may cause a long-term increase in pH.

Dissolved solids at all sites were within the recommended value indicating that there are less minerals dissolved in water at the time of sampling. Dissolved solids are not necessary for life however as they are a mixture of different compounds. The content of these minerals in the water is required to remain constant for aquatic animals to survive, and therefore it is not good for total dissolved solids in water to fluctuate.

Dissolved solids connect to hardness of water which is a measure of mineral content in the water. These minerals that are most often dissolved solids are calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates. Total dissolved solids come from a variety of places such as rock bits which are dissolved in water, others comes from rain water run-off, leaves, silt which is evident along the Malakua & Nawaka River. Chemicals from untreated sewage particularly domestic untreated sewage from houses situated along the river, pesticides and road salts and/or fertilizers can also be dissolved in water resulting in water-body contaminations. If the dissolved solids level in the river drops this means it would have a lower hardness and maybe good for drinking water or recreational activity provided that the faecal coliform count is low. Unfortunately, faecal coliform was not one of the parameters required to be tested by JICA.

Conductivity is one way to measure the amount of substances like calcium, bicarbonate, nitrogen, phosphorus, iron or sulphur dissolved in water. Raised levels of dissolved minerals affect how suitable surface water is in protecting ecosystems. Most rivers and streams have a fairly constant range of conductivity under normal circumstances. Significant changes in value can indicate that a discharge or some other source of pollution has entered the water.

Four of the seven sites are situated downstream of Malakua and Nawaka River and may have some tidal influence which has contributed to the increased in conductivity and salinity levels.

Higher conductivity levels also indicate the presence of clay soils which tends to increase the conductivity due to the existence of materials that ionize when washed into the water. Discharges to streams can also change the conductivity levels depending on the discharge make-up. Other causes would be by the changes in the geology of an area, seepage of groundwater, stormwater runoff, etc. The value of conductivity can vary significantly. Values are normally lowest during high river flows and conductivity increases as river flows decrease. An extreme amount of conductivity may occur during periods of drought. Conductivity outside of the acceptable range could indicate that the water is not suitable for certain species of fish and macro-invertebrates.

There were some levels of salt content from Site 1 to Site 4 indicating that the seawater along Nadi River travels as far up as Site 4. From Site 5 to Site 7 is entirely fresh-water with no significant level of salt content as indicated from the results obtained. It is also natural for rivers to contain a certain amount of salt. In low salinity rivers, there is a much greater diversity of species, with each site having a different set of species, but as salinity increases the number of species at a site decreases. High levels of salinity affect freshwater invertebrates and these invertebrates play a significant role in recycling terrestrial vegetation like leaves that fall into streams and providing food for fish and birds.

Turbidity is the reduction of clarity in water due to the presence of suspended particles and is measured by the amount of light which is reflected by the particles. Turbidity in water is caused by suspended matter such as clay, silt and organic matter that interferes with the passage light through water. It is closely related to total suspended solids but also includes plankton and other organisms.

The level of turbidity at Site 1, Site 2, Site 3 and Site 5 were above the recommended guideline value with Site 5 recording the highest of 25.9 NTU.

Figure 3 Evidence of High Turbidity and Floating Debri Along Nadi River

Throughout the sampled area, it was established that downstream of the two rivers are the most turbid area. The high turbidity downstream is mainly due to vegetation clearing for agriculture purposes as well as soil erosion along the river banks. From Site 5 and above the Nawaka Bridge, there seems to be slightly better clarity in the water as there was a significant sign of good water flow with fishes and other invertebrate present.

The levels of suspended solids at all sites of the river are within the guideline. Suspended solids in a body of water are often due to natural causes. These natural solids include organic materials such as algae and inorganic materials such as silt and sediment. Inorganic materials can easily become suspended due to runoff, erosion, etc. However, when suspended solids exceed the expected concentrations, they negatively impact a water body. As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. It can also destroy fish habitat because suspended solids tend to settle to the bottom and can eventually blanket the river bed.

Pollution also contributes to either organic or inorganic depending on the source. During river sampling, the cause of suspended solids to name a few are due to agricultural land runoff during rainy weather, soil erosion along river bank, vegetation clearing too close to the river bank for farming, etc. Animals such as cows and horses are tied close to the river bank to graze as well as bathing of animals. Cow and horse dung was found close to the river which also contributes to the rise in suspended solids.

Figure 4 Animals Use the River for Drinking & Bathing

Phosphorus is a nutrient used by organisms for growth and it occurs in natural water and wastewater bound to oxygen to form phosphate. Under natural conditions phosphorus is typically scarce in water but along the Malakua and Nawaka River, the levels of total phosphorus at all sites appear to be within the recommended value. Phosphorus comes from a variety of sources including agricultural fertilizers, domestic wastewater, detergents, industrial process wastes and geological formations. However, the relatively low concentration is enough to limit the growth of algae and/or aquatic plants but ought to be monitored.

Nitrate is an essential nutrient for aquatic plants and animals and is the form in which plants utilize nitrogen, therefore can have a great influence on the amount of plant growth in water. Along the Malakua and Nawaka River, the levels of nitrate at all sites were higher than the recommended value. This is an indication of runoff from fertilized lawns and croplands, domestic waste discharges, etc. The Nawaka River upstream is widely used for a mixture of activities by human and animals for instance, washing of clothes, swimming, fishing and diving for sustainable living, animal bathing and drinking as well. These activities have greatly impacted the river through the increase levels of nutrients such phosphorus and nitrates.

Nitrates are a form of nitrogen which is found in several different forms in terrestrial and aquatic ecosystems. It is an essential plant nutrient, but in excessive amounts can cause significant water quality problems. Along with phosphorus, nitrates in excessive amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn affects dissolved oxygen, temperature and other indicators. Again these levels need to be monitored.

The level of Biological Oxygen Demand (BOD) in the river is below the guideline value; however the values obtained are above 10mg/L but less than 20mg/L suggesting that there are low levels of organic waste with fewer bacteria present. With low BOD, dissolved oxygen levels will be high.

Biological Oxygen Demand (BOD) is performed to measure the potential of wastewater and other waters to deplete the oxygen level of receiving waters. In other words, BOD test is undertaken to determine what effect dirty water, containing bacteria and organic materials will have on animal and plant life when released into a stream. When there is an abundance of bacteria and organic materials, the bacteria will take in oxygen in order to breakdown these molecules, if bacteria are taking in large amounts of oxygen, this will have detrimental effect on the surrounding ecosystem.

The Chemical Oxygen Demand (COD) analysis is commonly used to indirectly measure the amount of organic compounds in water. Most application of COD determines the amount of organic pollutants found in surface water such as rivers or wastewater, making COD a useful measure of water quality. According to the river surface water results, the level of COD at all sites were found to have a constant mass of oxygen of less than 28mg/L throughout the river of Malakua and Nawaka indicating that there is activity of oxygen being consumed by organic compounds.

Overall, the Malakua and Nawaka River is considered to be greatly disturbed due to a number of factors such as activities carried out by human and animals on the river and these include land clearances for agricultural purposes close to the rivers edge causing river bank erosion, the disposal of household and industrial waste into the river, large amount of debris, rotting wood and vegetation, animal grazing close to river banks, bathing of animals in river, and the washing of clothes, etc.

A copy of the water quality results from the IAS is attached to this report as Appendix A.

Appendix A Water Quality Analysis Report – IAS Lab

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Additional Environmental Field Survey – Malakua & Nawaka Rivers

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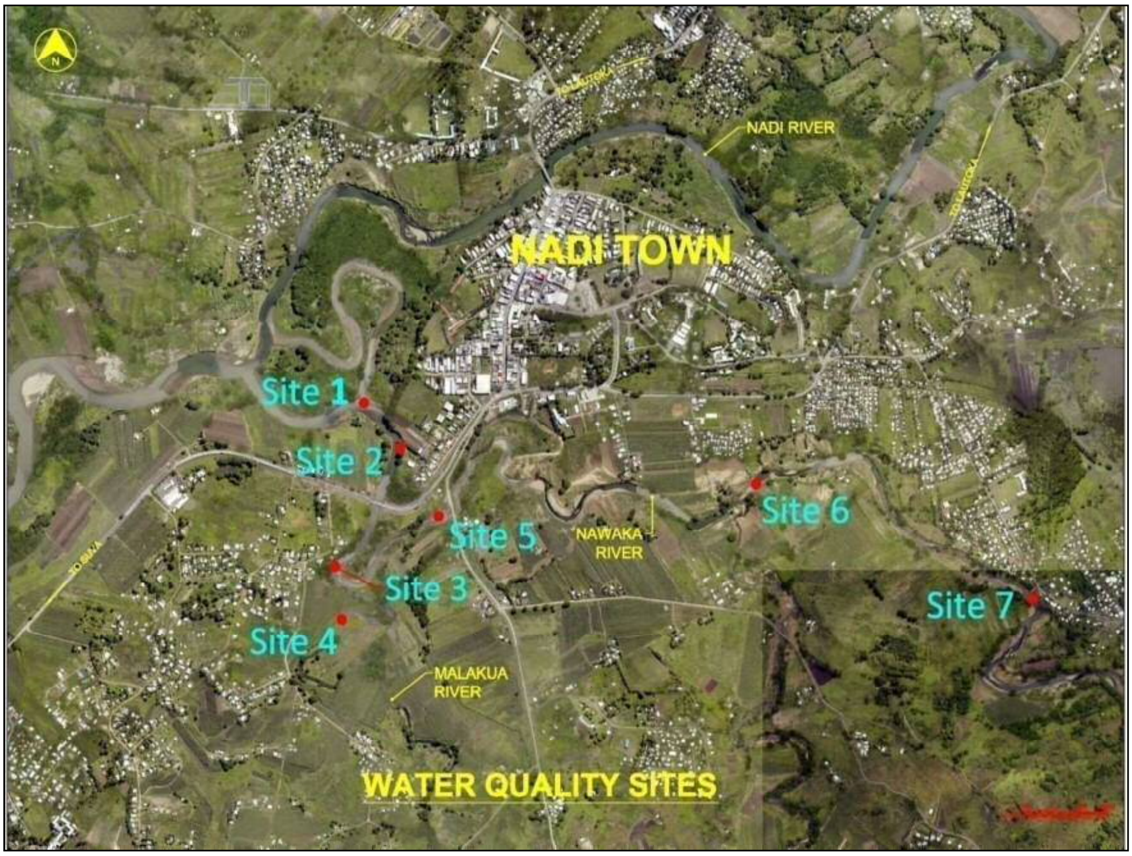

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Salinity	ppt	0.1	0.1	0.1	0.1	0	0	0	0.0128-0.16*
Dissolved Oxygen	mg/L	7.89	8.15	7.83	8.76	8.83	9.55	9.27	<6*
Turbidity	NTU	16	15.5	17	7.4	25.9	9.9	6.6	2-15*
Conductivity	mS/cm	0.354	0.356	0.288	0.29	0.196	0.164	0.157	0.02-0.25*
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a – Guideline for recreational water quality and aesthetics (ANZECC 2000)

Dissolved Oxygen (DO) levels at all sites were within the ANZECC's recommended guidelines of <6 mg/L with levels ranging between 7.83-9.55 mg/L. The higher levels are an indication of an adequate supply of oxygen present in the river. This gas is essential for the survival of aquatic organisms including fish, invertebrates, bacteria and plants. Aquatic organisms use oxygen in respiration, similar to organisms found on land, or terrestrial organisms. The atmosphere is a major source of dissolved oxygen in river water. Waves and tumbling water mixes atmospheric oxygen with the river water and it is also produced by rooted aquatic plants and algae as a product of photosynthesis. Most healthy water bodies generally record high levels of DO; however certain water bodies naturally have lower levels of DO. A deficiency in this area is a sign of an unhealthy river with variety of factors affecting levels of dissolved oxygen.

A stable measuring tool used in analyzing the acidity or alkalinity of any surface water is pH. It responds to changes in dissolved carbon dioxide (CO2) concentrations, alkalinity and in a small way to temperature. ANZECC guidelines state that the pH of river should fall within pH6.0 – 9.0 and sample results indicate that the pH level at all seven sites were well within the recommended guidelines. The water pH determines the solubility and biological availability of chemical constituents such as nutrients and heavy metals. The greatest natural cause for change in pH in surface water is seasonal and daily variation in photosynthesis.

Respiration and decomposition process lowers the pH levels. For this reason, pH is higher during daylight hours and during the growing season when photosynthesis is at its peak. The more common concern in pH changes is caused by discharge of municipal or industrial effluents. Small changes in pH can have many indirect impacts on surface water. Polluted conditions typically correspond with increased photosynthesis in surface water; pollution may cause a long-term increase in pH.

Dissolved solids at all sites were within the recommended value indicating that there are less minerals dissolved in water at the time of sampling. Dissolved solids are not necessary for life however as they are a mixture of different compounds. The content of these minerals in the water is required to remain constant for aquatic animals to survive, and therefore it is not good for total dissolved solids in water to fluctuate.

Dissolved solids connect to hardness of water which is a measure of mineral content in the water. These minerals that are most often dissolved solids are calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates. Total dissolved solids come from a variety of places such as rock bits which are dissolved in water, others comes from rain water run-off, leaves, silt which is evident along the Malakua & Nawaka River. Chemicals from untreated sewage particularly domestic untreated sewage from houses situated along the river, pesticides and road salts and/or fertilizers can also be dissolved in water resulting in water-body contaminations. If the dissolved solids level in the river drops this means it would have a lower hardness and maybe good for drinking water or recreational activity provided that the faecal coliform count is low. Unfortunately, faecal coliform was not one of the parameters required to be tested by JICA.

Conductivity is one way to measure the amount of substances like calcium, bicarbonate, nitrogen, phosphorus, iron or sulphur dissolved in water. Raised levels of dissolved minerals affect how suitable surface water is in protecting ecosystems. Most rivers and streams have a fairly constant range of conductivity under normal circumstances. Significant changes in value can indicate that a discharge or some other source of pollution has entered the water.

Four of the seven sites are situated downstream of Malakua and Nawaka River and may have some tidal influence which has contributed to the increased in conductivity and salinity levels.

Higher conductivity levels also indicate the presence of clay soils which tends to increase the conductivity due to the existence of materials that ionize when washed into the water. Discharges to streams can also change the conductivity levels depending on the discharge make-up. Other causes would be by the changes in the geology of an area, seepage of groundwater, stormwater runoff, etc. The value of conductivity can vary significantly. Values are normally lowest during high river flows and conductivity increases as river flows decrease. An extreme amount of conductivity may occur during periods of drought. Conductivity outside of the acceptable range could indicate that the water is not suitable for certain species of fish and macro-invertebrates.

There were some levels of salt content from Site 1 to Site 4 indicating that the seawater along Nadi River travels as far up as Site 4. From Site 5 to Site 7 is entirely fresh-water with no significant level of salt content as indicated from the results obtained. It is also natural for rivers to contain a certain amount of salt. In low salinity rivers, there is a much greater diversity of species, with each site having a different set of species, but as salinity increases the number of species at a site decreases. High levels of salinity affect freshwater invertebrates and these invertebrates play a significant role in recycling terrestrial vegetation like leaves that fall into streams and providing food for fish and birds.

Turbidity is the reduction of clarity in water due to the presence of suspended particles and is measured by the amount of light which is reflected by the particles. Turbidity in water is caused by suspended matter such as clay, silt and organic matter that interferes with the passage light through water. It is closely related to total suspended solids but also includes plankton and other organisms.

The level of turbidity at Site 1, Site 2, Site 3 and Site 5 were above the recommended guideline value with Site 5 recording the highest of 25.9 NTU.

Figure 3 Evidence of High Turbidity and Floating Debri Along Nadi River

Throughout the sampled area, it was established that downstream of the two rivers are the most turbid area. The high turbidity downstream is mainly due to vegetation clearing for agriculture purposes as well as soil erosion along the river banks. From Site 5 and above the Nawaka Bridge, there seems to be slightly better clarity in the water as there was a significant sign of good water flow with fishes and other invertebrate present.

The levels of suspended solids at all sites of the river are within the guideline. Suspended solids in a body of water are often due to natural causes. These natural solids include organic materials such as algae and inorganic materials such as silt and sediment. Inorganic materials can easily become suspended due to runoff, erosion, etc. However, when suspended solids exceed the expected concentrations, they negatively impact a water body. As levels of TSS increase, a water body begins to lose its ability to support a diversity of aquatic life. It can also destroy fish habitat because suspended solids tend to settle to the bottom and can eventually blanket the river bed.

Pollution also contributes to either organic or inorganic depending on the source. During river sampling, the cause of suspended solids to name a few are due to agricultural land runoff during rainy weather, soil erosion along river bank, vegetation clearing too close to the river bank for farming, etc. Animals such as cows and horses are tied close to the river bank to graze as well as bathing of animals. Cow and horse dung was found close to the river which also contributes to the rise in suspended solids.

Figure 4 Animals Use the River for Drinking & Bathing

Phosphorus is a nutrient used by organisms for growth and it occurs in natural water and wastewater bound to oxygen to form phosphate. Under natural conditions phosphorus is typically scarce in water but along the Malakua and Nawaka River, the levels of total phosphorus at all sites appear to be within the recommended value. Phosphorus comes from a variety of sources including agricultural fertilizers, domestic wastewater, detergents, industrial process wastes and geological formations. However, the relatively low concentration is enough to limit the growth of algae and/or aquatic plants but ought to be monitored.

Nitrate is an essential nutrient for aquatic plants and animals and is the form in which plants utilize nitrogen, therefore can have a great influence on the amount of plant growth in water. Along the Malakua and Nawaka River, the levels of nitrate at all sites were higher than the recommended value. This is an indication of runoff from fertilized lawns and croplands, domestic waste discharges, etc. The Nawaka River upstream is widely used for a mixture of activities by human and animals for instance, washing of clothes, swimming, fishing and diving for sustainable living, animal bathing and drinking as well. These activities have greatly impacted the river through the increase levels of nutrients such phosphorus and nitrates.

Nitrates are a form of nitrogen which is found in several different forms in terrestrial and aquatic ecosystems. It is an essential plant nutrient, but in excessive amounts can cause significant water quality problems. Along with phosphorus, nitrates in excessive amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn affects dissolved oxygen, temperature and other indicators. Again these levels need to be monitored.

The level of Biological Oxygen Demand (BOD) in the river is below the guideline value; however the values obtained are above 10mg/L but less than 20mg/L suggesting that there are low levels of organic waste with fewer bacteria present. With low BOD, dissolved oxygen levels will be high.

Biological Oxygen Demand (BOD) is performed to measure the potential of wastewater and other waters to deplete the oxygen level of receiving waters. In other words, BOD test is undertaken to determine what effect dirty water, containing bacteria and organic materials will have on animal and plant life when released into a stream. When there is an abundance of bacteria and organic materials, the bacteria will take in oxygen in order to breakdown these molecules, if bacteria are taking in large amounts of oxygen, this will have detrimental effect on the surrounding ecosystem.

The Chemical Oxygen Demand (COD) analysis is commonly used to indirectly measure the amount of organic compounds in water. Most application of COD determines the amount of organic pollutants found in surface water such as rivers or wastewater, making COD a useful measure of water quality. According to the river surface water results, the level of COD at all sites were found to have a constant mass of oxygen of less than 28mg/L throughout the river of Malakua and Nawaka indicating that there is activity of oxygen being consumed by organic compounds.

Overall, the Malakua and Nawaka River is considered to be greatly disturbed due to a number of factors such as activities carried out by human and animals on the river and these include land clearances for agricultural purposes close to the rivers edge causing river bank erosion, the disposal of household and industrial waste into the river, large amount of debris, rotting wood and vegetation, animal grazing close to river banks, bathing of animals in river, and the washing of clothes, etc.

A copy of the water quality results from the IAS is attached to this report as Appendix A.

Appendix A Water Quality Analysis Report – IAS Lab

SCOPE PACIFIC LIMITED
STRATEGIC CONSULTANTS IN PLANNING & ENGINEERING

JICA Study Team
Planning of the Nadi River Flood Control Structures Project

Additional Environmental Field Survey – Malakua & Nawaka Rivers

FRESHWATER ECOLOGICAL ASSESSMENT

Final Issue
March 2016

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FRESHWATER ECOLOGICAL ASSESSMENT REPORT

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Contents

1. Background

The Government of Fiji and Japan signed a Memorandum of Agreement in late 2014 for the study of the Planning of the Nadi Flood Control Structure Project to address flooding along the Nadi River catchment area and the Region.

In 2015 SCOPE Pacific was engaged by the JICA Study Team to carry out basic data gathering and environmental field survey works which included terrestrial flora and fauna assessment, water quality sampling and analysis, freshwater ecological assessment, and sediment sampling and descriptive assessment of the sample sites of the Nadi River and which were undertaken in August 2015.

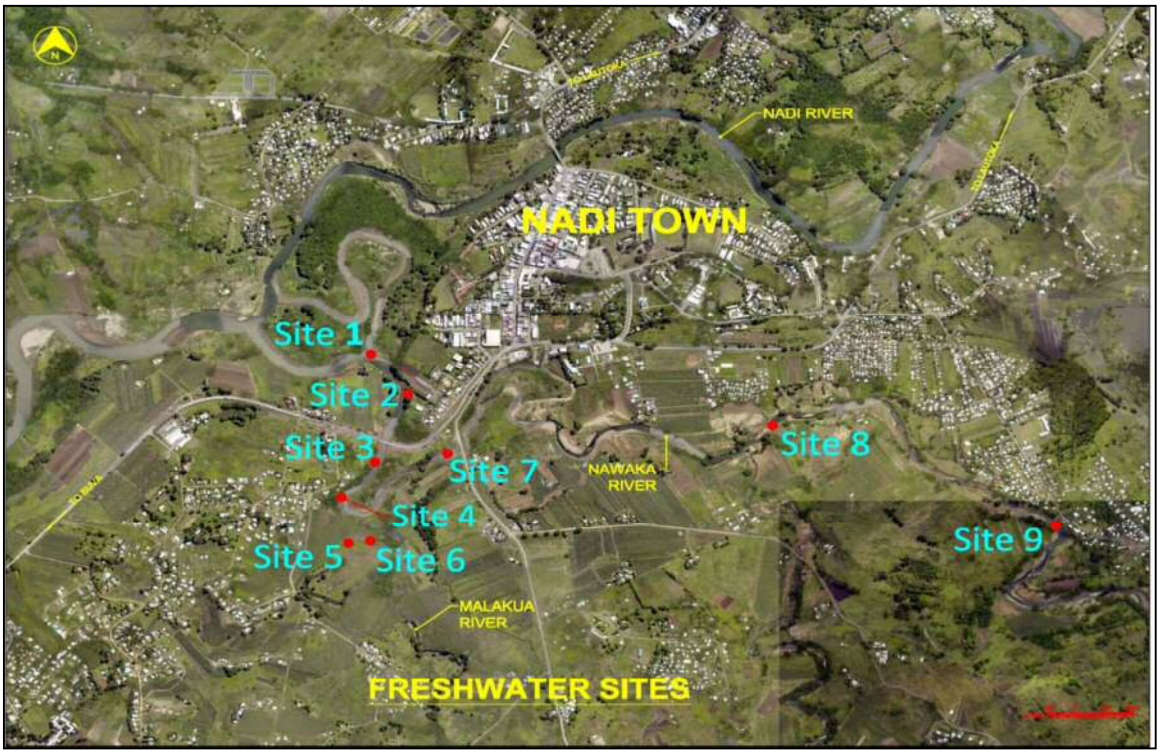
In December 2015, JICA requested SCOPE to undertake additional environmental field surveys along the Malakua and Nawaka Rivers as well as around Moala village and the Nadi River mouth, comprising the same assessments and parametres as undertaken for the Nadi River. These additional areas were required to be covered in the environmental surveys due to proposed dykes, river diversion and retaining walls being considered by the JICA Study Team in these areas.

2. Introduction

A baseline freshwater assessment of the river ecology was undertaken over two day's period from 29th February to 1st March, 2016 in dry weather conditions.

A total of nine sites were selected; five sites located along Malakua while four sites were situated along the Nawaka River as shown in Figure 1. Most sites were easily accessible by boat and walking while few were rather difficult to access due to the selected sites being located near large cane field and also from high river banks with no pathway down to water. The freshwater assessment was carried out in order to gain a thorough understanding of species presence and absence including stream flows, stream width and general health of the stream which was similar to the scope of assessment and methodology used during the initial freshwater survey of the Nadi River.

- **Figure 1 Freshwater Sample Sites along Malakua & Nawaka River**



It was expected that there would be significant change to the general health of the stream in this additional freshwater ecology assessment due to the effects of the Category 5 Tropical Cyclone Winston that battered Fiji a week before this survey took place.

3. The Existing Environment

3.1. Sampling Sites Location

A total of nine (9) sites were selected for freshwater ecology assessment. These were selected based on the extent of work to be carried for the proposed river re-alignment and dike within the Malakua and Nawaka Rivers as proposed by JICA. The surveyed sites were concentrated more on the lower catchment of Malakua River near Nadi Town from Site 1 – Site 7, whilst Site 8 was located in mid- catchment and Site 9 located on the upper catchment of Nawaka River. The field survey began downstream of the main Nadi River then continued towards the midstream of Malakua River and then ended upstream of Nawaka River adjacent to Nawaka Village.

3.1.1. *Site 1 Lower Catchment of Nawaka River*

The first site surveyed was located approximately 80m above from the tributary of Nadi River. The site's riparian zone of both banks consisted mainly of invasive grasses, shrubs and plants including saplings tree of an introduced species known as *Anil indigo* (vaivai) and coconut trees. The river bank was very much exposed with no standing trees observed providing riparian cover over the river as they had been removed by the recent cyclone and previously for farming which therefore has resulted in high turbidity. It was observed that the riparian vegetative zone width has mostly been healed over from rise in flood water level and also with the presence of pathways and/or stock access to stream.

- **Figure 2 Lower Catchment of Nawaka River as Site 1**

The bank stability on both banks is categorized as unstable with high erosion potential during floods as shown in Figure 2. The river at the time of sampling was generally flat with no riffles and shows a very poor habitat. There is evidence of channel alterations due to the frequency in flooding of the river. The sediment deposition in the river was very high with heavy deposit of fine materials. On the left side of the river there has been a slight increase in bar formation mostly from gravel with little bits of sand and fine sediment. The abundance and diversity of habitat at Site 1 was very poor with substrate unfavorable for invertebrate colonization. The fish cover was very rare or absent due to high turbidity, although one type of small fish, the mosquito fish was caught using a net during the field survey. There were no periphytons present at the time of sampling.

- **Table 1 Measurement Recorded at Site 1**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 1	60	70	1.0	0.23

The site was dominated mainly with mud and silt at 50%, 15% large pebbles, 5% small cobbles and 30% gravel. The active width of the site was around 60 metres whilst the flood plain width recorded up to 70 metres in width. The average depth of the river at Site 1 was around 1 metre with the velocity recorded at 0.23 m/s.

3.1.2. *Site 2: Lower Catchment Malakua River (below Bridge)*

The second site surveyed as shown in Figure 3 was located at the lower catchment of Malakua River just below the Malakua Bridge going into Nadi Town from Suva. The riparian vegetation comprised of invasive para grass, shrubs and an introduced rain tree (vaivai ni valagi), pawpaw trees with few vines and climbers and a riparian cover of 1%. The riparian vegetative zone width was very poor with evidence of human activity with both banks mostly been healed over. The bank stability is rated as poor and unstable showing many eroded areas with high erosion potential during flooding. The left river bank had severely eroded showing exposed tree roots with some fallen into the river.

- **Figure 3 Catchment of Site 2**

The study site shows poor frequency of riffle as well as habitat with substrate unfavorable for invertebrate colonization as the substrate was unstable where present or lacking. The sediment deposition is high with heavy deposits of fine material into the river which has caused the formation of a bar in the middle of the river mostly composed of gravel, sand and fine sediments. There was also no fish cover observed at the site as the habitat had no macrophytes present as well as no periphyton.

- **Table 2 Measurement for Site 2**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 2	70	80	1.2	0.24

An estimated riverbed percentage falls at 40% gravel, 10% large pebbles, 10% sand, 30% silt/mud and 10% debris. The active width of the river at Site 2 was 70 metres which would increase to 80 metres with the flood plain width areas. Average depth was 1.2 metres with the average velocity at 0.24m/s.

3.1.3. *Site 3: Lower Catchment Malakua River (Above Bridge)*

The 3rd site surveyed as shown in Figure 4 was located above the Malakua Bridge (entering Nadi Town from Suva). The riparian vegetative zone width was very poor with minimal tree presence acting as a buffer and this is similiar throughout the study sites upstream and downstream on both banks. The bank surfaces of both sides are covered by grass and shrubs and disruption of stream bank vegetation was very high.

- **Figure 4 Above the Malakua Bridge Before Nadi Town**

The vegetation observed was a rain tree (vaivai) and a lemon tree with riparian cover of 2% but paragrass dominated both sides of the bank. The river banks were also heavily grazed by cows and horses. The bank stability is categorized as poor with many eroded areas and is considered unstable as flood water continuously wash away river banks, exposing tree roots and over time causing the trees to fall into the river.

The frequency of riffles was rated as poor since river water was generally flat/calm with no riffles and poor river habitat observed. The river/stream reach was heavily deposited with fine materials with evidence of bar formation on the left side of the river mostly from gravel, sand and fine sediments. The abundance and diversity of habitat was very poor with substrate unfavorable for invertebrate colonization. There was no fish cover sighted as well as no macrophytes or periphytons spotted.

▪ **Table 3 Measurement for Site 3**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 3	50	80	0.79	0.20

The stream bed cover is estimated to be around 50% gravel (course, medium, and fine) as dominant substrate, 10% large pebbles and 30% mud and silt. The active width of the Malakua River at Site 3 was 50 (m) with an average depth of 0.79 (m) and a velocity of 0.20 (m/s).

3.1.4. *Site 4: Lower Catchment Malakua River (Meander near Vuniyasi Road Residents)*

The location of Site 4 as shown in Figure 5 was situated at the meander, 170 metres upstream of Site 3. The site assessment found that the riparian vegetative zone was very poor with evidence of human activity as communities were observed to be living close to the river along Vuniyasi Road.

▪ **Figure 5 Meander of Malakua River**

There were presence of pedestrian pathways, dumped rubbish and livestock accessing the stream. Both bank surfaces are covered by grasses, shrubs and trees such as rain tree providing very poor riparian cover to the river of about 3% only. It was noted that the vegetation of the stream's bank has been highly disrupted by human activity as well as through frequent flooding that occurs in Nadi. Both banks were noted to be moderately unstable with moderate erosion potential during flooding. To the left of the river bank is a small tributary covered mostly with silt, mud and debris which join up into the main Malakua River and thus contributing to the very high turbidity levels of the stream reach.

The river was generally flat with no riffle and has a very poor habitat not favorable for invertebrate colonization. No fish cover was visible with sides of the river banks lacking macrophytes and periphyton.

▪ **Table 4 Measurement for Site 4**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 4	30	70	0.78	0.39

The heavy deposits of fine material within the stream reach was high particularly on the right side where there were some deposition of gravels of about 35%, 15% pebbles, 5% cobbles and 45% of fine sediment (mud/silt) which was highly settled on the left side of the river. The water velocity recorded was 0.39m/sec with an active width of 30m as shown in Table 4.

3.1.5. *Site 5: Tributary of Malakua River (next to sugar cane farm along Vuniyasi Road)*

The 5th site surveyed was located upstream of Site 4 at the second meander of Malakua River. Locating the site was difficult due to the large cane farm that was used to access the river and another 50-60m before reaching the river bank. At most places along the river, the height of the bank was too high so alternative accesses to the stream had to be considered. During the survey, it was observed that the river banks and riparian was densely covered with paragrass and weeds and was therefore, widely used for grazing of animals. The riparian vegetative zone width is mostly healed over and there is presence of pathways for livestock access to stream as shown in Figure 6.

- **Figure 6 Malakua River**

The bank surfaces are also covered by shrubs and trees such guava with no riparian cover to shade the river. There were also root crops and vegetable farming evident near the river which survived the floodwaters during TC Winston whilst others were destroyed. The river banks were mostly exposed, eroded and unstable.

The river was generally flat with no riffle and the stream reach was significantly poor in habitat with no substrate favorable for invertebrate colonization or fish cover. The river habitat also lacked macrophytes and periphyton whether visible or prolific. The surveyed area was heavily deposited with fine sediments in particular at the left bank side, however as you move in the middle, there were deposition of gravel of about 20%, 10% pebbles, 5% cobbles, 5% sand while 50% were silt and mud and 10% were debris trapped along the water's edge of river bank.

- **Table 5 Measurement for Site 5**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 5	25	40	0.37	0.31

Table 5 shows that the active width of the stream measured at 25m while the flood plain area was 40 metres wide as there were indication of flattened paragrass and affected crop and vegetables farm where flood waters reached. The average depth of the river was less than ½ a metre with water velocity flowing at a rate of 0.31 metres per second.

3.1.6. *Site 6: Downstream Meander of Malakua River*

Site 6 was located at the lower bend or meander downstream from Site 5 as shown in Figure 7 and reaching the site was via wading through the stream water.

Figure 7 Meander of Malakua River

The riparian vegetative width is obvious affected by human activity as the presence of pathway and animal access to stream for drinking is evident. Both bank surfaces comprised mainly of paragrass, shrubs and weeds and appear highly disrupted. The banks are rated as unstable with high erosion potential during flooding. There were no trees growing on both sides of the banks to prevent the soil from eroding.

The river was generally flat with no riffles and stream habitat is considered poor with no favorable substrate for the colonization of invertebrates. Fish cover was also absent although there were woody debris, snags and submerged logs trapped along the river's edge which should be able to provide adequate habitat for fish over time.

Table 6 Measurement for Site 6

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 6	20	35	0.73	0.28

The stream substrate comprised of materials such as gravel with 35%, sand 20%, 5% pebbles, 10% cobbles, 20% silt/mud and 10% debris. There were no presences of macrophytes or periphyton observed on site. The velocity of water was 0.28m/sec with the active width recorded at 20m as shown in Table 6.

3.1.7. *Site 7: Below Nawaka Bridge*

The location of Site 7 was situated below Nawaka Bridge as shown in Figure 8.

- **Figure 8 Downstream of Nawaka River (below the bridge)**

The riparian vegetative zone of the surrounding is mostly dominated by paragrass and shrubs which appear continuous and dense along the river bank width with no standing trees though a few can be seen further away from the river. Also noted were pathways for accessing the river for fishing and other activity. The banks appear unstable with significant eroded areas with other areas having high erosion potential particularly, during flooding. Generally the river is flat with occurrences of infrequent riffles and is indicative of a fair habitat for invertebrates showing patchy fish cover during survey. There were submerged logs and snags that provided habitats for fish and substrate that were favorable enough for invertebrate colonization.

The river bed comprised 35% gravel, 10% cobbles, 15% pebbles, 10% sand, 20% silt and 10% debris. It was observed that there was an increase in bar formation on the left side of the river mostly from gravel, sand and fine sediments.

- **Table 7 Measurement of Site 7**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 7	100	>100	1.7	0.43

The width of the river at this point was 100 metres with the flood plain area greater than 100m, with average depths of 1.7 metres and water velocity of 0.43m/sec as shown in Table 7. The water velocity at this site was rated very good as it is within the range of moderate stream velocities which is ideal for healthy invertebrate and periphyton communities, although there were no periphyton communities sighted during the survey.

3.1.8. *Site 8: Midstream of Nawaka River (near Korociri settlement located Inland)*

At Site 8, the riparian vegetative zone width was mostly healed over from TC Winston. The site is located midstream of Nawaka River with Korociri settlement located inland about 200m from the river bank.

- **Figure 9 River Used for Bathing of Animals, Diving and Fishing**


There were pathways to the river observed serving mostly the nearby communities to access the stream and was observed that the area has been actively used for fishing, swimming and bathing of their animals as shown in Figure 9.

The bank surfaces were covered with grasses, shrubs and trees such as raintree (vaivai) with riparian cover of 5%. The stream bank vegetation was highly disrupted with exposed tree roots and flattened paragrass and shrubs indicating the high level of flood waters the area receives. Both banks were moderately unstable with high erosion potential during flooding however, the river had relatively frequent riffles signifying a good habitat of 10-30% substrate favorable for invertebrate colonization and with patchy fish cover. Due to the recent flood, the river lacked macrophytes as well as having no presence of periphyton and prolific.

There were no sign of siltation nor sedimentation in the river as the river had good stream flow. No islands or point bars were present within the river however, the river bed cover were mostly from gravel at 55%, 20% pebbles, 5% cobbles, 10% sand and 10% debris.

- **Table 8 Measurement of Site 8**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 8	15	90	0.42	0.84

The width of the river at this point was 15 metres while the flood plain area was 90m, with an average depth of 0.42 metres and water velocity of 0.84m/sec as shown in Table 8. The water velocity range represents moderate to high stream velocities that are likely to preclude some invertebrates such as caddis larvae although their casings were only observed to be present at the site.

3.1.9. *Site 9: Upstream of Nawaka River (at Nawaka Village)*

The last site surveyed was located upstream of Nawaka River adjacent to Nakawa Village as shown in Figure 10. The riparian vegetative zone width is mostly disturbed as the river has been accessed daily by the villagers for washing of clothes and dishes, swimming and bathing of villagers and animals. Upstream of the surveyed site along the stream bank were mostly covered with plantation.

Both bank surfaces were covered with grass and shrubs while most trees were present on the left bank of the river with the tree roots holding the bank together. The riparian cover on site was 5% as most were damaged due to flooding that occurred during TC Winston. The bank stability was rated as moderately stable with infrequent, small area of erosion which has mostly healed over.

- **Figure 10 Site 7 Nawaka River (village located on the right bank)**

The surveyed site was observed to have relatively frequent riffles indicating that the habit is good with 10-30% substrate favorable for colonization of invertebrates with patchy fish cover. m1t was noted during the survey that villagers use the river for fishing too as shown in Figure 11.

- **Figure 11 Site 7 River Used for Swimming, Bathing and Fishing**

- **Table 9 Measurement of Site 9**

	Active Width (m)	Active Width with Flood Plain (m)	Average Depth (m)	Water Velocity (m/s)
Site 9	25	80	0.47	0.35

The width of the river at this point was 25 metres however the flood plain area was 80m, with average depths of 0.47 metres and water velocity of 0.35m/sec as shown in Table 9.

4. Water Quality Results

4.1. Water Quality Physical Parametres

A comparative summary of the environmental and physical parametres recorded for each site is shown in Table 10 below.

Table 10 Water Quality Results

Parametres	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9
Temperature (°C)	29.7	30	30.13	30.21	29.82	26.43	28.04	27.25	27.72
pH	7.7	8.23	7.98	8.2	8.25	8.25	8.11	8.2	8.34
Conductivity (mS/cm)	0.293	0.263	0.256	0.374	0.306	0.29	0.196	0.164	0.157
Turbidity (NTU)	14.4	17.4	17.3	37.5	12	7.5	25.9	9.9	6.6
Dissolved Oxygen (mg/L)	8.11	7.83	7.86	7.88	7.99	9.57	8.88	9.55	9.34
TDS (g/L)	1.89	0.171	0.167	0.244	0.199	0.188	0.127	0.107	0.102
Salinity (ppt)	0.1	0.1	0.1	0.1	0.1	0.1	0	0	0

Every species has a preferred temperature range and therefore, stream temperature is very important. Temperature depends largely on time of year and weather conditions as well as stream type. For the case of Malakua and Nawaka River, the temperature recorded ranged between 26 and 30°C and is considered high for many sensitive aquatic invertebrates. Temperature recorded between that ranges are likely to be stressful to fish, stoneflies, mayflies and some caddis flies. Such high temperatures are a result of lack of shading which was evident during the survey as there were little to no trees acting as shade over the river and river water had a very sluggish flow.

The high temperature would often cause environmental damage over time as a result of human activities attributed by runoffs from the nearby activities such as agricultural farms, etc and also, the clearing of riparian vegetation on both sides by humans as well as the recent TC Winston flooding in Nadi.

The average value of pH for all sites was at 8 indicating the alkalinity of Malakua and Nawaka River and is still considered to be an optimal range for most life in rivers and stream. The normal pH of freshwater usually ranges from 6.5 to 9, although wide variation can occur because of catchment geology. Animals and plants in streams can adapted to certain ranges of pH though changes in pH levels outside the normal range of the water body can cause more sensitive species to die.

Conductivity is a measure of the total ionic strength of the water and is widely used in water quality studies as a quick field indication of the level of enrichment (i.e. nutrient content) of water. At all sites, the conductivity level ranges from 0.157 to 0.374mS/cm which rated from fair to poor indicating that the rivers at the surveyed sites were slightly to moderately enriched.

All rivers/stream waters contain some nutrients as a result of natural conditions and processes. The underlying rock type determines the base level of nutrients in the river. The high conductivity level is also attributed to runoff and seepage which in most cases are a natural process adding extra nutrients to the river. In agricultural areas surrounding the Malakua and Nawaka Rivers, these inputs may increase because of both non-point sources such as gradual runoff from cultivated land and direct inputs from stock faeces and urine.

As erosion occurs within a catchment, tiny particles of clays, silts or small organic particles are washed into rivers and streams. These tiny particles can be supported in the water current and are termed suspended solids. The faster the water is moving, the more suspended solids it can carry, this changes the water clarity. Two sites surveyed had high turbidity value of 37.5NTU at Site 4 of Malakua and Site 7 of Nawaka recorded 25.9 NTU. This is due to the slow rate of flushing and the fact that very fine particles are held in suspension almost indefinitely.

Where there is less light penetrating the water, there will be less photosynthesis and this can reduce the level of oxygen in the water. Dissolved oxygen is the small amount of oxygen gas dissolved in water. This oxygen is vital to fish and other aquatic animals, micro-organisms and plants which depend on it for the process of respiration. The level of DO is a useful indicator of water quality. It indicates the presence of certain pollutants particularly organic matter. The dissolved oxygen level at all sites ranged between 7mg/L and 9mg/L which is considered high indicating the presence of sewage effluent, decaying aquatic vegetation and animal manure which reduces DO levels through decomposition by micro-organisms. DO levels in natural waters depend on four factors such as how quickly oxygen is absorbed into the water from air, how quickly oxygen is used up by organisms in the water, photosynthesis of plants and algae and flow variation.

A total of 6 sites out of the 9 sites surveyed showed some levels of salinity as observed in the lower reaches of river. Salinity poses major threat to freshwater river systems since organisms thriving in such rivers can tolerate certain ranges of water salinity. However, much greater species diversity can be found in low salinity river.

5. Freshwater Ecology Findings

5.1. Macro-invertebrates

■ **Table 11 Macro-invertebrates Observed At the 7 sites**

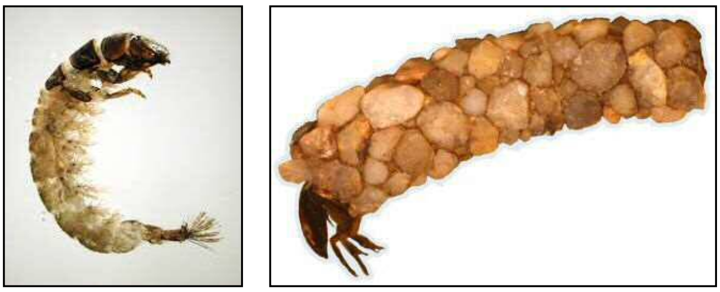
Scientific order	Species	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Total
Trichoptera (Caddisflies)	*Triaenodes fijianus*	-	-	-	-	-	-	-	1	-	1
Decapoda	*Macrobrachium equidens*	-	-	-	-	-	-	4	5	7	16
Neritidae (Family)	*Neritina varigaeta*	-	-	-	-	-	5	4	-	-	9
Total											**26**

A total of three orders were observed to be present from Site 6 to Site 9 (refer Table 11) and from Site 1 to Site 5, the study area showed no presence of macro-invertebrate as the locations were situated downstream where there is brackish water due to river being tidal. The species present proved to be low in terms of species abundance and diversity. Even with low numbers, the species presence was a good indication of fauna being resilient and adaptive in a degraded environment like the Malakua and Nawaka Rivers. It also demonstrates how the river system is able to withstand changes and in the process restore the fauna at any given time particularly during favorable weather conditions.

5.1.1. Caddisfly

Caddisfly casing as shown in Figure 12 was observed to be present at Site 8 upstream of Nawaka River indicating that there is presence of caddisfly where water quality is moderately disturbed and proved to be low in number during the survey, signifying the river quality and also the recent flooding of TC Winston. Caddisfly larvae are aquatic and have a soft body which sheath into casing made from silk that are covered in various materials such as sand or plant debris to provide protection and camouflage. Caddisfly larvae are sometimes used as environmental indicators of water quality.

■ **Figure 12 Photographs of Caddisfly Larvae and Casing**



5.1.2. Decapoda

Macrobrachium equidens species shown in Figure 13 were observed inhabiting upstream of Nawaka River from Site 7 to Site 9. They are able to adapt to a wide range of salinities (euryhaline), however most were found upstream of Nawaka where there is no salt content. The organisms are euryhaline because their life cycle involves migration between freshwater and marine environment.

Figure 13 Macrobrachium equidens species

5.1.3. Neritidae

Vittina variegate species inhabits small streams, near the mouth within tidal influence and often in mud. They are herbivorous and presumed to feed by scraping algae and diatoms.

Figure 14 *Vittina variegata*

5.1.4. *Functional Feeding Groups*

The macro-invertebrates identified were a mixture of grazers, scrapers and shredders feeding groups which help describe their role in an aquatic system.

5.1.4.1. Fisheries Observed

A total of 3 different species from 3 different families shown in

Table 12 were observed during the survey, out of the 3 different species observed, 2 were natives while 1

Family	Species	Status	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Total
Syngnathidae (Ragged tail pipe-fish)	*Microphis retzi*	Native	-	5	-	-	-	-	-	-	-	5
Ambassidae	*Ambasis miops*	Native	-	-	-	-	-	-	-	-	5	5
Poeciliidae	*Gambusia affinis*	Introduced	2	-	-	1	1	-	4	6	7	21

was introduced which mostly invaded Site 7 to Site 9. The introduced species can dominate the entire ecosystem at an alarming rate in future if not controlled.

Table 12 Fisheries Observed

Family	Species	Status	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8	Site 9	Total
Syngnathidae (Ragged tail pipe-fish)	*Microphis retzi*	Native	-	5	-	-	-	-	-	-	-	5
Ambassidae	*Ambasis miops*	Native	-	-	-	-	-	-	-	-	5	5
Poeciliidae	*Gambusia affinis*	Introduced	2	-	-	1	1	-	4	6	7	21

5.1.4.1.1. Syngnathidae (Ragged Pipe-fish)

Figure 15 Ragged pipe-fish

The ragged pipe-fish under the family of Syngnathidae as shown in Figure 15 was seen at Site 2 located downstream of Malakua River and is classified in the same family as the seahorses and sea dragons. The species is known to be present in temperate and tropical seas across the world. Most species inhabit shallow, coastal waters but few are also known to be present in open ocean conditions near associated sargassum mats.

5.1.4.1.2. Ambassidae (Flagged-tail Glass Perchlet)

The flagged-tail glass fish shown in Figure 16 was observed at Site 9 and the species distribution can be locally common but not seemed to be abundant.

Figure 16 Ambassidae *Ambasis miops*

The species can be found in clear freshwater streams and/or in the lower reaches of rivers and streams. Its food habitats may depend upon the habitat, with the species feeding on more crustaceans and small fish in estuaries than in freshwater where terrestrial insects and their larvae are dominant.

5.1.4.1.3. Poeciliidae

Gambusia affinis or mosquitofish shown in Figure 17 is an introduced species to Fiji and were found to be highly populating upstream of Nawaka River from Site 7 to Site 9. It is a widespread and common freshwater species and is small in size in comparison to many other freshwater fish. The name "mosquito fish" was given because at times their diets consist of large numbers of mosquito larvae, relative to their body size. They typically feed on zooplankton, beetles, mayflies, caddisflies, mites and other invertebrates and mosquito larvae make up only a small portion of their diet.

- **Figure 17 Female mosquitofish**

6. Discussion

6.1. Overall River Health

At all the 9 sites surveyed, the riparian vegetative zone widths were rated as poor with evidence of human activities involving the removal of vegetation for farming and stock grazing, pathway present for people as well as livestock to access the river for drinking, bathing and other activities. It was observed that at all sites, the vegetative zone widths have mostly been healed over from the recent flood waters that took place in Nadi during TC Winston. The bank surfaces were covered mainly with paragrass, shrubs and very few trees acting as riparian cover over the river. The land-use on either sides of the river bank were found to be mostly agricultural farms where runoff and erosion easily came from and into the receiving environment due to large areas of land clearance and stripping of vegetation close to the river's edge. The bank vegetation were highly disrupted as well as heavily grazed by livestock.

At all sites, the river banks were considered to be unstable with evident of many eroded area. The bank has erosional scars of around 60-100% as well as high erosion potential during floods. The river is generally flat with no riffles observed downstream while upstream of Nawaka has infrequent occurrence of riffles with bottom stream contours providing habitat. The substrates downstream were not favorable enough for the colonization of invertebrate and found low fish cover. These sites also lacked macrophytes as it provides habitat to fishes and other organisms as well as no indication of any periphyton nor prolific. The sediment deposition was high with heavy deposits of fine material affecting the bottom stream of about 50-80%, also evident were the bar formation composed mostly of gravel, sand and fine sediment.

The river bank widths vary throughout the site and river depths of not more than 2m deep. The velocity as it represents one of the most important environmental factors affecting the biota was rated as poor due to the slow flows therefore representing unfavorable conditions for stream life. Under these conditions, the oxygen supply is restricted and there is potential for wide variations in both pH and temperature which can be harmful to aquatic invertebrates. From Site 7 – Site 9, the velocity were somewhat rated as good with some trivial signs of invertebrates and fishes. The area has slightly faster flowing water that was able to support a range of both pollution-tolerant and pollution-sensitive invertebrates.

6.1.1. Water Quality Physical Parametres

The overall water quality along Malakua and Nawaka River indicates that it is highly disturbed and was rated as fair on some sites whilst poor on most of the surveyed sites. The poor water quality is also a result of the after effect of TC Winston's flooding as well as other factors such as agricultural farming, animal grazing near river banks, animal bathing and drinking in the river. Nearby communities living close to the river bank also uses the river for washing of clothes and kitchen utensils, fishing and diving.

6.1.2. Macro-invertebrates

With less to no macro-invertebrates identified, it is indicative that the river cannot support aquatic life to its full potential. The ecosystem processes have been greatly impacted resulting in loss of biodiversity. The aquatic organisms cannot play their role due to the degraded state of the river. The physical parametres proved that there will neither be aquatic insects nor macro-invertebrates present due to the poor quality of water and flow.

6.1.3. Fisheries

The fish abundance and diversity were too low simply due to the effects of the recent flood. The nine (9) sites surveyed only recorded 3 different species with high numbers of introduced species populating Nawaka River. The introduced species adapt very well to the physical state of the river as they are able to survive in areas with high pH, temperatures, turbidity and low dissolved oxygen.

6.1.4. Algae & Macrophytes

There was no sign of algae or macrophytes observed at any of the surveyed sites.

7. Conclusion

The baseline freshwater surveys of the nine selected sites indicate that there were no ecologically sensitive habitats or significant natural sites located within these additional nine (9) sites surveyed as well as no freshwater fauna and flora of any conservation significance identified.

The river is heavily affected with sediments/silts due to recent flooding, river bank erosion as well as runoff from adjacent agricultural farms. The general health state of the river is rated as poor with a declining number of invertebrates, fisheries and other organisms. Management of the upper and lower catchments through rehabilitation should be undertaken in order to restore the ecosystem functions and these includes replanting of riparian vegetation throughout the river bank for it to be able to act as a buffer zones. Improvements to the flow of the river flow through dredging and management of human activities such as farming and river use through education and awareness programmes to support the proposed river re-alignment and dike works is also recommended to improve the freshwater water ecology of both the Malakua and Nawaka Rivers.

1. Description of Sediment Sampling Sites for Malakua & Nawaka Rivers

The sediment sampling sites for the Malakua and Nawaka Rivers was undertaken as part of the environmental studies of Nadi River Flood Control Study by JICA Study Team.

Sediment sampling was undertaken on Tuesday, 1st March 2016. A total of eight (8) sediment samples were collected at specific sites along the Malakua and Nawaka Rivers. The eight sites are indicated in Figure 1 and were in addition to the sediment sample collected from the Nadi River in September 2016.

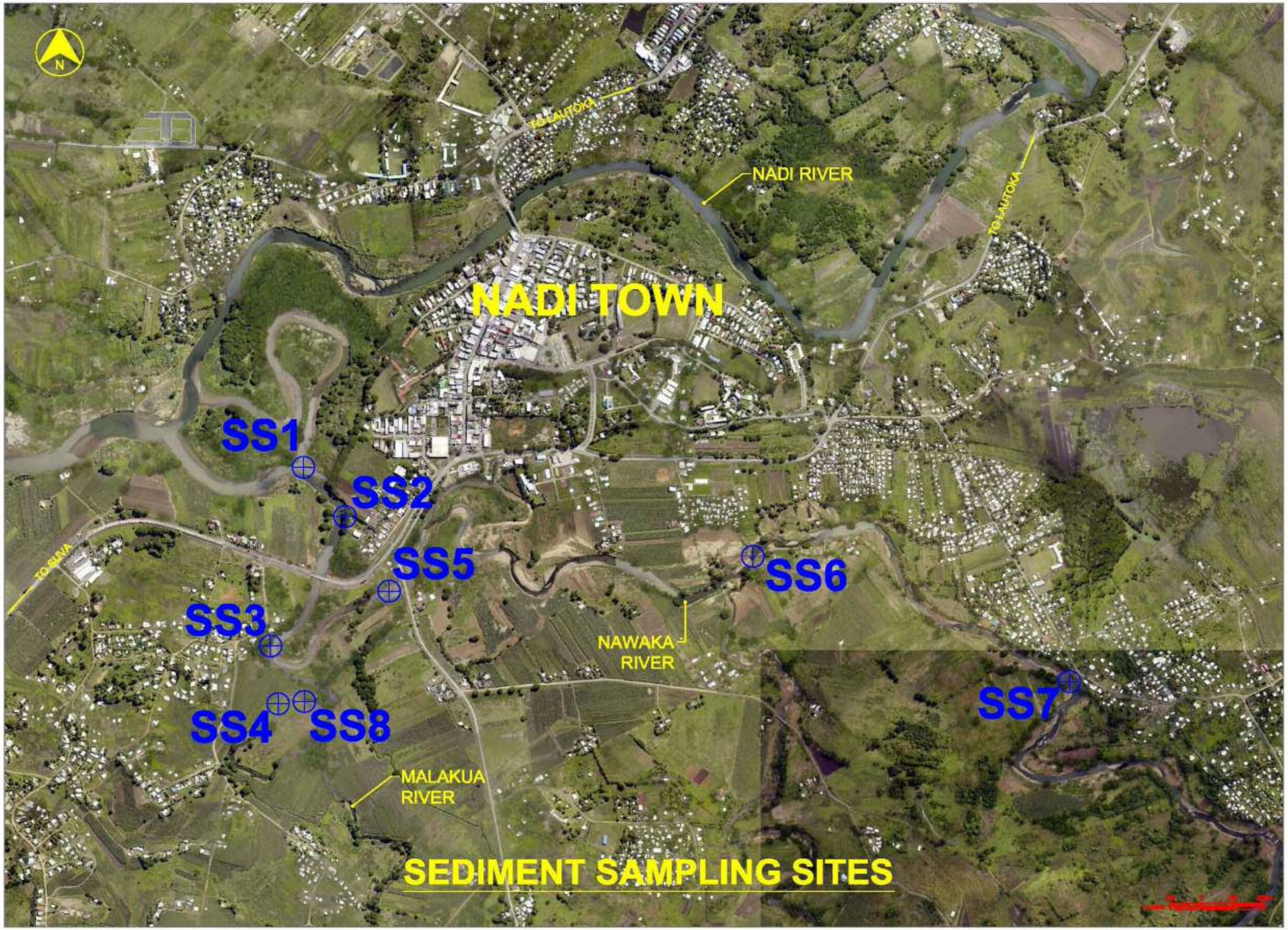
These eight (8) additional samples were similarly collected and sent via courier to Hills Labs in Hamilton, New Zealand for analyses of the following physical and chemical parameters:

- Organic matter content;
- Dry matter content;
- Ash content;
- Moisture content;
- Total recoverable Manganese (Mn);
- Total recoverable Phosphorous (K);
- pH;
- Nitrites;
- Nitrates
- Heavy metals trace
    - Arsenic (As)
    - Cadmium (Cd)
    - Chromium (Cr)
    - Copper (Cu)
    - Nickel (Ni)
    - Lead (Pb)
    - Zinc (Zn)
    - Mercury (Hg)

1.1. Sampling Methodology

Sediment samples were collected from 8 sites within Nawaka and Malakua Rivers over a 4-hour period, between 6am and 10am, and were collected within the proposed river alignment and riverbank improvement areas as identified to SCOPE by the JICA Study Team. Weather on the day was fine and dry. Sampling points were approximately 2 – 4 kilometers apart, hence the longer timeframe for sampling events. Sediment samples were collected from the same sites water samples were collected from, with an additional sediment sampling site along the Malakua River.

- **Figure 1 Locality Map Showing the Sediment Sampling Sites**



■ **Picture 1 Samples packed in Styrofoam Esky**

Samples were collected from as close to the centre of the river as possible at each sampling site, depending on the depth of the river and access to the site. Samples were collected using a shovel and basin in areas where the riverbed was undisturbed by water sampling actions.

Samples were sealed in air-tight sealed plastic bags, labelled and placed in a styrofoam esky and delivered to the courier service company, DHL, at the Nadi International Airport for delivery to Hills Laboratory in Hamilton, New Zealand. All customs clearance documentation as required was completed, scanned and emailed to Hills Laboratory for ease of clearance once received.

1.2. Site Description

Sediment Sampling was carried out at the following sites:

Site 1 – Behind Nadi Town Industrial Area

Site 2 – Downstream of Malakua River Bridge

Site 3 – Upstream of Malakua River Bridge

Site 4 – Along Malakua River adjacent to Sugarcane Fields

Site 5 – Downstream of Nawaka River Bridge

Site 6 – Midpoint of Nawaka River at Korociri Settlement

Site 7 – Outside Nawaka Village

Site 8 – Along Malakua River bend, adjacent to Sugarcane Fields

1.2.1. Site 1 – Behind Nadi Town Industrial Area

Sediment samples were collected from the portion of the Malakua River outside the Nadi Town industrial zone at 6.35 a.m. during fine weather. Riverbank vegetation at the sampling site comprised thick paragrass and raintrees.

The river in this area is mainly influenced by the tides; thus river depth at this location was not very deep as sampling was undertaken during falling tide, and samples were collected from knee-deep water (Picture 2L). Preliminary observation of the sample indicated it comprised of more silt and clay.

- **Picture 2 L & RSampling behind the Nadi town industrial zone.**

1.2.2. Site 2 – Downstream of Malakua River Bridge

Sediment samples were collected approximately 90 meters downriver of the Malakua River bridge and 343m upriver of Site 1. Both sites are situated behind the Nadi Town Industrial Area.

Samples were collected at 7.15 a.m. Access to the site was via a narrow track on the outskirts of the industrial area. Sampling proved difficult as the river surface was situated approximately 5meters below the edge of the riverbank.

- **Picture 3 Left – Access to the Site via Tree Roots. Garbage and Woody Debris Strewn along the Riverbank; Right – Sediment Sample being Transferred to the Sample Bag from the Bucket**

Riverbank vegetation on both sides were similar to Site 1, comprising thick para grass and raintrees, and observation of the sample indicated it was very similar to Sample 1 which comprised a lot of silt and clay. A sizeable amount of household and industrial litter as well as woody debris were observed on the riverbank (Picture 3L).

1.2.3. Site 3 – Upstream of Malakua River Bridge

Sediment samples were collected at 7.37 a.m. at approximately 317 meters upriver of the Malakua bridge and 300 meters southeast of Nadi Town. Access to the site was relatively easy as it was situated behind a residential property and a track led down to the water's edge where sampling was undertaken.

Riverbank vegetation on both sides comprised of large stands of para grass and shrubs, and observation of the sample indicated it comprised much of silt and clay. The river bank was quite slippery with a lot of mud observed on the bank and the riverbed. There was quite a lot of household rubbish observed on the riverbank.

- Picture 4 – Sediment Sampling at Site 3

1.2.4. Site 4 – Along Malakua River (adjacent to sugarcane fields)

Sediment samples were collected at 8.05 a.m. from a site approximately 0.5 kilometers upriver of the Malakua River bridge and approximately 0.65 kilometers southeast of Nadi Town. The site was situated adjacent to sugarcane fields, and access to the site was via an old dirt road running through the sugarcane field and trekking across an abandoned, overgrown vegetable plantation to get to the riverbank.

The river was quite shallow and the riverbed surface comprised mainly of silt and mud. Samples were collected from knee-deep water.

Riverbank vegetation on both sides comprised thick para grass and riparian vegetation with some eroded, exposed areas. Sediment samples at this site were very similar to those found at the first three sites, comprising silt and clay.

- **Picture 5 – Riverbank Vegetation Showing Thick Para Grass and Eroding Riverbank Areas Where Exposed**

- **Picture 6 Left – Overgrown Field Next to River that Provided Access to Sampling Site; Right – SCOPE Team undertaking Sediment Sampling**

1.2.5. Site 5 – Downstream of Nawaka River Bridge

Sediment samples were collected at 8.50 a.m. adjacent to and immediately downriver of the Nawaka River bridge which is located approximately 150 meters southeast of Nadi Town. Access to the site was relatively easy as a track led from the road to the riverbank.

The river was quite wide and deep at the sampling site, and riverbank substrates comprised of silt, sand and mud on one side and sand and gravel on the other side. Large rock boulders were also observed next to the bridge to assist in protecting the banks from erosion. Women from nearby communities were observed fishing onsite.

Riverbank vegetation on both sides comprised of paragrass and some shrubs, as was observed in previous sampling sites. The sediment samples at this site comprised sand and gravel.

- **Picture 7 Left – Sampling Site Showing Silt and Sandy Mud on One Bank and Sand and Gravel on the Other Side; Right – Local Women Fishing Next to Large Rock Boulders Placed Near Bridge**

1.2.6. Site 6 – Midpoint of Nawaka River (Korociri Settlement)

The 6th sampling site was located around the midpoint of Nawaka River, outside an informal settlement known as Korociri. Access to the site was relatively easy as the sampling spot was a popular swimming spot with the local community and the sampling team was able to follow a track that led right to the water's edge. Samples were collected in waist-deep water at 9.24 a.m. during fine weather.

The river widened in some areas and narrowed further down where a narrow inlet joined the river. Riverbank substrate comprised of sand and gravel, as did the riverbed sample. Riverbank vegetation comprised of para grass, shrubs and big rain trees that had their roots exposed on the riverbank, indicating riverbank erosion.

- **Picture 8 Sampling Site Showing Sand and Gravel Riverbanks and Rain Trees Growing on Opposite Bank with Roots Exposed Due to Bank Erosion**

- **Picture 9 Left – SCOPE Team Undertaking Sediment Sampling; Right – Effects of Flooding by TC Winston Week Earlier Showing Riverbank Vegetation**

1.2.7. Site 7 – Outside Nawaka Village

The 7th sampling site along the Nawaka River was located outside Nawaka village. Access to this site was also relatively easy as the sampling spot was a popular swimming spot and washing (for clothes and bathing) area with the village community and the sampling team was able to follow a track that led right to the water's edge.

Samples were collected at 9.50 a.m. during fine weather. In addition to swimming and washing clothes, the SCOPE team observed that the local community also used the area as a fishing spot and also as a watering hold for cows and horses to drink and bathe in.

The river was quite deep in certain areas but shallow at the sampling site. Riverbank vegetation comprised of grasses, shrubs, banana trees, castor bean and rain trees. Riverbank substrate comprised rock on the sampling side and sandy soil on the opposite bank, while riverbed substrate comprised sandy soil and gravel.

- **Picture 10 Sampling Site Outside Nawaka Village**

- **Picture 11 Top Left & Right – SCOPE Team Undertaking Sediment Sampling; Bottom – In Addition to Being a Popular Swimming Spot, Nawaka River is also Used By the Village Community for Washing Clothes (Left) and Fishing (Right)**

1.2.8. Site 8 – Along Malakua River Bend (Adjacent to Sugarcane Fields)

The 8th sampling site was situated along the Malakua River, approximately 120 meters downriver from Site 4, at a bend in the river. The site was selected because it may possibly be cut off from the main river during proposed river realignment works. Samples were collected in thigh-deep water at 8.15 a.m.

Riverbank vegetation comprised of thick para grass and shrubs, and some exposed areas displayed eroded river banks. Riverbank substrates indicated clay soil, as did the riverbed sample.

- **Picture 12 Final Sediment Sampling Site along the Malakua & Nawaka Rivers**

■ **Picture 13 Left – Exposed River Bank Displaying Soil Erosion; Right – SCOPE Team Undertaking Sediment Sampling**

1.3. Sediment Analysis Results

Analysis of sediment samples was undertaken by Hills Labs of Hamilton, New Zealand. Results of the analysis are outlined in Tables 1 & 2. The Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC 1992) have been used in this report in the absence of appropriate sediment quality guidelines for Fiji. The ANZECC provides sediment quality guidelines for Australia and New Zealand, and the guidelines apply slightly to moderately disturbed and highly disturbed aquatic ecosystems.

■ **Table 1 Results of Sediment Analyses for the 8 Sites in Comparison with ANZECC Guidelines**

Sediment Analysis Parameters – Heavy metals	Unit	1	2	3	4	5	6	7	8	Guidelines*
Arsenic (As)	mg/kg	1.8	0.9	1.0	1.1	0.7	0.7	0.8	1.2	20
Cadmium (Cd)	mg/kg	0.09	0.37	0.12	0.05	0.04	0.06	0.08	0.06	1.5
Chromium (Cr)	mg/kg	35	58	29	15.5	32	42	35	17	80
Copper (Cu)	mg/kg	40	59	42	21	17.8	24	24	25	65
Lead (Pb)	mg/kg	4.8	2.4	2.3	1.3	0.64	0.96	1.1	1.1	50
Mercury (Hg)	mg/kg	0.017	0.015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.15
Nickel (Ni)	mg/kg	21	32	20	12.8	24	27	30	16.1	21
Zinc (Zn)	mg/kg	86	95	74	55	51	52	51	68	200

*ANZECC (2000) recommended guideline values, tabulated as Interim Sediment Quality Guideline (ISQG) – Low (Trigger value).

The results outlined in Table 1 indicate that heavy metal values fall well below the recommended ANZECC guidelines, with the exception of Nickel. Recommended maximum guideline values for

Nickel are 21 mg/kg; however results indicate that trace values for Nickel at four of the sites (Site 2, Site 5 – 7) exceeded the recommended guideline values and ranged from 24 – 32 mg/kg.

Nickel occurs in the environment at very low levels and is vital in small doses but can be dangerous when maximum tolerable amounts are exceeded. The major sources of nickel contamination in soil are metal plating industries, combustion of fossil fuels, nickel mining and electroplating. Nickel can also end up in surface water when it is a part of wastewater streams. Sites 2 and 7, which were located behind the Nadi town industrial area and Nawaka village respectively, were situated near garbage disposal areas, as evidenced by the mounds of rubbish and debris observed; this may have played a role in the high trace amounts of Nickel recorded within the samples.

The larger part of all Nickel compounds that are released to the environment will adsorb to sediment of soil particles and become immobile as a result. Micro-organisms can also suffer from growth decline due to the presence of Nickel, but they normally develop resistance to it after a while.

Table 2 outlines the results of sediment analysis for other physical and chemical parameters including pH and nutrients like nitrates, phosphorous and manganese. Unfortunately there are no recommended guidelines in Fiji's Environmental Management Waste Regulations 2007 to compare the results against.

- **Table 2 Sediment Analysis Results for Physical Parameters**

Sediment Analysis Parameters	Unit	1	2	3	4	5	6	7	8
pH	unit	7.5	7.7	6.9	7.7	7.8	6.7	7.3	7.1
Organic Matter	g/100g	4	6.1	4.4	2.6	1.86	1.66	2	3.7
Dry Matter	g/100g	65	66	66	77	89	85	89	71
Ash	g/100g	96	94	96	97	98	98	98	96
Manganese	mg/kg	470	1,220	700	690	480	370	640	960
Phosphorous	mg/kg	340	230	320	360	340	260	230	390
Nitrite + Nitrate	mg/kg	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	1.4	<1.0

JICA Study Team
Planning of the Nadi River Flood Control Structures Project

Additional Environmental Field Survey

Malakua & Nawaka Rivers

TERRESTRIAL ASSESSMENT

- Final Issue
- March 2016

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1. Contents

1. Introduction

The Government of Fiji and Japan signed a Memorandum of Agreement in late 2014 for the study of the Planning of the Nadi Flood Control Structure Project to address flooding along the Nadi River catchment area and the Region.

In 2015 SCOPE Pacific was engaged by the JICA Study Team to carry out basic data gathering and environmental field survey works which included terrestrial flora and fauna assessment, water quality sampling and analysis, freshwater ecological assessment, and sediment sampling and descriptive assessment of the sample sites of the Nadi River and which were undertaken in August 2015.

In December 2015, JICA requested SCOPE to undertake additional environmental field surveys along the Malakua and Nawaka Rivers as well as around Moala village and the Nadi River mouth, comprising the same assessments and parameters as undertaken for the Nadi River. These additional areas were required to be covered in the environmental surveys due to proposed dykes, river diversion and retaining walls being considered by the JICA Study Team in these areas.

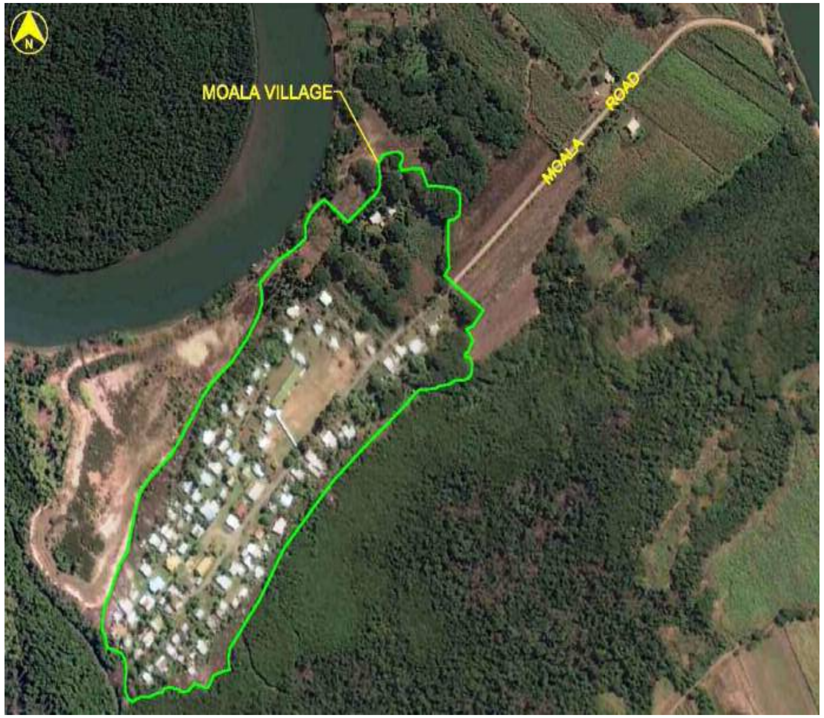
A terrestrial flora and fauna assessment was undertaken March 2016 around Moala village as well as along the banks of the Malakua and Nawaka Rivers over a three-day period, from 29th February to 2nd March. This terrestrial assessment covered an area of 1.5 kilometers around Moala village as well as approximately 4.5 kilometers of riverbank as required by the JICA Study Team.

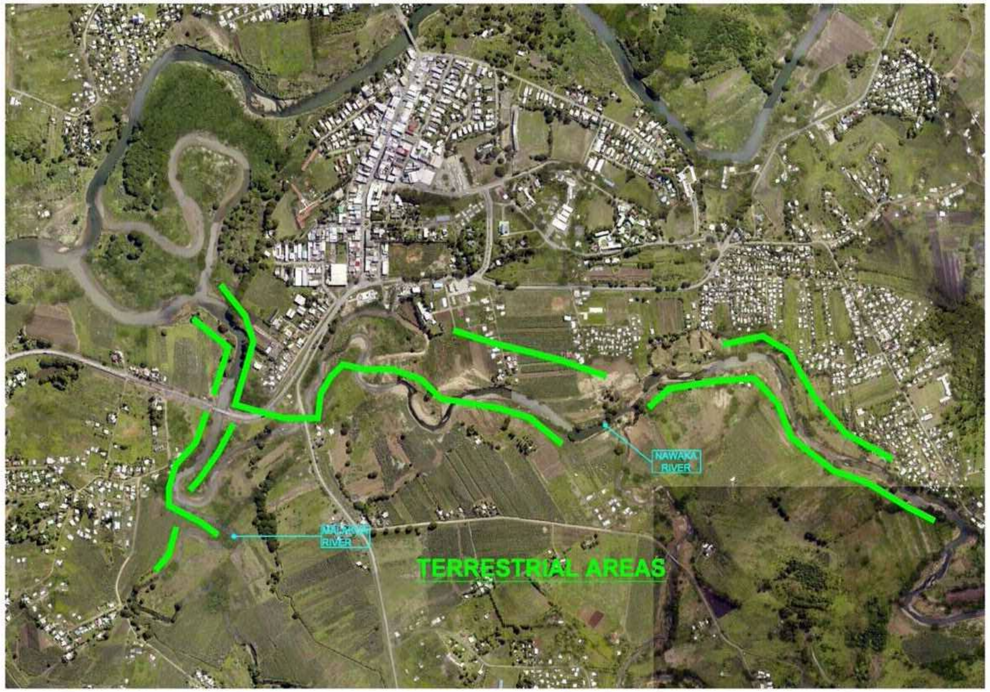
1.1. Methodology

The terrestrial ecological assessment was undertaken on differing sides of the Malakua and Nawaka Rivers, and an aerial photograph was used to randomly identify and select the different types of vegetation cover along the river banks within the study area. The areas covered in the surveys are depicted in Figure 1.

Methodology for the surveys comprised of visual observation, analysis and inventory-taking to record the types of vegetation (flora), animals (fauna) and birds (avifauna) present on-site whilst walking the entire length of riverbanks within the study area. Descriptions of the physical terrain and surrounding land uses were also noted down.

■ **Figure 1 Locality Maps Showing Terrestrial Survey Areas**





2. Description of the Existing Environment

2.1. Vegetation Types

A total of 67 species of vegetation were recorded along the banks of the Malakua River and the Nawaka River. A lesser number of species were recorded along these rivers as compared to the Nadi River terrestrial surveys; one factor that may have played a role in the lesser number of species recorded is the fact that the surveys were undertaken a week after TC Winston ravaged the country, and cyclone weather most likely adversely affected riverbank vegetation at the time of recording. Dead and damaged plants and trees were apparent on the riverbanks within the areas of study.
As with the Nadi River surveys, vegetation remained uniform along both banks of the Malakua and Nawaka Rivers, with several species recorded consistently along the areas of study. Land use along the banks of both rivers comprised of vegetable and root crop plantations and sugarcane fields as well as a lot of access tracks or 'shortcuts' used by the many residential communities and villages located on both sides of the Nawaka River. Remainder of the vegetation that were recorded comprised mainly of bushland and thick grassy areas that made walking along the riverbanks difficult in most areas.

- **Table 1 Categories of Vegetation and Number of Species Recorded in Each Category.**
***Note: Some species appear in more than 1 category.**

Vegetation Type	No. of species recorded
Shrub/Grasses	24
Food/Fruit	24
Medicine	10
Domestic Use	7
Ornamental Value	5
Weed	3
Timber value	3
Commercial use	1

2.1.1. Shrubs and Grasses

A total of 24 shrubs and grasses were recorded; majority of the species are aboriginal introductions to the region and are common within woodland areas.
Paragrass (*Brachiaria mutica*) was abundant and was observed in all transects; thick paragrass riparian vegetation was apparent along both banks of the Malakua and Nawaka Rivers, except for areas that had been cleared for rootcrop and sugarcane plantations. Paragrass is an aboriginal introduction that has become naturalized and is common in all areas along the Nadi, Malakua and Nawaka Rivers.

- Picture 1 Thick Paragrass Riparian Vegetation Along The Banks of the Malakua River

Other naturalized grass species observed within the study area include Goose grass (*Eleusine indica*), Jungle rice (*Echinochloa colona*), Beach wiregrass (*Dactyloctenium aegyptium*), Carpet grass (*Axonopus compressus*), Indian dropseed (*Sporobolus diander*), Swollen fingergrass (*Chloris barbata*) and Hilo grass (*Paspalum conjugatum*).

Three species of sedges were observed within study areas; these included the Umbrella sedge (*Cyperus involucratus*), the Navua sedge (*Kyllinga polyphylla*) and the Bunchy flat sedge (*Pycreus polystachyos*). All three species are aboriginal introductions that have become naturalized over time.

Other shrubs recorded onsite included the Broomweed (*Sida rhombifolia*), Coat buttons (*Tridax procumbens*), Garden spurge (*Chamaesyce hirta*), Sandbur (*Cenchrus echinatusi*) and countless others.

A total of twenty (20) species of shrubs, sedges and grasses were recorded on the outskirts of Moala village; these are outlined in the following tables. All recorded species are introduced species that have become naturalized over time.

- Table 2 Different Sedge Species Recorded In Moala Village

Sedge			
Local Name	**English Name**	**Scientific Name**	**Description**
-	Navua sedge	*Kyllinga polyphylla*	Aboriginal introductions that have become naturalized over time
-	Umbrella sedge	*Cyperus involucratus*	
-	Bunchy flat sedge	*Pycreus*	

- Table 3 Different Grass Species Recorded In Moala Village

Grass			
Local Name	**English Name**	**Scientific Name**	**Description**
Para	Paragrass/ California	*Brachiaria mutica*	

-	Goose grass	*Eleusine indica*	Aboriginal introductions that have become naturalized over time
-	Indian dropseed	*Sporobolus diander*	
-	Jungle rice	*Echinochloa colona*	
Co	Carpetgrass	*Axonopus compressus*	
Co	Swollen fingergrass	*Chloris barbata*	
-	Beach wiregrass	*Dactyloctenium aegyptium*	

▪ **Table 4 Different Shrubs Recorded In Moala Village**

Shrub			
Local Name	**English Name**	**Scientific Name**	**Description**
-	Cocklebur	*Xanthium strumarium*	Aboriginal introductions that have become naturalized over time
Deniose	Broomweed	*Sida rhombifolia*	
-	Ivy gourd	*Coccinia grandis*	
-	Wild	*Passiflora foetida*	
-	Coral berry	*Rivina humilis*	
-	False mallow	*Malvastrum*	
-	Prickly	*Solanum torvum*	
-	Coat buttons	*Tridax procumbens*	
-	Garden	*Chamaesyce hirta*	
-	Sandbur	*Cenchrus echinatus*	

A complete inventory of the different shrubs, grasses and sedges observed on-site is found within Appendix A.

2.1.2. Edible Fruits and Plants

A total of 24 species of edible fruits and plants were recorded within the study area. Some vegetables, fruits and root crops were grown in plantations while some were found to also grow in the wild. The majority of these are outlined in Table 5.

▪ **Table 5 Vegetables, Fruits and Root Crops Observed within Study Areas**

Vegetables & Fruits		
Local Name	**English Name**	**Scientific Name**
Quwawa	Guava	*Psidium guajava*
Niu	Coconut	*Cocos nucifera*
Moli karokaro	Lemon	*Citrus limon*
Jaina	Banana	*Musa acuminata*
Uto	Breadfruit	*Artocarpus altilis*
Tamarini	Tamarind	*Tamarindus indica*
Tavola	Tropical almond	*Terminalia catappa*
Bele	Aibika/ Hibiscus manihot/	*Abelmoschus manihot*
-	Curry tree	Ivi
Ivi	Tahitian chestnut	*Inocarpus fagifer/ Inocarpus edulis*
Dovu	Sugarcane	*Saccharum officinarum*

Tubua	Spiny amaranth	*Amaranthus spinosus*
Weleti	Pawpaw	*Carica papaya*
Papukeni	Pumpkin	*Curcubita spp.*
Baigani	Eggplant	*Solanum melongena*
Moli	Kumquat	*Citrus japonica*
Rokete	Chillies	*Capsicum frutescens*
Moli batiri	Wild orange	*Citrus macroptera*
Maqo	Mango	*Mangifera indica*
Root Crops		
Local Name	**English Name**	**Scientific Name**
Dalo	Taro	*Colocasia esculenta*
Tavioka	Cassava	*Manihot esculenta*
Via	Giant swamp taro	*Cyrtosperma chamissonis*

In Moala village, a total of nine (9) species of trees with edible fruits were recorded. These included the Raintree (*Samanea saman*), Guava (*Psidium guajava*), Wild orange (*Citrus macroptera*), Mango (*Mangifera indica*), Lemon (*Citrus limon*), Banana (*Musa acuminata*), Breadfruit (*Artocarpus altilis*), Tamarind (*Tamarindus indica*), and the Tahitian Chestnut (*Inocarpus fagifer*).

Two (2) species of trees bearing edible nuts were recorded onsite; these were the Coconut (*Cocos nucifera*) and the Tropical Almond tree (*Terminalia catappa*). Three (3) common root crops were observed growing onsite; these were Taro or '**dalo**', Giant swamp taro or '**via**', and Cassava or '**tavioka**'.

Edible hibiscus or '**bele**' was also recorded onsite; it is a common food plant normally consumed by many indigenous households and is generally served as the greens portion in several local dishes. The Curry-leaf tree (*Murraya koenigii*) was observed growing on the outskirts of the village; as the name suggests, the leaves of this tree are commonly added to local curry dishes to enhance the flavor of the dish. Golden senna (*Senna surattensis*) was also observed growing abundantly outside the entrance to the village; it is generally consumed as a vegetable in other parts of the world, but not in Fiji.

A complete inventory of the different fruits, vegetables and root crops observed on-site is found within Appendix A.

2.1.3. Medicinal Trees & Plants

Several shrubs and herbs and some ornamental plants and trees observed have high medicinal value for local communities. A total of 10 medicinal species were identified; these included the Commelina (*Commelina diffusa*) or '**co qaloqalo**', the Ti tree (*Cordyline terminalis*) or '**vasili**', the Noni (*Morinda citrifolia*) or '**kura**', the Mile-a-minute vine (*Mikania micrantha*) or '**wabosucu**',and the Edible hibiscus (*Abelmoschus manihot*) or '**bele**'.
The juice from the leaves of the Commelina (**co qaloqalo**) is commonly used to relieve menstrual pain, while the roots of the Ti tree (**vasili**) are used to cure toothaches. The juice from the leaves of Ti trees is also used to treat ear-aches as well as to relieve colds and coughs.
The Noni, or '**kura**' as it is locally known, and the Mile-a-minute creeper vine or '**wabosucu**' were recorded during the Nadi River survey and have been identified again in this report as they are immensely popular medicinal plants within local communities.
The Noni has been used as a natural remedy for treating numerous sicknesses and ailments including joint pain and swelling, backaches, headaches, muscle pain, arthritis, sprains and strokes. It is also used as a

general elixir and poultice to treat skin infections and inflammation, and the fruit juice has become a major export for the South Pacific region to Europe and North America; in addition, secondary products such as shampoos, soaps, skin creams, herbal tea and tablets have been manufactured and marketed (Pande et al., 2005). Local communities also utilize the bark and roots of the Noni tree, a native species, as natural dyes.
The leaves of the Mile-a-minute creeper vine (**wabosucu**) are rubbed on to cuts and wounds to staunch bleeding, and native women that have recently borne children via caesarian section operation normally drink a concoction made from the leaves to help their bodies heal quicker from the inside.
A juice made from the leaves of the Edible hibiscus (**bele**) is sometimes consumed by native women just before they give birth, to aid in the delivery process.
Medicinal plants recorded on the outskirts of Moala village also included Noni (**kura**), Commelina (**co qaloqalo**), Ti tree (**vasili damu**) and the Edible hibiscus (**bele**), as well as the Anil Indigo plant (*Indigofera suffruticosa*) or **'vaivai'**, which is used as an anti-inflammatory medicine, and the Giant swamp taro (*Cyrtosperma chamissonis*) or **'via'**. The Giant swamp taro is not only a common root crop for local indigenous communities, but the heated sap of the stem is dripped into ears to treat earaches or boils in the ear, and the roots are also used to treat swollen lymph glands.
A complete inventory of the many plants of medicinal value found at all sites is found within Appendix A.

2.1.4. Timber Trees and Plants of Important Domestic Use

Three (3)trees of timber value were observed within the study area; the Raintree (*Samanea saman*) or **'vaivai-ni-vavalagi'**, the Tropical almond (*Terminalia catappa*) or **'tavola'**, and the Chinese-lantern tree (*Hernandia nymphaefolia*) or **'evuevu'**.
The Raintree was the dominant tree species along the banks of the Nawaka River and was also recorded along the Malakua River. The Raintree is an introduced species whose wood can be used in timber production and whose fruit is edible.

- **Picture 2 Raintrees (*Samanea samani*) on the bank of the Nawaka River.**

The Tropical almond and the Chinese-lantern tree are both native species that can be utilized in house building and also have important domestic value such as wood used to make canoes and other artefacts. The Tropical almond also has edible, nut-like fruits.
Four (4) other species of trees and plants of important domestic value were recorded within the study areas. These were the Noni (*Morinda citrifolia*) or **'kura'**, the Red mangrove (*Rhizophora stylosa*) or **'tiri'**,

the Screwpine (*Pandanus tectorius*) or '**balawa**', the Bamboo (*Schizostachyum glaucifolium*) or '**bitu**', and the Chinese-lantern tree (*Hernandia nymphaeifolia*) or '**evuevu**'.
As mentioned in the previous section, juice made from Noni fruit has become a major export for the South Pacific region to Europe and North America, and other products such as shampoos, soaps, skin creams, herbal tea and tablets have been manufactured and marketed. In addition to this, local communities commonly utilize the bark and roots of the Noni tree to create natural dyes.
Screwpine (**balawa**) plays an important role within Fijian society because its leaves are used to weave mats that can be found in all Fijian households, as well as thatches, sails, baskets, hats, etc. Mats also play an important role in Fijians' traditional structure because they are commonly presented as gifts during weddings, funerals, farewell ceremonies, and all other Fijian social ceremonies. In addition the edible fruit and prop roots are a source of food and native medicines in various parts of the Pacific.
Bamboo (**bitu**) wood is commonly used to make water rafts and is also used as water containers and fishing poles.
Mangroves (**tiri**) are vital in coastal areas as they protect shorelines from the eroding activities of waves and from potential damage to coastal areas during storm surges and high wave events. In addition, they are vital nurseries and breeding grounds for many important fish species as well as invertebrates and other aquatic organisms. Mangrove wood is also a very good source of firewood, and the bark of the **tiri** is used by local women to produce the brown dye used in printing tapa.

Timber trees recorded in Moala village were the Rain tree and the Tropical Almond tree, while trees and plants of important domestic use recorded in Moala village also included the **kura**, **balawa**, and **tiri**. Another species of domestic importance that was recorded was the Coconut (*Cocos nucifera*) or '**niu**'. It is known in the Pacific region as the Tree of Life as all parts of the tree are utilized; coconut milk is a major part of the daily diets of local villagers, the leaves are used to make *sasa* brooms and are also woven into baskets to store food, coconut husks are commonly used as kindling in cooking fires, and coconut trunks have also been utilized by local manufacturing companies to make furniture.

2.1.5. Weeds and Invasive Species

A total of three (3) species of weeds and invasive species were recorded within the study area; these included the Cocklebur (*Xanthium strumarium*), Castor-bean plant (*Ricinus communis*), and Sensitive grass (*Mimosa pudica*) or '**co gadrogadro**'. All three species are introduced species that have become naturalized over time. In addition to its status as a weed, the Castor-bean plant is also considered a commercially viable plant in other parts of the world; this is discussed more in the following sections.
All three species were recorded in Moala village as well as from the other study areas.

2.1.6. Ornamental Plants & Flowers

A total of five (5) species of ornamental trees, plants and flowers were recorded within the study areas; these included the Umbrella sedge (*Cyperus involucratus*), the Ginger plant (*Alpinia purpurata*), the Royal palm (*Roystonea regia*), the Golden Cane or Areca palm (*Chrysalidocarpus lutescens*), and the Indian Mast tree (*Polyalthia longifolia*), all of which are introduced species. Of these, the Ginger plant and the Umbrella sedge were recorded in Moala village.

- **Picture 3 Umbrella Sedge (*Cyperus involucratus*) Observed on the Outskirts of Moala Village**

- **Picture 4 Royal Palm (*Roystonea regia*) Growing on the Bank of the Nawaka River**

2.1.7. Plants of Important Commercial Value

The only plant of important commercial value that was recorded within the study areas was the Sugarcane (*Saccharum officinarum*) or **'dovu'**.
As mentioned in the Nadi River terrestrial assessment, large-scale sugarcane production is common in the western region of Viti Levu where Nadi is located and it is one of the oldest and most vital primary industries in Fiji. The stem of the sugarcane is commercially processed for the production of brown sugar which is a major export commodity of the Fiji economy and which is also sold locally.

- **Picture 5 Sugarcane Field Situated Along the Bank of the Malakua River**

2.2. Fauna and Avifauna

A total of twenty-two (22) species of animals, insects and birds were recorded along the banks of the Malakua and Nadi Rivers and on the outskirts of Moala village. The recorded number of fauna and avifauna species comprised five (5) species of animals, eleven (11) species of insects of which seven (7) species were butterflies, and six (6) species of birds.

2.2.1. Animals and Insects

Animals recorded comprised locally common species including the Horse (*Equus ferus caballus*) or **'ose'**, Cow (*Bos taurus*) or **'bulumakau'**, Pig (*Sus scrofa domesticus*) or **'vuaka'**, Toad (*Bufo bufo*) or **'boto'**, and the Red-Clawed Crab (*Sesarma erythrodactyla*) or **'kuka'**.
Insects included the Red dragonfly (*Diplacodes bipunctata*), Wasp (*Polistes olivaceus*) or **'pi'**, Honeybee (*Apis mellifera*) or **'oni'**, the Ladybug (*Coccinellidae*), and seven (7) species of butterfly which are outlined in Table 6. The Red dragonfly is native to Fiji.
Of the seven recorded species of butterflies, three species are endemic to Fiji – the Common Crow, Blue Moon, and Capper White.

- **Table 6 Butterflies Recorded Within the Study Areas Along the Malakua & Nawaka Rivers and Around Moala Village**

Butterflies		
English Name	**Scientific Name**	**Status**
Common Blue	*Zizina otis*	Introduced, naturalized, common

Common Sulphur	*Eurema hecabe sub. sulphurata*	Introduced, naturalized, common
Small Grass Yellow	*Eurema brigitta australis*	Introduced, naturalized, common
Common Crow	*Euploea lewinii sub. eschscholtzii*	Endemic
Blue Moon	*Hypolimnas bolina sub. pallescens*	Endemic
Evening Brown	*Melanitis leda sub. solandra*	Native
Capper White	*Belenois java sub. darissa*	Endemic

Animals and insects observed on the outskirts of Moala village were cows, horses, pigs, the small Red-Clawed Crab (in mangrove areas), wasps and honeybees. Three (3) species of butterflies were also recorded; the Small Grass Yellow, the Common Blue and the Common Crow.

2.2.2. Birds

Six (6) species of birds were recorded within the study area; of these, two (2) species are native to Fiji. Details of these species are highlighted below in Table 7.

- **Table 7 Birds Recorded Within the Study Areas Along the Malakua & Nawaka Rivers and Around Moala Village**

Local Name	English Name	Scientific Name	Status
Maina	Common Mynah	*Acridotheres tristis*	Introduced
Ulurua/ Uluribi	Red-vented Bulbul	*Pycnonotu scafer*	Introduced
Ruve	Feral Pigeon	*Columba livia*	Introduced
Matayalo	Vanikoro Broadbill	*Myiagra vanikorensis*	Native
Belo	Eastern Reef Heron	*Egretta sacra*	Native
Manumanu ni Doa	Pacific Swallow	*Hirundo tahitica*	Native

The Common Mynah is an introduced species that is primarily a ground-feeding insectivore and also expanded its diet to feed on fruit, grains and domestic waste. The Common Mynah's habitat is restricted to the proximity of human households, and was purposely introduced to Fiji in 1890 to control insect pests of the emerging sugar industry.

The Red-vented Bulbul was also introduced in the late 19th century or early 20th century; however it was not a deliberate introduction but instead may have likely arrived with the indentured labourers. Bulbuls are omnivorous with the bulk of their diet comprising fruits and berries and a smaller portion of insects. Flowers also form a significant part of their diet, as do the fruits of weed species such as the Prickly Solanum which was present in several of the sites studied. Bulbuls are aggressive species that may disrupt native bird populations; therefore their spread should be restricted wherever possible.

The Feral Pigeon may have arrived with the missionaries in the mid-19th century, as early as 1840. Its habitat is normally restricted to urban areas where it feeds on grains and domestic scraps, and this species rarely establishes in agricultural areas.

The Vanikoro Broadbill is considered a regionally near-endemic species. It is a native species that has adapted to man-modified habitats and is distributed from montane forests to mangroves. It feeds on insects and is an avid 'leaf-snatching fly-catcher' that is able to take insects from the underside of leaves on short aerial sallies. The Vanikoro Broadbill also persistently harasses predatory bird species that enter the vicinity of its nest.

The Eastern Reef Heron is a common species in Fiji and the region. It is found in any aquatic habitat from an exposed reef to a small inland stream in thick forest. The heron's diet comprises fish, crustacean and molluscs, and sometimes also includes insects and lizards.
The Pacific Swallow is found throughout Fiji and is an aerial feeder of flying insects and is commonly found in coastal and estuarine habitats, as well as along rivers inland.
Four (4) species of birds were recorded in Moala village – the Feral Pigeon, the Common Mynah, the Red-vented Bulbul, and the Vanikoro Broadbill.
A complete inventory of the types of animals, insects and birds found on-site is attached as Appendix B.

3. References

1. https://books.google.com.fj/books?id=jxvMfprugfAC&pg=PA212&lpg=PA212&dq=Commelina+diffusa+fijian+medicinal+uses&source=bl&ots=KEgSBAZAiy&sig=nmOntu-55gxXSFfpXW3H06xb_fQ&hl=en&sa=X&redir_esc=y#v=onepage&q=Commelina%20diffusa%20fijian%20medicinal%20uses&f=false [accessed 17 March 2016]

2. Patrick, B. & Patrick, H. 2012. *Butterflies of the South Pacific*. Otago University Press. Dunedin, New Zealand.

3. Watling, D. 2004. *A Guide to the Birds of Fiji & Western Polynesia*. Environment Consultants (Fiji) Ltd.

4. Whistler, W. 1994. *Wayside Plants of the Islands – A Guide to the Lowland Flora of the Pacific Islands*. Everbest Printing Company Ltd. Hong Kong.

5. Marinov, M. & Waqa-Sakiti, H. 2013. *An Illustrated Guide to Dragonflies of Viti Levu, Fiji*. USP Press. Suva, Fiji.

Appendix A Complete Flora Inventory List

Appendix B Complete Fauna & Avifauna Inventory List

Nadi River Flood Control Study

SOCIAL SURVEY

- Final Issue
- April 2016

D14-128

Nadi River Flood Control Study

SOCIAL SURVEY

- Final Issue
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1. Introduction

Japan International Cooperation Agency (JICA) is undertaking the Nadi River Flood Control Study which aims to understand current physical data for the Nadi River basin as well as social data that will assist JICA in determining affected local communities' connection to the Nadi River and its tributaries and the uses/livelihoods they derive from the river and its surrounding areas.

Social data for the flood control study was derived from surveys of households and a few commercial operators that were undertaken in various areas around Nadi that are situated near the Nadi River and are likely to be affected.

1.1 Methodology

The households selected for the social surveys were chosen based on area and the types of flood control measures proposed such as river widening, retarding basin, dykes, ring dykes and retaining walls for river bank stabilization.

A total number of 121 households were surveyed in 8 areas that included 4 villages over a 2-day period from 2nd – 3rd March, 2016.

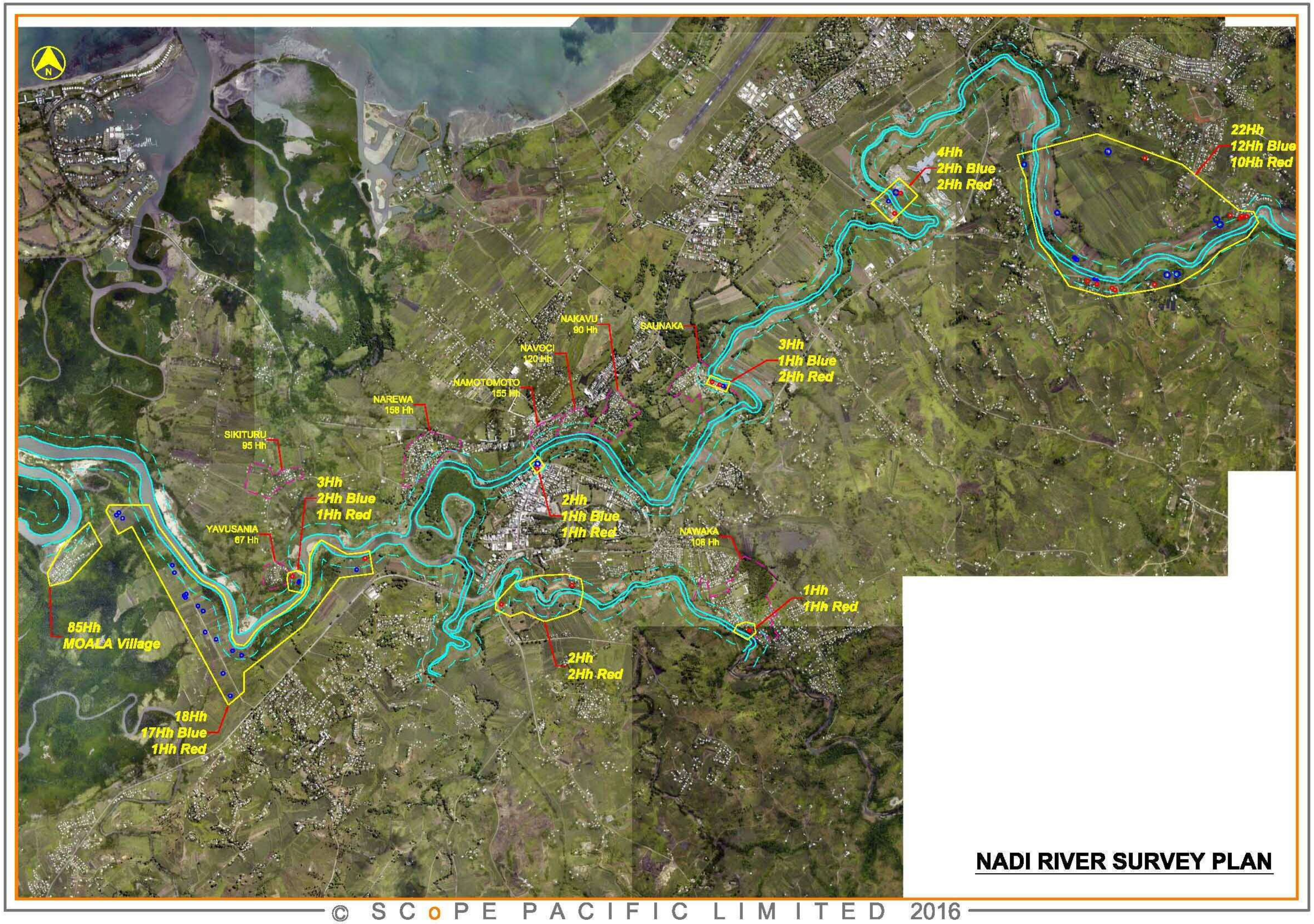
Table 1 Survey areas including number of households surveyed in each area.

Survey Area	*No. of Households*	*% of Total Survey Area*
Votualevu	14	12%
Moala Rd	16	13%
Moala Village	76	63%

Saunaka Village	5	4%
Nawaka Village	1	1%
Yavusania Village	1	1%
Nadi town entrance	3	2%
Off Nadi Back Road (Old Queen's Road single lane bridge)	5	4%
Total	**121**	

The largest numbers of households surveyed were situated in Moala village (63%), along Moala Road (13%) and in Votualevu ((12%) as these are likely to be the most affected areas during river upgrading and flood control works. The other areas surveyed covered the remaining area (12% of those surveyed) which included Nadi town, Saunaka and Nawaka and Yavusania villages, and off the Nadi Back Road (near the old Queen's Road single lane bridge).

▪ **Figure 1 Survey Areas along the Nadi and Nawaka Rivers**



1.1.1 Affected Areas (Displacement & Non-Displacement)

Affected areas have been categorized into two groups – Displacement and Non-displacement – on the basis of the types of flood control and river upgrading works to be carried out and which are envisaged to have a direct impact on identified areas. The types of upgrading works and associated affected areas are outlined below in Table 2, while Table 3 highlights property details for properties to be displaced and those not to be displaced.

Table 2 Affected Areas According to Type of River Flood Control and Upgrading Works

Flood Controls/River Upgrading Works	No. of Properties Affected	Area	Land Tenure
Required for Displacement			
River widening	6*	Yavusania village (x2)	Native
		Saunaka village (x1)	
		Nadi Town (x1)	
		Off Nadi Back Road (old single lane bridge) (x2)	Freehold
Not required for displacement			
Retarding basin	14	Votualevu	Freehold
Ring dyke	85	Moala village	Native
Riverbank improvements	17	Moala Road	Freehold
Total HH	***122****		

**Six (6) properties are highlighted as being affected by proposed river widening works; however 2 of those properties belong to 1 person (Yavusania village) and has therefore been counted as one household making the actual number of households surveyed totalled 121.*

Table 3 Breakdown of Property Details for those Properties Required for Displacement and those Affected But Not Being Displaced

Location	Owner	Structure	No. of structures	Tenure	Area (m^2)
Required for displacement					
Yavusania Village	Paula	Timber/ Iron	2	Native	4,910.2
Nadi Town	Vinal Naidu	Concrete/ Timber	1		460.53
Saunaka Village	Josateki Sovau	Concrete	1		55
Off Nadi Back Road	Razia Bibi	Concrete/ Timber	1	Freehold	2,244.33
	Kulaia	Timber	1		4,415.6
Not Required for Displacement					
Moala Village	All properties	Concrete	34	Native	20,313.2
		Concrete/ Timber	30		
		Timber	6		
		Iron	5		
		Concrete/ Timber/ Iron	1		
		Bure	1		

Votualevu Plains	Rajeshwar Prasad	Concrete/ Timber	1	Freehold	3,528.97
	Asinate Varo	Concrete/ Timber	1		13,562.56
	Asinate Varo	Timber/ Iron	1		13,562.56
	Shanil Chandra	Concrete	1		13,562.56
	Avenina Mereula	Concrete	1		Not disclosed
	Deb Merana	Concrete	1		6,764.56
	Deb Merana	Concrete	1		1,618.73
	Madukhant Devi	Concrete/ Timber	1		14,902.84

1.2 Survey Areas

1.2.1 Moala Village

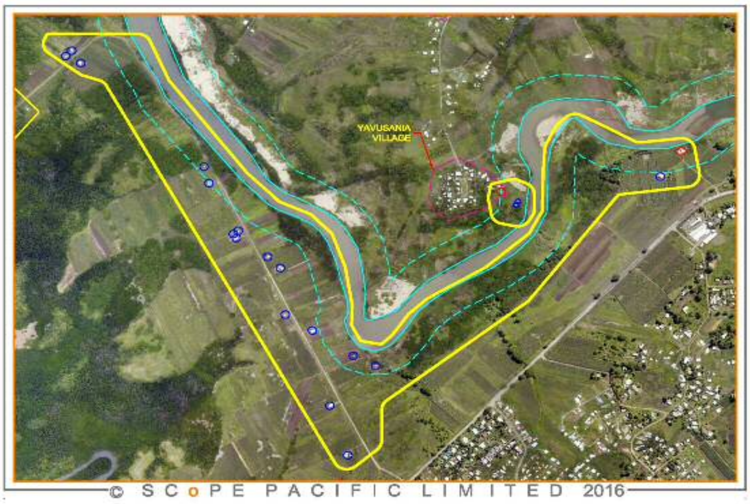
A total of seventy-six (76) households were surveyed in Moala village, although eighty-five (85) properties had been selected using aerial imagery. The remaining nine (9) properties that were excluded from the household surveys were observed to be the village hall, houses whose owners owned more than one house, and vacant houses and student lavatories within the Ralete Primary School compound.

- **Figure 2Properties within the Boundaries of Moala Village**

1.2.2 Moala Road & Yavusania Village

A total of sixteen (16) properties situated along Moala Road as well as two properties belonging to one owner which was counted as one household situated across the river at Yavusania village were selected for the household surveys. The two properties in Yavusania village will be displaced.

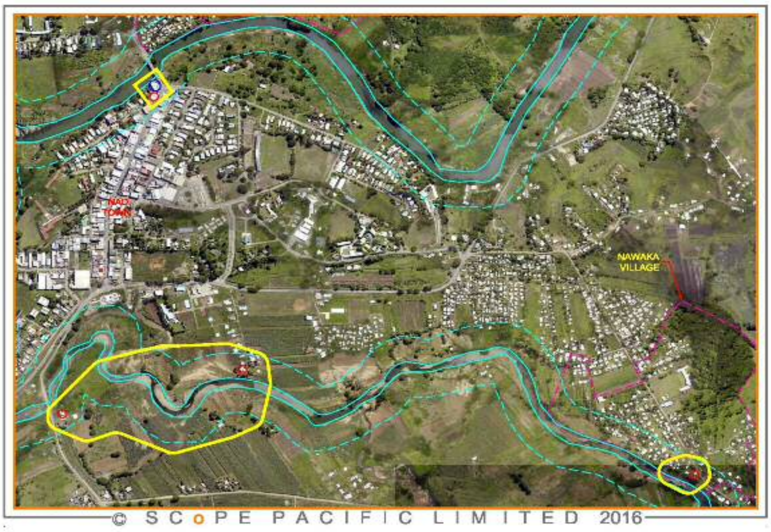
- **Figure 3Location of Properties along Moala Road and One Property in Yavusania Village**



1.2.3 Nadi Town and Nawaka Village

Three (3) properties situated near the entrance to Nadi Town (Sigatoka side) were selected for the household surveys, as was one (1) property at the eastern end of Nawaka village. One (1) property was also selected from the other entrance to Nadi town (Namotomoto side) for the commercial use survey as this property has been identified for displacement.

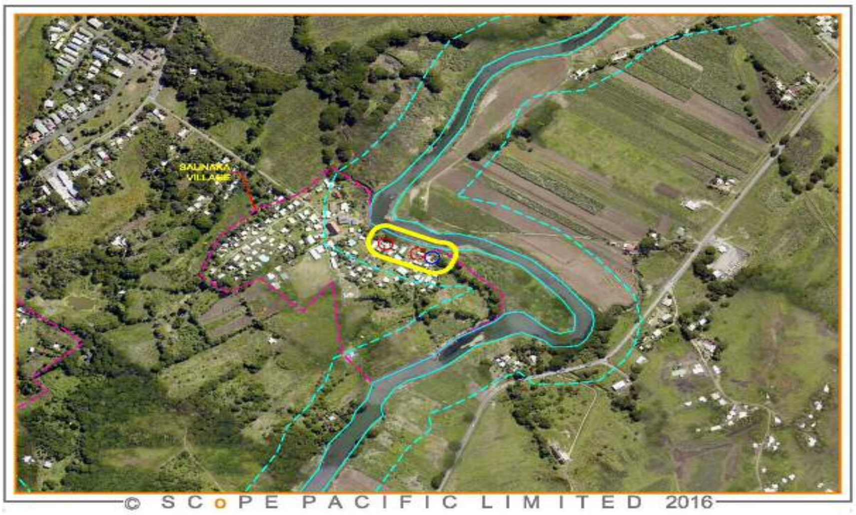
- **Figure 4Location of Properties Selected from Nadi Town & Nawaka Village**



1.2.4 Saunaka Village

Five (5) properties were selected from Saunaka village on the basis of their proximity to the Nadi River being within 100 metres of the river bank; their houses were observed to be situated in places near the riverbank where soil erosion was quite evident. One of these properties in Saunaka was also identified to be displaced.

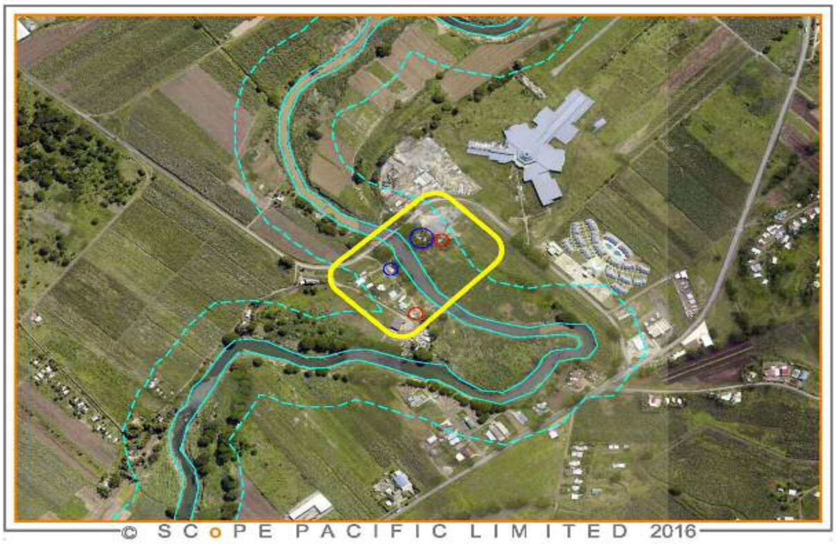
- **Figure 5 Location of Five Properties in Saunaka Village Adjacent to the River Bank**



1.2.5 Off Nadi Back Road (old single lane bridge)

Five (5) properties were selected near the old Queens Road single lane bridge off the Nadi Back Road. These properties were situated on either side of the river within 100 metres of the river bank. One of these five properties off the Nadi Back Road will be displaced.

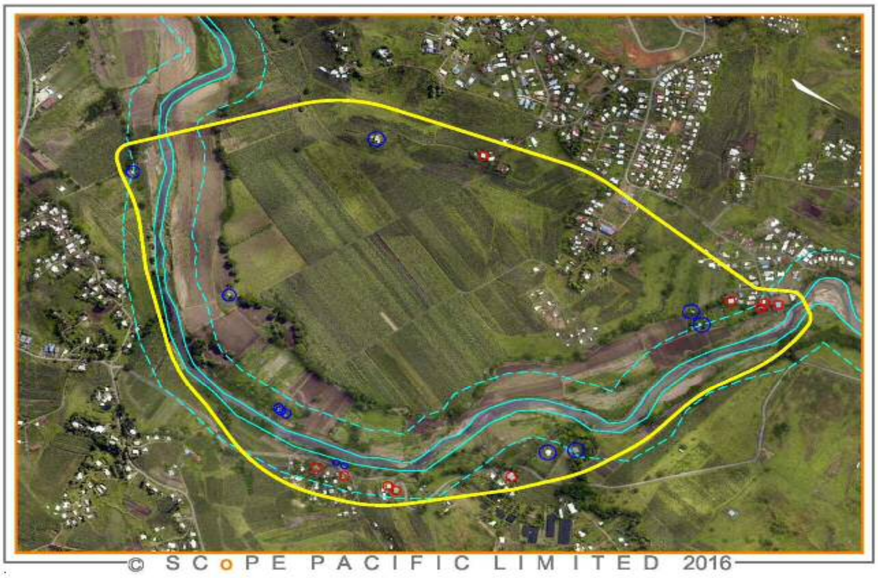
- **Figure 6Location of Five Properties Near the old Queen Queens Road Single Lane bridge**



1.2.6 Votualevu

Fourteen (14) properties were selected from the Votualevu area and the area on the opposite bank where the retention basin and dykes are proposed. There were no properties within the Votualevu area which were identified for displacement.

- **Figure 7Location of Fourteen (14) properties in the Votualevu area**



2. Household Survey Results

Questionnaires for the household surveys focused on the following key areas:

- Gender, ethnicity, marital status, and length of time residing in each area;
- Education;
- Employment;
- Income and livelihood;
- Land tenure;
- House structure and use;
- Land use;
- Access to utility services;
- Sanitation services;
- Solid waste disposal;
- Drainage issues;
- Local use and knowledge of the Nadi River; and
- Flooding issues related to the Nadi River.

2.1 Gender, Ethnicity, Marital Status, and Length of Stay

According to the survey results, females made up the majority of those interviewed at 58% (70) with 42% (51) males (Table 4). Of those surveyed, 79% (95) were *iTaukei* or indigenous Fijians while were 20% Indo-Fijians (25) and only 1 person was recorded as other ethnicity (1%) as shown in Table 5. Majority of Indo-Fijians interviewed reside along Moala Road and within the Votualevu area whilst others resided near Nadi Town and off the Nadi Back Road near the old single lane bridge.

- **Table 4 Gender Distribution of Those Surveyed**

	Male	Female
Votualevu	3	11
Moala Rd	5	11
Moala Village	36	40

Saunaka Village	4	1
Nawaka Village	0	1
Yavusania Village	0	1
Nadi town entrance	2	1
Off Nadi Back Road (single lane bridge)	1	4
Total	**51**	**70**
Total HH	***121***	
Total %	**42%**	**58%**

Table 5Ethnic Distribution of Those Surveyed

Ethnicity	Total No.	%
Indigenous Fijians (*iTaukei*)	95	79%
Indo-Fijians	25	20%
Others	1	1%
Total	**121**	

A total of 64% of those interviewed were married while 17% were single (majority of these were in Moala village) and 9% were widowed. Divorcees made up only 1% while the remaining 9% of interviewees did not specify their marital status.

Table 6 Marital Status of Those Interviewed

Marital Status	Total No.	%
Single	20	17%
Married	77	64%
Widowed	12	9%
Divorced	1	1%
Unspecified	11	9%
Total	**121**	

Majority (63 HH) of those interviewed indicated that they have resided in survey areas for more than 20 years (52%); of this figure, the majority were from Moala village (83%). As shown in Table 7 below, 30% surveyed stated they resided in the area for between 2 – 10 years (36HH) whilst 12% have resided in the surveyed areas for 11 – 19 years. The remaining 7% surveyed have resided in survey areas for less than 1 year. Quite a number of interviewees indicated they were not originally from the area they were residing in and have travelled from all parts of Fiji (32%); however majority of interviewees indicated they were originally from survey areas (66%), while only a small number did not disclose whether or not they were originally from survey areas (2%). Reasons behind moving to survey areas vary and include employment opportunities, education opportunities, farming, and for personal reasons.

Table 7 Length of Stay in the Surveyed Area (Years)

No. of Years	Total No.	%
Less than 1 year	7	6%
2 – 5 years	17	14%
6 – 10 years	19	16%
11 – 15 years	9	7%
16 – 20 years	6	5%
More than 20 years	63	52%
Total	**121**	

A total of 33% of these surveyed were in their mid-20's to late 30's, with 19% middle aged between 40-59 years old and 12% were between 60 to 77 years old; a small number were either in their early 20's or younger (6%),with 4% reluctant to disclose their age.

2.1.1 Critically Affected Areas (Displacement)

General information about the 5 property owners in Critically Affected Areas (CAAs) who were previously highlighted in Table 3 (required for displacement) is outlined in Table 8.

- **Table 8 Gender, Ethnicity, Marital Status, Land Use, No of Years Living/Operating in Area & Age of Property Owners in CAAs for Displacement**

General Information		Total No.
Gender	Male	2
	Female	3
	Total	**5**
Ethnicity	Indigenous (*iTaukei*)	3
	Indo-Fijian	2
	Total	**5**
Marital Status	Married	4
	Not disclosed	1
	Total	**5**
Land Use	Residential	4
	Commercial	1
	Total	**5**
No. of years living/operating in area	2 – 5 years	3
	6 – 10 years	2
	Total	**5**
Age	Late 20's	2
	Mid-40's	1
	Late 50's	1
	Not disclosed	1
	Total	**5**

2.2 Education

Of the 121 households interviewed, 96 households clarified the presence or absence of children in their homes while 25 households did not indicate the presence or absence of children. Table 9 indicates the number of children in each household, the total percentage of children in all 121 households interviewed, and the total percentage of children in the 96 households out of the total 121 that confirmed the presence or absence of children living in their homes.

Majority of households with childrenhave an average of 1 – 3 children (63%). A lesser number have 4 children in their households (12.5%), closely followed by those having no children at all (10%). 15 % of the households interviewed were recorded as having approximately 5 or more children.

Children from approximately 60% of households attend primary school (6 – 13 yrs) while the remainder are students attending secondary school (14 – 17 yrs) or tertiary institutions (18 yrs and older). Majority of the students in areas surveyed attend school in Nadi while a very small number were recorded as attending schools in Lautoka, Suva and Tailevu.

- **Table 9 Number and total percentage of children living in households in survey areas.**

No. of Children in HH	Total No. of HH	% (121 HH)	% (96 HH)
0	10	8%	10%
1	21	17%	22%
2	16	13%	17%
3	23	19%	24%
4	12	10%	12.5%
5	7	6%	7%
6+	8	7%	8%
Not disclosed	24	20%	-
Total	**121**		**96**

According to survey data, approximately 50% of students attend schools that are situated close to the Nadi River and are affected by flooding; however, desktop reviews of aerial imagery of the Nadi area indicate that only Ralete Primary School, which is situated in Moala village, is situated near the proposed river upgrading area and will therefore be affected by proposed works in and around Moala village. In addition, Ralete Primary School has been affected in past events of flooding in Moala village.
The majority of the primary school students in Moala village attend Ralete Primary School, which has a school roll of sixty-one (61) students, of which thirty-nine (39) live in Moala village and twenty-two (22) who travel to the school by bus from surrounding areas (Table 10).

- **Table 10 Name of School along the Affected Area, Number of Students, and Mode of Travel to School**

Name of the School	Location	Number of Students	Mode of Travel to School	
			Walk	Bus
Ralete Primary School	Moala Village	61	39	22*

** Students from outside Moala village*

The main mode of transportation for all school students in areas surveyed is either public transportation i.e. travelling by bus, or by walking. A minor few travel by car or hitch rides to areas close to their schools.
A small number of children who are above 15 years of age but do not attend school were recorded as having already joined the employment sector and work in farming, domestic duties, retail businesses, industrial work, and hotel work while one teenager was recorded to be staying home because of mental disabilities.

2.2.1 Critically Affected Areas (Displacement)

Of the 4 households in CAAs, the Yavusania household had 3 children, the Saunaka household had 7 children, one of the Nadi Back Road households had 4 children and the other household was an Indo-Fijian couple with no children. The 5th property in the CAAs was a commercial property and therefore personal information including the presence/absence of children did not apply.
Of the 3 residential properties with children, all 3 households had children attending primary school and the Nadi Back Road household also had children attending secondary school. All students from these households attended schools in the Nadi area and either walked to school or travelled by bus. Additionally, the Nadi Back Road household indicated that they had children above 15 years of age who were not receiving formal means of education but had instead joined the work field and were employees of Standard Industries and Post Fiji.

2.3 Types of Employment

Information from the household surveys conducted in all areas of interest revealed the many varied types of work that people living in those areas are involved in. These have been categorized into the following sectors:

- **Table 11 Eighteen (18) Different Sectors of Employment in Surveyed Areas**

Sector	No. of People	Sector	No. of People
Tourism	37	Marketeer	2
Farming	16	Manufacturing	1
Government	11	Construction	1
Sales & Retail	7	Management	1
Tradesman	6	Professional	1
Aviation	5	Services	1
Education	5	Domestic Services	1
Security Services	5	Administration	1
Fisheries	3	Civic (Religious)	1

The tourism sector (37 people) recorded the highest number of people, as is to be expected as Nadi is the tourism hub of the country. This was followed by those in the agricultural sector (farming – 16 people) and the public sector (Government – 11 people). Sales and retail followed, as did those in the trades sector. Aviation, education and security services recorded equal numbers of people (5 people). The fisheries sector (3 people) also recorded people involved in the fishing industry, as did those working as market vendors (2 people). Remaining sectors each recorded one person which included manufacturing, construction, management, professional experts, service trades, domestic services, administration and religious work.

2.3.1 Critically Affected Areas (Displacement)

Of the 4 residential properties in CAAs, the interviewee from Saunaka village indicated that all members of the household were unemployed. The interviewee at Yavusania village indicated that 2 members of their family worked, one as a hotel worker at Sheraton Resort on Denarau Island and the other as a security guard in the Namaka, Nadi.
The 2 interviewees from the properties off the Nadi Back Road indicated that members of their families worked for the Dai-Itchi company as a construction worker and the other for the national postal service, Post Fiji, based at Nadi Airport.
The interviewee of the sole commercial property known as Dulcinea Plaza indicated that he was merely the property manager, Mr Vimal Naidu who is responsible for looking after the commercial propertyfor the owner, Mr Suresh Patel who is a prominent business man in the Nadi area.

2.4 Household Occupants, Income & Livelihood

The results of the household survey revealed that the average permanent number of people in a household was 4 – 6, as was indicated by more than half of the interviewees (51%). Approximately 26% were recorded as having either 1 – 3 occupants whilst 20% had 7 – 9 people living within the household. Only 3 households indicated that there were more than 10 people living in their homes permanently. Very few households in survey areas had people living in the household temporarily with the exception of Moala village which recorded approximately 27 households (35%) with people living under temporary status.

- **Table 12 Amount of income recorded from survey areas in conjunction with land tenure.**

	House Holds		

Amount of Income	Native	State	Free	Not specified	Total No.	%
35,001 - 40,000FJD	1	-	-	-	1	1%
30,001 - 35,000FJD	1	-	-	-	1	1%
25,001 - 30,000FJD	1	-	-	-	1	1%
20,001 - 25,000FJD	1	1	2	-	4	3%
15,001 - 20,000FJD	2	-	-	-	2	2%
10,001 - 15,000FJD	9	1	1	1	12	10%
5,001 - 10,000FJD	13	1	2	-	16	13%
Less than 5,001 FJD	34	6	7	3	50	41%
Not specified	28	2	3	1	34	28%

The employment rate for survey areas was better than average, with more than half of the interviewees indicating that members of their households were either employed on a full-time (67%) or part-time (13%) basis. However, 19% of the interviewees indicated being unemployed. Most of those unemployed were recorded from Moala village, although 1 person living along Moala Road also indicated being unemployed due to physical disabilities.

Interviewees comprised mainly low income earners, with 41% earning less than $5,000 per annum with 23% earning $5,000 to $15,000 per annum. Only 2 households out of the 121 households interviewed recording incomes of $30,000 - $40,000 per annum which is classified as middle income earners.

The most common mode of travel recorded for workers is public transportation (65%) which comprised the public bus, taxis or mini-van operators. A total of 21% stated walking as their main mode of transportation whilst other modes of transportation recorded included private transportation (cars/motor bikes/bicycles), horses, boats, and hitching rides (15%).

The majority of interviewees (77%) indicated they did not own private vehicles such as cars. For those that did own vehicles, the most common type of vehicle was a car (33%), followed by those with tractors (15%), trucks and bicycles (6%), vans and motorbikes (3%).

2.4.1 Critically Affected Areas (Displacement)

Of the two households interviewed off Nadi Back Roadone household indicated having 6 people living permanently in their household whilst the other hadonly 2 people. Those interviewees in Saunaka and Yavusania villages recorded having 4 and 3 people respectively who were permanently living there.

A total of four households indicated annual incomes of less than $5,000 and these were households located off Nadi Back Road, Saunaka and Yavusania villages.The household members in Saunaka village are unemployed. The interviewees off Nadi Back Road and Yavusania village stated they travelled to work by bus whilst the household in Saunaka village owns a vehicle.

The sole commercial property owner's income status was not obtained as the person interviewed at the time of the survey was the property manager and not the owner who was overseas. The owner of the property is a well established businessman in Nadi who resides in Lautoka City.

2.5 Land Tenure

The household surveys revealed that the majority of interviewees resided on native land (61%) while a smaller number resided on freehold land (26%). Table 13 indicates the total area of native reserve land that the villages of Moala, Yavusania and Saunaka cover.

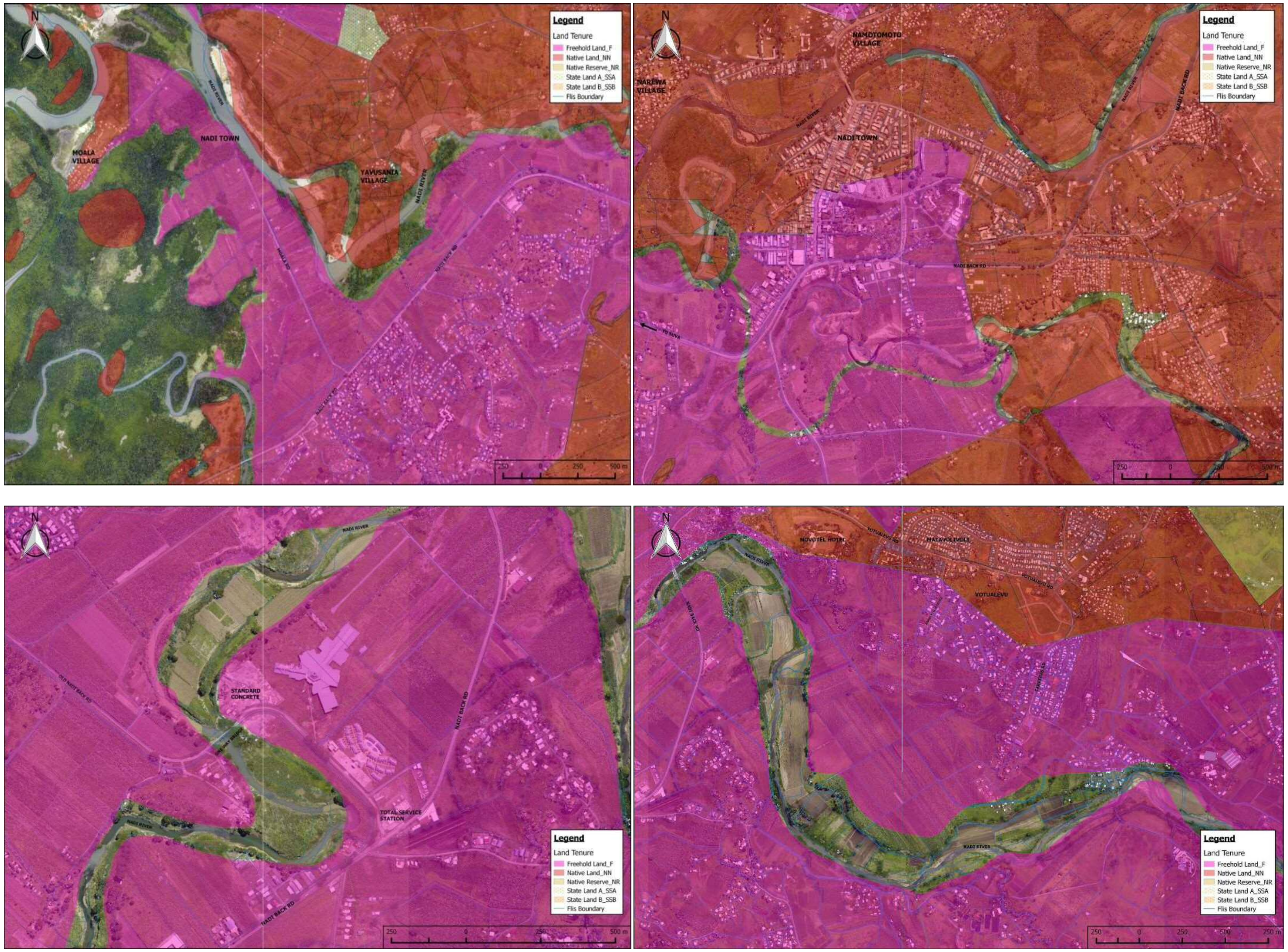
- **Table 13 Total approximate areas in villages envisaged to be affected by river upgrading works.**

No.	Location(Village/Sub District)	Land Type	Land Tenure	Affected (m^2)	Total Affected

					area (m^2)
1	Moala Village	Farm land & Residential Use	Native	20,313.2	25,278.4
2	Yavusania Village	Farm land & Residential Use	Native	4,910.2	
3	Saunaka Village	Farm land & Residential Use	Native	55	

However, land tenure maps acquired from the Department of Town and Country Planning (DTCP) indicated that all areas surveyed fell under either native land or freehold land as shown in Figure 8 on page 19.

■ **Figure 8 Land tenure maps for Moala Village and Moala Road (top left), Nadi town (top right), Off Nadi Back Road (bottom left) and Votualevu (bottom right).**



Source: Department of Town and Country Planning (2016)

Despite the land tenure information received from DTCP indicating that surveyed areas were situated on native or freehold land, some interviewees indicated that they resided on State land (9%) while a very small number indicated that they were not sure of the type of land tenure their residences were situated on (4%).
More than half of those interviewed (69%) indicated they have secured tenure over the land they reside on while some (10%) stated they did not hold secure tenure or were not sure about their land tenure situation (2%). Almost all interviewees holding State leases stated they were not sure about the number of years remaining on their leases, although a small number had less than 20 years or 50 years remaining, with the exception of those in Moala, Saunaka, Yavusania and Nawaka villages who are situated on native reserve land which are not subject to any lease periods.

The majority of those interviewed (82%) indicated they own the houses they reside in while a very small number (7%) indicated they were either renting/leasing their properties, staying with relatives (6%), or were caretakers for the properties (1%) or occupying teachers' quarters provided by the Government (1%). Those interviewees in Votualevu and Off Nadi Back Road stated that they were rent payers paying approximately $100 per month and $280 per month respectively in those areas.
Those households that were renting out their properties in Votualevu, Nadi Town and off Nadi Back Road disclosed that they were collecting approximately $330 per month, $405 per month and $350 per month respectively.

2.5.1 Critically Affected Areas (Displacement)

Survey results indicate that the residential properties within Saunaka and Yavusania villages are situated on native reserve land while the commercial property in Nadi town is situated on native leased land; the commercial property has 50 – 70 years left on its lease. The 2 remaining properties within the CAAs off the Nadi Back Road are both located on freehold land.
Interviewees from Saunaka and Yavusania villages, one property in off the Nadi Back Road area and the commercial property in Nadi town all clarified that they own their properties, while the second property off Nadi Back Road stated that they are renting on the premises and were paying monthly rental of $350.

2.6 Residential Structures & Use

The majority of houses surveyed were concrete (42%) structures or a combination of concrete and timber (32%); several homes had iron frames (14%) or were wooden homes (12%), and 2 houses along Moala Road were constructed from shipping containers and a Fijian *bure* was sighted in Moala village.
Majority of the households in all areas surveyed were single storey structures (83%) and only a very small number were double storey structures (2%).

■ **Table 14 Type of housing structures and associated land tenure in all areas surveyed.**

Type of Housing	Tenure			
	Native	State	F/Hold	Unspecified
Concrete	37	7	7	2
Concrete/Timber	32	2	5	-
Iron frame	8	6	3	1
Timber	10	4	-	-
Concrete/Timber/Iron frame	1	-	-	-
Container house	-	-	-	2
Bure	1	-	-	-
Unspecified	1	-	-	1

The majority of households were used for residential purposes (90%) and a very small number were used for commercial purposes (6%), industrial purposes (1%), and other purposes not disclosed by interviewees (3%). The breakdown of the use of property in all areas surveyed is displayed in Table 15.

■ **Table 15 Breakdown of use of property in all areas surveyed.**

No.	Location(Village/Sub District)	Use of Property	# of Units Within Residential Property		Sub-Total(m^2) (Properties)	Total(m^2)
1	Moala Rd	Residential	1 unit	5	16	121
			2 units	5		
			3 units	1		
			4 units	1		
			5 units	2		
			7 – 8 units	0		
			Not specified	2		
2	Saunaka Village	Residential	1 unit	5	5	
3	Votualevu	Residential	1 unit	4	12	
			2 units	3		
			3 units	1		
			4 units	1		
			7 – 8 units	1		
		Commercial			2	
4	Nadi Town Entrance	Residential	1 unit	1	3	
			2 units	1		
			5 units	1		
5	Yavusania & Nawaka Villages	Residential	1 unit	1	1	
		Other			1	
6	Off Nadi Back Road	Residential	1 unit	2	5	
			2 units	2		
			3 units	1		
7	Moala Village	Residential	1 unit	47	71	
			2 units	16		
			3 units	1		
			4 units	1		
			5 units	3		
			7 – 8 units	2		
		Commercial			4	
		Industrial			1	

Many interviewees claimed that they did not have any intentions to further develop their properties in future (60%); however the few that did have future plans for their properties indicated they wished to modify their single storey buildings into double storey buildings, or they wished to add extensions to the existing structures, or to add vegetable plots and crops to their properties (36%).

■ **Table 16 Future plans for residential properties.**

No	Location(Village/Sub District)	Rebuild Damaged Structures	Build Double Storey	Additional Units	House Extension	Farming	No Plans	Unknown	**Total**
1	Moala Rd	1	2	1	1	-	11	-	**16**
2	Saunaka Village	-	-	-	-	-	4	1	**5**
3	Votualevu	-	-	-	-	-	12	2	**14**
4	Nadi Town Entrance	-	1	-	1		1	1	**4**
5	Yavusania/Nawaka Villages	-	1	-	-	1	-	-	**2**
6	Off Nadi Back Road	-	-	-		-	4	1	**5**
7	Moala Village	-	-	-	32	-	43	-	**75**

2.6.1 Critically Affected Areas (Displacement)

The residential structure in Saunaka village comprised of a concrete structure while the structure in Yavusania village was made of timber. Of the two properties off the Nadi Back Road, one was a wooden structure and the other was a combination of concrete and timber.
Interviewees from Saunaka village and off Nadi Back Road confirmed they did not have future plans for the further development of their properties, while the interviewee from Yavusania village clarified they intended to modify their home from a single-storey structure to a double-storey structure in future.
All 4 residential properties were recorded as single storey structures. The commercial property in Nadi Town is also a single storey but is a structure on wooden piles elevated over the rivers edge due to flooding risks from the Nadi River.

2.7 Land Use

Majority of households interviewed indicated they undertook farming activities (86%) while a minor few clarified they did not undertake any farming activities (12%); a very small number chose not to disclose whether they were farming or not (2%).
Those that did undertake farming activities mainly did so in areas beside their residences or villages, or along the river, or on village reserve land, or near school compounds or work places, etc. (68%); the remaining respondents farmed within the land near their homes (32%).
Survey data indicated that the majority of the farming was undertaken on native land (58%) and a lesser number utilized freehold land (23%) or state land (10%). However several households indicated they were not sure of the type tenure that their farm land was located on.
Majority of households involved in farming activities clarified that 1 - 3 members of the household were involved in farming activities (76%); only a small number of households had either 4 – 5 or all family members involved in farming work (4%).
Majority of interviewees clarified that they undertook farming activities for subsistence purposes, i.e. for their own personal consumption (72%); some households sold their farm produce in local markets (14%) while 4 farmers (3%) grew fruits, vegetables and fruit crops for export though quantities of exported goods were not disclosed. Only 1 household (1%) confirmed keeping livestock for sale.
The types of fruits, vegetables and root crops grown in the surveyed areas as highlighted by the respondents are in Table 17, and the variety of trees recorded growing in household's compounds are displayed in Table 18. Livestock kept for subsistence use comprised mainly cows (41%), pigs (28%), goats (10%), chickens (10%), horses (9%) and ducks (1%).

■ **Table 17 Different Types of Produce and Crops Grownand Associated Land Tenure in Survey Areas**

Fruit/ Vegetable/ Root crop	Number of Farmers on			
	Native	State	Free	Unspecified
Dalo	22	1	1	1

Cassava	60	-	2	3
Kumala	8	1		-
Cabbages/greens	7	2	2	-
Beans/peas	8	3	2	-
Tomatoes	5	1	3	-
Cucumbers	4	-	1	-
Eggplants	23	1	8	-
Watermelon	2	-	1	-
Pumpkin	6	1	1	-
Carrots	-	-	1	-
Chilies	9	-	3	1
Ginger	-	-	1	-
Potatoes	-	-	1	-
Maize	-	-	1	1
Bele	9	-	1	-
Yams	4	-	-	-
Pineapple	1	-	-	-
Vudi	2	-	-	-
Sugarcane	4	3	2	-
Okra	-	-	1	-
Slender Amaranth (*tubua*	-	-	1	-
Tobacco	3		1	-

■ **Table 18 Types of Trees in Survey Areas**

No.	Location(Village/Sub District)	Type of Trees	No. of Properties	Sub-Total(m^2)	Total(m^2)
1	Moala Rd	Mango	2	12	104
		Banana	4		
		Lemon	5		
		Breadfruit	1		
2	Saunaka Village	Mango	2	3	
		Banana	1		
3	Votualevu	Mango	4	10	
		Banana	1		
		Lemon	2		
		Breadfruit	1		
		Coconut	1		
		Guava	1		
4	Nadi Town Entrance	Mango	1	4	
		Lemon	1		
		Coconut	1		
		Pawpaw	1		
5	Yavusania & Nawaka Villages	Banana	1	2	
		Coconut	1		
6	Off Nadi Back Road	Tahitian Chestnut (*Ivi*)	1	14	
		Mango	1		
		Banana	1		
		Lemon	8		

		Breadfruit	1		
		Coconut	1		
		Pawpaw	1		
7	Moala Village	Mango	14	59	
		Banana	23		
		Lemon	14		
		Breadfruit	4		
		Coconut	1		
		Orange	1		
		Mountain Apple (*Kavika*)	1		
		Cananga Tree (*Mokosoi*)	1		

2.7.1 Critically Affected Areas (Displacement)

The household in Yavusania village confirmed that they planted plantain, eggplants and cassava beside their home, and they kept cows as livestock. Several coconut trees were recorded growing onsite.
The household in Saunaka village confirmed that they planted taro, eggplants and chillies on village reserve land downriver of the village, and they kept pigs as livestock. Lemon trees were recorded to be growing around their property.
Of the 2 households off the Nadi Back Road, one household did not undertake farming activities, while the other household stated they commonly plant taro, cassava and eggplants near their home within their compound and that they kept pigs as livestock. Mango trees, banana trees and the Tahitian Chestnut (*ivi*) tree were recording growing onsite.

2.8 Access to Utility Services

Majority of households depend on more than one type of energy supply and water supply.
Majority of households surveyed (87%) are connected to the Fiji Electricity Authority (FEA) for electricity supply; some households also use kerosene lamps, batteries and solar powered cells (10%).

Table 19 Energy Sources of the Households in Surveyed Areas

Type of Electricity	Housing on			
	Native	State	Free	Undisclosed
Main Supply	67	10	30	14
Solar Lighting	1	-	-	-
Kerosene	3	2	1	-
Battery	1	-	-	-
Non	-	1	1	1

Approximately 94% of households surveyed are connected to the Water Authority of Fiji's (WAF) reticulated water supply network while some households rely on groundwater, rainwater and other sources that have not been disclosed. For those households that are connected to WAF's network, majority stated that the water was clean most of the time (84%) while a small number indicated that the water was dirty at times (9%) or there was intermittent supply of water (7%). Majority of households reported that water pressure was good (78%) while some complained that water pressure was quite low (14%); the issue of low water pressure was mainly recorded from Moala village.

Table 20 Access to Clean Water According to Land Tenure

Type of access to clean water (tentative)	Housing on			
	Native	State	Free	Not disclosed
Piped Private Tap	-	-	-	-
Piped Public Tap	69	10	29	5
Rainfall Tank	1	1	-	1
Borehole	-	-	-	-
Well	3	-	1	-
River / Creek	-	1	1	-

Majority of households interviewed indicated they used more than one type of energy source for cooking; the majority depended on firewood (41% - mainly in Moala village) as well as gas stoves (29%) and kerosene stoves (26%), while a very small number used electric stoves (4%).

Table 21 Energy Sources for Cooking According to Land Tenure

Type of Cooking Fuel	Housing on			
	Native	State	Free	Not disclosed
Cooking Gas	44	5	14	4
Kerosene Stove	37	3	17	1
Electric Stove	7	-	1	1
Firewood	59	9	24	2

2.8.1 Critically Affected Areas (Displacement)

Three of the four residential properties and the commercial property are connected to FEA's electricity supply network; only the interviewee from Yavusania village stated that their household uses solar powered cells as their source of electricity.

All five properties (four residential and one commercial) are connected to WAF's water reticulation network; four of the properties indicated that their water source was always clean with good water pressure; one property off the Nadi Back Road indicated that their water source was dirty at times and their property experiences low water pressure.

The four residential properties indicated that they use cooking gas, kerosene and firewood as the energy sources for cooking.

2.9 Sanitation Services

Survey results indicated that almost all households (93%) have proper flush toilets within their homes; of those with flush toilets, some households use water seal toilets (7%). A very small number of households were observed to use pit latrines (6%) for sewage disposal. Those households using water seal toilets were situated mainly along Moala Road while households using pit latrines were situated mainly in Moala village. A small few still dispose of sewage via direct discharge to waterways (7%).

Table 22 Sewage disposal systems and associated land tenure in survey areas.

Type of Sanitation System	Housing on			
	Native	State	Free	Not disclosed
Flush Toilet	70	10	31	4
PitToilet	5	2	1	1

Majority of households (74%) with proper flush toilets are connected to septic tanks as a large part of the Nadi area remains unsewered; only a small number of households are connected to WAF's sewer reticulation network (12%). One household confirmed using a soak pit for sewage disposal while 5 households indicated they used pit latrines to discharge of their sewerage waste (4%).

Majority of households surveyed did not have any issues with their current wastewater disposal system (60%); however a small number noted foul smells (11%), damage due to flooding (6%), and septic tank overflow during flooding events (4%). One household in Moala village stated that their liquid waste disposal system is presently affected by high tides.

2.9.1 Critically Affected Areas (Displacement)

All four residential properties and the commercial property use proper flush toilets onsite. The Yavusania village household and one of the properties off the Nadi Back Road utilize septic tanks for sewage waste disposal, while the other off the Nadi Back Road property and the Saunaka village household are connected to WAF's sewer reticulation network. The commercial property in Nadi town is also connected to WAF's sewer reticulation network.

The Saunaka village household noted foul smells emanating from their septic tank while the remaining four properties situated in CAAs did not face any issues with their sewage waste disposal systems.

2.10 Solid Waste Disposal

Solid waste disposal is a major issue in the Nadi area. The majority of all households interviewed stated that they are responsible for the solid waste disposal from their properties (87%); this is mainly because survey areas lie outside the Nadi town boundaries and therefore the municipal council does not collect solid waste from their areas; however, surveys of the 3 properties that lie near the entrance to Nadi town and are therefore within the town boundaries indicated that the solid waste from their properties is not collected by the municipal council's waste collection service.

The small number of households (7%) whose solid waste is collected by the municipal council waste collection service indicated that their rubbish is collected once or twice a week.

As a result of the issue of solid waste disposal in the Nadi area, majority of the households bury their rubbish, particularly tin cans and glass bottles (38%), and also burn their rubbish (38%) and a small number either dispose of the rubbish in designated areas outside their compounds (13%) or within their compounds (9%). Several households stated that they disposed of their rubbish in the Nadi River and in random areas. A small number of households stated they transport their rubbish to the Nadi market bins where the rubbish is disposed of.

General perceptions that were gleaned from the surveys regarding waste disposal issues were that there was a lot of rubbish in surrounding areas (31%), people not using rubbish bins (3%) or not having enough rubbish bins (11%), rubbish piling up in several areas (8%) and rubbish being disposed of in inappropriate places (6%). Several households also indicated that there was a shortage in appropriate toilet facilities (11%).

Many of the households surveyed indicated that they sort their solid waste into green waste for composting purposes, food scraps for animal feed, tins and bottles for burying, and paper for burning (78%).

2.10.1 Critically Affected Areas (Displacement)

All four residential households indicated that solid waste was not collected from their areas by the municipal council's waste collection service. Only the commercial property's solid waste is collected by the municipal council as the property is situated in Nadi town.

The interviewees from Saunaka and Yavusania villages dispose of their rubbish within their compound and via onsite burying respectively, while the interviewees off the Nadi Back Road indicated that they practiced onsite burning of rubbish. In addition, the interviewees off Nadi Back Road stated that they practiced segregation of their rubbish, i.e. sorting into green waste, food scraps for animals, bottles and tin cans for burying and paper rubbish for burning, while the interviewees from the two villages of Saunaka and Yavusania did not practice segregation of rubbish.

2.11 Standard of Living

The survey results indicated that 89% of the households surveyed had a somewhat good standard of living when taking into account the state of residential structures within their properties. Two households enjoyed very good standards of living (2%) while a small number suffered from poor standards of living (9%).

- **Table 23**

Standard of Living	Moala Village	Moala Road	Saunaka Village	Votualevu	Nadi Town Entrance	Off Nadi Back Road	Yavusania Village	Nawaka Village	**Total**	**Total %**
Very Good	-	-	-	2	-	-	-	-	**2**	**2%**
Good	86*	10	5	10	3	2	-	1	**117**	**89%**
Poor	-	6	-	2	-	3	1	-	**12**	**9%**

**Although 86 properties were recorded in Moala village using aerial imagery, only 76 households were surveyed because the remaining 10 structures comprised 2 village halls, abandoned buildings within the school compound or broken down structures within the village.*

2.11.1 Critically Affected Areas (Displacement)

Both the properties off Nadi Back Road and the property in Saunaka village were observed to have a good standard of living; however the property in Yavusania village appeared to have poor living conditions.

2.12 Drainage Issues

Drainage issues were highlighted by majority of the households surveyed (89%); these households stated that they experienced flooding often (13%), on a regular basis (14%), or only sometimes (27%) or rarely (38%). A small number of households stated that they do not experience flooding events related to drainage issues (9%).
Majority of households interviewed stated their opinions that flooding issues arose due to a lack of drainage channels for properties (44%) or an insufficient number of drainage channels (20%). Several households indicated that the drainage network in surrounding areas was either damaged or blocked (13%). A small number of households indicated that they did not know about flooding and drainage issues in their areas (10%) or that flooding was not an issue for them (6%).

2.12.1 Critically Affected Areas (Displacement)

The interviewees from Saunaka village and one property off Nadi Back Road indicated that their properties usually flooded during heavy rain events because there are no drainage channels to assist in discharging stormwater runoff.
The interviewee from Yavusania village indicated that their property sometimes floods because there are not enough drainage channels available for stormwater runoff, while the second property at Nadi Back Road indicated that they rarely face flooding issues but their drainage channels have become blocked with debris due to lack of cleaning.
The commercial property in Nadi town did not disclose any information relating to issues with drainage systems in Nadi or the immediate area.

2.13 Local Use and Knowledge of the Nadi River

A large number of households interviewed indicated that they use the Nadi River for boat access and they use the riverbanks to collect firewood, plant crops and vegetables, collecting medicinal plants, and for grazing animals (73%). A large number also use the river for bathing and recreational activities (59%), and some households indicated that they wash laundry and dishes in the river on a daily basis.

Survey results revealed that the most important use of the river for many communities was for fishing (41%), and the species most frequently fished for were the Mangrove Jack (*Lutjanus argentimaculatus*) or **'damu'**, Tilapia (*Tilapia mossambica*) or **'malea'**, Bluetail Mullet (*Valamugil seheli*) or **'kanace'**, and the Great Trevally (*Caranx ignobilis*). Moala Road residents and members of Moala village indicated that some households fish on a daily basis, several times a week, or only on some occasions.

Other species normally fished for or collected from the Nadi River (mixture of freshwater and seawater near the river mouth), and its surrounding mangrove areas, include Mangrove crabs (*Scylla paramamosain*) or **'qari'**, Land crabs (*Cardisoma carnifex*) or **'lairo'**, Mangrove prawns (*Palaemon concinnus*) or **'ura'**, Ark shells (*Anadara cornea*) or **'kaikoso'**, and Freshwater clams (*Batissa violacea*) or **'kai'**.

The main fishing areas along the Nadi River for those households that are involved in fishing activities include the river mouth, upstream of Saunaka village, and the Votualevu area.

Majority of households surveyed indicated that they were not aware of any archaeological sites of significance along the Nadi River (74%); however several households indicated that there were family burial sites and chiefly burial grounds near the river that needed to be taken into consideration and respected (22%). Members of Moala village also indicated that the old village site was situated within the mangroves near/around the Nadi River.

2.13.1 Critically Affected Areas (Displacement)

The interviewee from Saunaka village indicated they normally swim in the Nadi River and they tether their cows along the riverbank for grazing purposes.

The interviewee from Yavusania village indicated that they normally collected firewood from the banks of the river (**vaivai**) and they used the riverbanks as shortcuts to other areas and to tether cows for grazing and to supply water for their cows. They also regularly swam in the river and fished for Bluetail Mullet (*Valamugil seheli*) or **'kanace'** on some occasions.

One of the two properties off the Nadi Back Road indicated that they normally collect firewood from the riverbanks (**vaivai**), as well as medicinal plants (**botebotekoro, wabosucu**). They regularly swam in the river and sometimes fished for Tilapia (*Tilapia mossambica*) or **'malea'** and collected Freshwater clams (*Batissa violacea*) or **'kai'**.

The second property off the Nadi Back Road and the commercial property in Nadi town indicated that they did not use the Nadi River or its riverbanks for any activities.

2.14 Past Flooding Experiences Related to the Nadi River

Majority of the respondents stated that there has been widespread erosion along the banks of the Nadi River. Some interviewees from Saunaka village have stated that they have planted coconut trees, breadfruit trees, lemon trees and bamboos along the riverbanks to prevent soil erosion.

Interviewees also highlighted that debris commonly blocks local waterways which causes the river to burst its banks during heavy rain events, leading to flooding issues. Additionally, insufficient drainage channels are unable to cater for large amounts of stormwater runoff during heavy rain events, which exacerbates flooding issues along the Nadi River. Interviewees also stated that landslides were another major concern during heavy rain events.

The majority of households interviewed stated that they did not have any issues with any flood control measures likely to be proposed by JICA (72%), but several households raised their concern that their properties were situated close to the river so they might be affected by river upgrading works (24%). Some households from Moala village and Moala Road also requested that riverbanks be raised, and they stated that the river was too deep in some areas to allow them to continue crossing to the other side and they requested that this be taken into consideration during upgrading works.

2.14.1 Critically Affected Areas (Displacement)

The interviewee from Yavusania village stated that flooding issues during heavy rain event were destroying their farmlands, while the interviewee from Saunaka village indicated that soil erosion and floating debris were a big problem during flooding events. One of the properties off the Nadi Back Road stated that flooding events led to landslides and riverbank erosion, as well as causing accidents and damage to plantations and farming land. The second property off the Nadi Back Road did not disclose any information with regard to flooding events.

The commercial property in Nadi town stated that erosion and flooding were major issues for the Nadi River.

All five properties indicated that they did not have any issues with any of JICA's proposed flood control measures and river upgrading works.