THE INSTITUTE OF APPLIED SCIENCES

FIJI RIDGE TO REEF PROJECT

ACTIVITY 1.1.1.3

SUB-ACTIVITY: FRESHWATER FAUNA, FLORA AND HYDROLOGICAL BASELINE ASSESSMENT IN SIX SUB-CATCHMENTS OF THE BA RIVER.

DECEMBER, 2019

December 2019

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EXECUTIVE SUMMARY

This report documents the aquatic fauna and flora in six sub-catchments of the Ba River. A desktop assessment was undertaken, including a review of databases, literature and previous baseline studies conducted in the study area. Baseline surveys of aquatic habitat condition, aquatic flora, macroinvertebrates and fish was undertaken in 17 sites in April 2019.

Key results for the survey were:

- A total of 73 unique taxa out of 10,120 individuals were recorded from the 17 sampling stations. Insects represented 70% of the total taxa recorded while crustaceans represented only 15% and molluscs and worms represented the minority; 8% and 6% each respectively.
- A total of 33 macroinvertebrate taxa (47% of total recorded taxa) recorded were unconfirmed Fiji endemics and a total of 10 taxa (14% of total recorded taxa) were endemic to Fiji. These include the five caddisflies (*Abacaria fijiana, Abacaria ruficeps, Anisocentropus fijianus*, *Goera fijiana and Oxyethira fijiensis*), the endemic damselfly*,* *Nesobasis* spp. (genus endemic to Fiji), a shrimp (*Caridina fijiana*), endemic genus of micro-water striders *Fijivelia* sp., the endemic water cricket (*Hydropedecticus vitiensis*) and spring snails *Fluviopupa* spp.
- The most commonly recorded phytoplankton taxa include three Chlorophyta taxa (*Botryococcus*; 16 sites, *Microspora*; 14 sites, and *Spirogyra*; 13 sites), one Cyanobacteria taxa (*Stigonema*; 13 sites) and three Bacillariophyta taxa (*Fragilaria* ; 11 sites) and *Cyclotella;* 11 sites and *Microcystis;* 10 sites).
- The most frequently recorded zooplankton taxa across the creeks were baetid mayfly (*Pseudocloeon;* 17 sites) and chironomids (non-biting midge) of sub-family chironominae (14 sites).
- The exotic submerged species *Potamogeton* and *Hydrilla* was however recorded in low cover in the mid Nadrou and lower Nakara systems respectively where river characteristics at these sites (i.e., sluggish flow and gravel/sand streambed), and good water clarity, provide conditions are more conducive to plant establishment

and survival. Both macrophytes support few invertebrate taxa such as the native shrimps, odonata naiads, mayfly naiads and leech.

- Two native fish species (*Anguilla marmorata* and *Sicyopterus lagocephalus*) and the introduced western mosquitofish (*Gambusia affinis*) and Tilapia (*Oreochromis* niloticus) were relatively abundant, while other species caught were in moderate abundance or were rare. Fish species richness was moderate at most sites, with variation between sites most likely related to differences in available habitats at each site, such as deep pools and over-hanging banks or position in the catchment. No endemic species were caught during this survey. Thus, the presence of native fish and crustaceans at a site indicates that it is ecologically connected to the ocean and that no major natural or artificial barriers (e.g. waterfalls or major dams) occur between the site and the estuary.

Maintaining connectivity between freshwater and marine environment is key to the regenerative natural process of sustaining fish stocks in rural inland communities of the Ba catchment. Despite the low productivity of oceanic freshwater systems when compared to the marine environment, the resources therein are important nonetheless to many rural villagers in Fiji.

Contents

LIST OF ACRONYMS AND ABBREVIATIONS

C3	Community Centered Conservation
FLMMA	Fiji Locally Managed Marine Areas (Network)
IAS	The Institute of Applied Sciences (USP)
IMR	The Institute of Marine Resources (USP)
LMMA	Locally Managed Marine Areas
LoA	Letter of Agreement
MACBIO	Marine and Coastal Biodiversity Management in Pacific Island Countries
MMA	Marine Managed Area
MOE-PMU	Ministry of Environment - Project Management Unit
MPA	Marine Protected Area
NFMV	Nature Fiji Mareqeti Viti
QMC	Quality, Marketing and Communications Unit (USP-IAS)
R2R	Ridge to Reef
SMS	School of Marine Studies (USP)
SPRH	South Pacific Regional Herbarium (USP-IAS)
UNDP	United Nations Development Program
USP	The University of the South Pacific
WWF	World Wildlife Fund

1 INTRODUCTION

1.1 Background and literature review

Past research and environmental impact assessments aligned with the Fiji GEF 5 STAR R2R project objectives: (i) to preserve biodiversity and (ii) ecosystem services in a ridge to reef context are limited. There are also few studies in Fiji which investigate the specific biodiversity parameters covered in this Institute of Applied Sciences (IAS) baseline assessment of Ba Catchment. Within this limited literature, there have been studies of ichthyofaunal fish communities abundance and diversity (Jenkins and Jupiter, 2011) benthic invertebrates studies (Haynes, 1987; 1999), effects of forested cover on macroinvertebrate communities (Rashni, 2014) and wider impacts of anthropogenic disturbances (Lin, et al., 2017). Studies in Fiji most relevant to this IAS hydrology assessment have included research on the impacts of cyclones and climate on river hydrology (Kostaschuk, et al., 2003; 2001; Terry, et al., 2001), rainfall-runoff studies (Waterloo, et al., 2007) land-use change (Ankita and Kazuo, 2014) and drought impacts (Terry and Raj, 2001).

There have also been a range of wider nationwide studies including the assessment of urban and wastewater management (ADB, 2016), Yeo's flood resilience assessment (2013), Pacific Water's overview of nationwide fluvial geomorphology (2011), the Wildlife Conservation Society's national protected area network report (2010) and SPREP's overview of wetland ecosystems (2008).

Other studies and assessment reports have also covered the other objectives of the Fiji GEF 5 STAR R2R project including (iii) sequestering carbon, (iv) improving climate resilience (see Pacific Water, 2011; AFB, 2011) and (v) sustaining livelihoods (IUCN, 2014; AFB, 2011).

This section presents findings of a study of freshwater macroinvertebrate, periphyton and planktonic communities within the six sub-catchments (Nabiaurua, Nakara, Navisa, Nadrou, Waisali and Wainamau) of Ba River catchment undertaken by IAS (USP) consultants. The primary objective was to provide a comprehensive list of taxa, describe community structure, and identify those taxa that are endemic or of potential conservation interest. This section also provides supporting information relating to aquatic flora (algae and macrophytes) and planktonic taxa to assist with the interpretation of macroinvertebrate results and identify potential habitats or systems of high ecological value.

The Fijian Islands freshwater macroinvertebrate fauna is represented by seven Phyla and approximately 62 Families, that include Insecta (40 families), Crustacea (4 families), Mollusca (9 families), Nemotoda (2 families), Annelida (3 families), Platyhelminthes (1 family), Nematomorpha (1 family) and Porifera (2 families) (Haynes 1999, Haynes 1988). Many Fijian freshwater macroinvertebrates are yet to be fully described to genus and species level and many aquatic insect larvae have not been matched with their described flying adults. Prior to this study, little was known about the composition of macroinvertebrate communities within the waterways of interest to this study.

Previous studies conducted on freshwater macroinvertebrates within the connecting systems to the current waterways of interest include the Sigatoka-Ba hydropower EIA, Ba hospital EIA and a flood retention weir EIA. An Environmental Impact Assessment was conducted as part of the Sigatoka – Ba hydropower project from 25th - 31st August 2004 whereby the Ba River was sampled for macroinvertebrates. Due to steepness of the sides of the Naidadara creek, the Ba catchment was sampled only once 200 m below the proposed power station. A total of 12 taxa were collected. These included Mayfly nymphs (*Pseudocloeon* sp.), case caddisfly (Philorheithridae), aquatic beetles (Coleoptera), prawns (Macrobrachium spp.) and four species of gastropods (*Melanoides tuberculata* , *Melanoides lutosa*, *Fijidoma maculata* and *Neritina pulligera*). The prawns were abundant and harvested by villagers for consumption. The most significant finding was the collection of the endemic thiarid gastropod Fijidoma maculata which is considered to be a threatened species and of conservation interest. This is because Fijidoma maculata is endemic to Viti Levu and has a very patchy distribution; to date recorded only from tributaries of major rivers (headwaters of Lami, Ba and Rewa River) (Haynes, 2004).

As part of the Ba hospital EIA, a total of four sites across Vutuni River that drains into the Namosau area of Ba were sampled for freshwater macroinvertebrates. The four sites were highly modified by anthropogenic activities. A total of 23 freshwater macroinvertebrate taxa were identified and these comprised of 13 species of aquatic insects, four species of worms, four species of decapod crustaceans and three species of gastropod snails. Due to a highly modified system this species rich macroinvertebrate community comprised of species resilient to sedimentation and degraded water quality. Therefore the community represented a typical modified riverine system in Fiji. The introduced thiarid gastropod *Melanoides tuberculata* and the damselfly naiads of the family Lestidae were present at all four sites. *M. turbeculata* is a resilient species that occupies a wide range of water quality and usually found on stream edges. Lestidae damselfly naiads have been known to be common in disturbed streams.

Freshwater macroinvertebrate community survey within the vicinity of the proposed flood retention weirs, based on sampling in Qalinabulu and Nadrou creeks (tributaries of the Ba River) revealed a total of 29 distinct freshwater macroinvertebrate taxa. The macroinvertebrate communities recorded were representative of those that can tolerate moderate to poor water quality and habitat degradation. The most common taxa recorded were clinging mayflies (Pseudocloeon sp.) and the net-spinning caddisflies (*Abacaria fijiana*) that are able to tolerate siltation effects in lotic systems. There was evidence of thick Potamogeton beds, siltation and murky water at both sites; indicating stream and riparian habitat degradation. Only four macroinvertebrate taxa were endemic to the Fijian Islands and these include the three caddisflies (*Abacaria fijiana*, *Anisocentropus fijianus* and *Goera fijiana*) and the endemic damselfly, *Nesobasis* sp. (genus endemic to Fiji).

1.2 Objectives

The assessment of hydrology of the upper Ba Catchment measures the following parameters with the overall aim of providing a baseline set of bio-indicators to measure change generated through the Fiji GEF 5 STAR R2R project.

Parameter	Significance for R2R objectives (i-v):
Hydrological	Stream channel depths, cross sectional areas, velocity of flow, discharge volume, and flow patterns all provide a means of measuring factors related to objectives (i) biodiversity and (ii) ecosystem services. Channel depths and flow regimes are linked to habitat suitability for fish and macroinvertebrates which in turn contribute to food chain ecosystem services. Volumes of discharge and flow patterns also shed light on water security. Hydrology is also important for objectives (iii) carbon sequestration – riparian vegetation ecosystems, (iv) climate resilience – water and food security and (v) sustainable livelihoods – fisheries and public health.
Fluvial geomorphology	Stream bank dimensions and structure, bed material types, riparian vegetation and stream habitat types all provide a characterisation of the ability of the river streams to provide a diverse range of ecosystem services (ii) and habitats for a diverse range of biota (i). Riparian vegetation is directly linked to objective (iv) carbon sequestration capacity.
Anthropogenic disturbance	Bridge, crossing or other barrier to streamflow and ecological connectivity, deforestation, presence of paths, roads contributing to erosion, distances measured to nearest village/settlement/activity, agriculture (chemical contamination), livestock (faecal contamination), household drainage (chemical contamination), latrine septic tanks (faecal contamination). Each of these forms of disturbance are likely to impact (i) biodiversity and (ii) ecosystem services.

2 METHODOLOGY

2.1 Water physicochemistry

Water physicochemical parameters were measured in-situ at each site using a calibrated multi-water quality meter (Aquaread AP 2000) to assist with interpretation of macroinvertebrate data. Parameters measured included temperature, dissolved oxygen, conductivity, pH, TDS, turbidity and salinity.

2.2 Habitat

Habitat characteristics were assessed within 100 m reaches at each site to assist with the interpretation of biological community data. The instream habitat features and condition at each site were assessed following the procedures of AUSRIVAS protocol but tailor made based on the experience of the two lead ecologist. The length of the reach was approximately 100 m depending on the availability of a range of habitats within the reach. This was done to ensure that each reach sampled was representative of the stream along which it was located. Habitat characteristic data collected included:

- Habitat type – the relative proportion (%) of each habitat type (e.g., run, riffle, pool) in the 100 m survey reach was estimated.
- Streambed substrate – streambed substrate composition was assessed at each site. The procedure involved a visual estimation of substrate across a 100 m reach. Size classes included bedrock, boulder (>256 mm), cobble (64 to 256 mm), pebble (16 to 64 mm), gravel (4 to 16 mm), sand (1 to 4 mm) and silt (<1 mm).
- Riparian character and channel shade – a general assessment of riparian vegetation characteristics and the percentage channel shade at each site.
- The above habitat data were recorded on standard habitat assessment forms. Photographic records of instream and the surrounding environment were taken at each site.

2.3 Aquatic Flora

- Periphyton (algae) – A single periphyton sample was collected from selected wadeable sites by scrubbing the surface of ten randomly selected cobbles with a nylon brush and placing on ice or preserving with Lugol's iodine. Samples were examined under a compound microscope by using the key of Belcher & Swale (1976) and Janse van Vuren et al. (2005) to lowest taxonomic level possible.
- Macrophytes (aquatic plants) – an assessment of macrophyte streambed cover and species present at sampling sites.

2.4 Macroinvertebrates

SAMPLE COLLECTION

Macroinvertebrate samples were collected from sites using a combination of 'quantitative' and 'qualitative' survey methods to allow an assessment of macroinvertebrate density at selected sites and to compile a comprehensive list of taxa for all sites. The following describes the quantitative and qualitative sampling methods:

- Quantitative assessment – three replicate Surber (area $0.1m^2$, 0.5 mm mesh) samples were collected from riffle habitats at stony streambed sites following Protocol C3 (Stark et al. 2001) during the survey. Protocol C3 is a 'quantitative' method that provides a measure of macroinvertebrate density.

- Qualitative assessment – a single sample was collected from each site using a kick-net (mesh 0.5 mm) from edge habitats for taxa that prefer these habitats (e.g., snails and damselflies). A 10m kick-netting (5m on each bank (True Left Bank and True Right Bank) edge) was undertaken to increase the chances of collecting rare species but also to ensure that all habitat types at a site were sampled (i.e., not just riffles). Samples were collected by disturbing habitats and sweeping the kick-net through the water to collect dislodged macroinvertebrates.

SORTING AND IDENTIFICATION

Macroinvertebrate, periphyton and plankton samples were sorted and identified by Bindiya Rashni and crustaceans by Laura Williams (Crustacean specialist) following the guides of Haynes and Rashni (unpub. key to aquatic insects of Fiji), Pendergrast & Cowley (1966), Williams (1980), Haynes (2009), Fossati & Marquet (1998), Davis & Christidis, (1999), Choy (1991), Nandlal (unpub. key to the species of the genus Macrobrachium from Fiji) and key of Belcher & Swale (1976).

Abundance of species that were present in large numbers in samples was estimated (e.g., Abacaria fijiensis caddisflies and Pseudocloeon sp. mayflies). Sorted and Identified macroinvertebrates were placed in small vials containing 100% ethanol and kept for further examination if required.

DATA ANALYSIS AND PRESENTATION OF DATA

- Macroinvertebrate density – an assessment of the density of macroinvertebrates in riffle habitats at selected stony streambed sites based on quantitative Surber sample data. Densities (per 1 m^2) were calculated by multiplying mean Surber sample abundance data (per 0.1 m^2) by a factor of ten to give abundance/m^2.
- Coded macroinvertebrate abundance – the contribution that each taxon made to total community abundance at each site was calculated using the combined Surber and kick-net data set collected during the survey. Abundance data is presented as either one of five coded abundance categories, which include: highly abundant (>100), abundant (20-99), common (5-19), few (2-4) or very few (1). Coded abundance data is presented in a table.
- Taxa richness – the total number of taxa recorded at each site was calculated from the combined Surber and kick-net/opportunistic data set over all surveys. A full list of taxa recorded at each site is presented in a table.
- Status, distribution and taxa of interest – presents a summary of whether taxa recorded were endemic to Fiji, unconfirmed endemics, native to other regions (e.g., Pacific, South Pacific, Indo-Pacific, Fiji-Australia, South East Asia), introduced tropical species or other (worldwide). Macroinvertebrate taxa of potential interest were also identified and included taxa that are known to be rare in Fiji or potentially have restricted distributions (island and or area endemics).

2.5 Freshwater vertebrates

SAMPLE COLLECTION

Fish communities were surveyed at each site using a Smith-Root LR 24 backpack electrofisher. A standardised electrofishing effort of around 300 seconds was employed at each site. Multiple pass electrofishing within representative habitat types across the reach was carried out. Short 3 – 5 m sections were electrofished. Stunned fauna were collected downstream in a handheld beach seine net (1 mm^2 mesh) for sorting and identification.

The following data were recorded for fish communities at each site:

- total abundance (total number of individuals caught at a site)
- species richness (the number of species caught at a site)
- presence of exotic species (Boseto and Jenkins 2006)
- presence of listed threatened species under the IUCN Red List

2.6 Hydrology

REACH SELECTION

Sites for hydrological assessment consisted primarily of 100 metre length transects of stream. Each of these transects were divided into 25 meter reach sections. These sections were distanced from riffles and bends to improve accuracy of hydrological measurements.

HYDROLOGICAL MEASUREMENTS

Stream channel widths were measured using a 50m measuring tape. A two-metre long measuring staff was used to measure depths at intervals. The staff also used a level to ensure channel geometry was consistent. Around 20 vertical measurements were taken for each stream at equal distance: at approximate 5% width intervals consistent with best practice as outlined in the guidelines in stream hydrology for ecologists. Cross-sectional areas were derived from the depth measurements and width measurements calculated as the areas of trapeziums and triangles. Velocity (ms^{-1}) was measured using a C2 Hydromett flow meter at intervals of 40 seconds.

Table 1: Flow velocity equations for Barel 19192 OTT Hydromett flow meter.

$n \leq 1.43$ $\mathrm{v} = 0.0952\,\mathrm{n} + 0.033$	$n = \frac{r}{T}$
$1.43 \leq n \leq 19.17$ $\mathrm{v} = 0.1032\,\mathrm{n} + 0.023$	$r = number\ of\ rotations$ $T = time\ interval\ (s^{-1})$

Note, this method was only used in lower flows and dry conditions. The float method for higher flows under wet conditions. Oranges were used at 25m reach sections and the time taken to flow to the end of each reach section was measured and averaged over at least three float velocity tests. Discharge volume (m3s-1) was calculated by cross-sectional (m^2) area multiplied by flow velocity (ms-1). Note, discharge was calculated as ML per day assuming constant flow. Flow patterns were recorded at each site at 25m reach sections and the trends for velocity and depth were plotted across each ~100m transect.

ANTHROPOGENIC DISTURBANCE

Anthropogenic disturbances were recorded including: bridges, crossings or other barrier to streamflow and ecological connectivity, deforestation, vicinity of paths and roads, erosion / streambank stability and cover, approximate distance to nearest village/settlement/activity, agriculture (chemical contamination), livestock (faecal contamination), household drainage, latrine septic tanks (faecal contamination).

2.7 Study site

Figure 1 shows the map of the seventeen sampling in the Ba catchment. A total of six sub-catchments were sampled in the Ba watershed. Each sub-catchment was divided into upper, mid and lower catchment. Upper Waisali could not be accessed due to very poor road conditions.

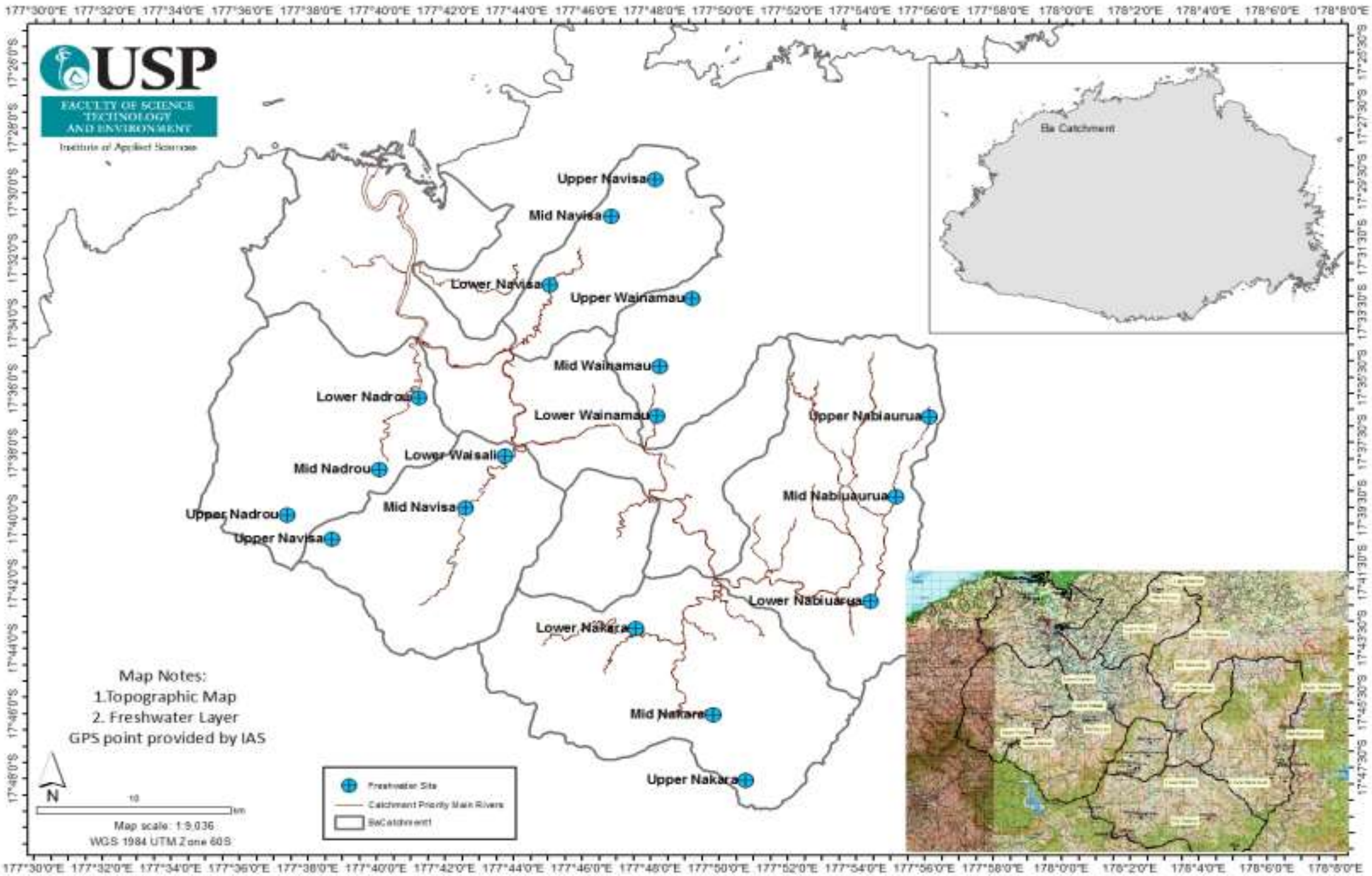

Figure 1: Map of the study area

3 RESULTS & DISCUSSION

3.1 Habitat characteristics

The six sub-catchments were perennial waterways that can be characterised as mid to low-gradient reaches. The sampled sites drain steep and rugged catchments. These four sites were highly modified due to anthropogenic factors (cattle grazing, plantations and gravel extraction). A diverse aquatic habitat for fauna was recorded, with run and riffle habitats present in the six sub-catchments. Deeper runs and pools increased as the team moved further downstream towards the main Ba River. Habitat complexity was also increased with the presence of logs and branches that provide shelter for aquatic fauna.

Streambeds were largely coarse and comprised high proportions of cobble and pebble sized substrate. The proportion of boulders was higher at the upper reach sites of the six sub-catchments and this gradually decreased moving downstream. The percentage of sand and silt gradually increased moving downstream to sites FE-03 and FE-04. As the river slowly waned in energy (e.g., water velocities reduced), the deposition of fine particles increased at the two lower reach sites (FE-03 and FE-04), and was clearly evident at site FE-04 where the highest silt content was recorded. Overall the four sites had minimum riparian cover due to agricultural activities by villagers. There was a high presence of exotic riparian plants (Quava trees *Psidium guajava* etc.) along the river margins.

3.2 Substrate composition

The substrate compositions at sites within the six sub-catchment areas are dominated by gravel, pebbles and cobbles. Sites in upper catchment areas had a slightly higher proportion of cobbles, whereas sites in mid and lower catchment areas had a slightly higher proportion of gravel. Several sites had mid-channel bars of cobbles, gravel, fine pebbles, sand or silt that comprised a minor component of the substrate.

3.3 Channel diversity

The watercourse channel at the Project sites was well-defined, with all sites having clear bed and bank features. Sand, gravel and/or silt bars had formed within the channel at some sites, creating small anabranches of flowing water within the channel. Sites in upper catchment areas had narrower channels with moderate stream gradients, whereas sites in mid- and lower- catchment areas had wider channels with low stream gradients.

Plate 1: Mid-reach site characterized by high disturbance from the nearby settlement.

Plate 2: Mid-gradient river

3.4 In-stream habitat

In-stream habitat (i.e. physical habitat elements and flow habitat types) provides shelter, refuge and feeding locations for aquatic fauna, such as fish and macroinvertebrates. In-stream habitat was similar across sites in the six sub-catchments. Physical in-stream habitat elements included undercut banks, boulders, cobbles and gravel, and flow habitat types included pool, riffle and run habitats.

3.5 Aquatic flora

PERIPHYTON FLORA

A checklist of periphyton taxa is presented in Table 1. A total of 34 taxa were recorded; eight Chlorophyta, 19 Bacillariophyta, six Cyanobacteria and one Dinophyta. The most common form of periphyton recorded at sampling sites with stony streambeds was thin light/dark brown films. Periphyton communities growing on stable cobble substrates in run and riffle habitats were made up by uni-celled Bacillariophyta (e.g., *Fragilaria*, *Navicula*, *Pinnularia* and *Surirella*), unbranched filamentous Bacillariophyta (e.g., *Melosira*), Chlorophyta (e.g.,*Microspora*, Spirogyra, *Mougeotia, Stigeoclonium* and *Ulothrix*) and Cyanobacteria (e.g., *Oscillatoria*, *Anabaena* and *Peridinium*).

Singled-celled diatoms *Fragilaria*, *Navicula*, *Pinnularia* and *Surirella,* uni-celled Chlorophyta *Botryococcus* and unbranched filamentous Chlorophyta *Microspora* were the most widely distributed and abundant periphyton taxa recorded across stony streambed sites. These uni-celled taxa were most likely to represent the main component of thin periphyton films recorded as being most abundant at stony streambed sites. The upper, mid and lower Nadrou Creeks supported the highest abundance of the uni-celled diatom *Fragilaria*. *Fragilaria* species tend to be associated with circumneutral to slightly alkaline fresh waters. Filamentous algae were generally patchy but growths were noted along the channel margins of slow flowing habitats at many sites. Long (>20 mm) filamentous green algae was generally common but did occur in moderate cover (30% cover) in the lower Nadrou and upper Wainamau (Koroboya village). The filamentous green charophytic algae *Chara* sp. (family Characeae) was recorded in submerged bed form at upper Wainamau (Koroboya village) and mid Nadrou. At mid Nadrou *Chara sp.* was thriving alongside the ribbon weed, *Hydrilla verticillata* within a water depth range of 0.5->1m. The combination of these flora systems was observed to be shelter for few invertebrates such as, leech, shrimps and young *Melanoides* snails. The *Chara* bed at Koroboya village provided a micro-habitat for the native dragonfly and damselfly naiads including the invasive leech *Helobdella europaea*.

Plate 3: Filamentous green charophytic algae *Chara* sp.

MACROPHYTE FLORA

Macrophyte species are of significance as they provide potential habitat for aquatic invertebrates and shelter for fish but their extensive growth may adversely affect flow efficiency. Macrophytes (aquatic plants) at stony streambed sites were either 'not present' or observed growing as small isolated stands. Macrophytes were only observed in the lower Nakara, mid Nadrou and upper Wainamau. Patchy growths of water hyacinth *(Eichhornia crassipes)* along bank edges were commonly observed. The emergent water hyacinth is able to establish along the sluggish flowing margins/edge of the waterways without being affected by poor water clarity.

The curly pondweed species *Potamogeton* sp. grew in low density/small bed form at mid Nadrou creek system. The mid Nadrou creek system supported small *Potamogeton* beds due to the habitat in this inland section comprising a higher proportion of sluggish moderately deep run habitats that had gravel/sand/silt streambed substrates, which allowed roots to establish. The filamentous green charophytic algae *Chara* sp. (family Characeae) was thriving alongside the curly pondweed *Potamogeton* sp. within a water depth range of 0.5->1m. The combination of these flora systems was observed to support a good population of native dragonfly and damselfly naiads, shrimps, tuberculate snails and native leeches. The riibbon weed, *Hydrilla* sp. beds were observed at lower Nakara.

The absence of aquatic macrophytes at other sites reflected the generally unsuitable nature of habitat for aquatic macrophyte growth. The rivers of interest typically had coarse cobble/gravel streambeds and a high proportion of turbulent riffle/chute habitats that most likely restricted the establishment and growth of rooted aquatic macrophytes. The likelihood of frequent high flows during wet periods of the year is also likely to restrict the establishment of macrophytes in many of the mid-upper creek systems of Ba catchment.

PLANKTONIC TAXA

A checklist of zooplankton and phytoplankton recorded at waterways of interest is presented in the appendix. A total of 57 planktonic taxa were recorded; 16 zooplankton and 41 phytoplankton.

The most frequently recorded zooplankton taxa across the creeks were baetid mayfly (*Pseudocloeon;* 17 sites) and chironomids (non-biting midge) of sub-family chironominae (14 sites). *Pseudocloeon* were dominant at mid Navisa and mid and lower Nadrou while Chironomids were dominant taxa at upper Wainamau. Zooplankton taxa that were rare (single site) included a crustacean megalopae, stratiomyidae (soldier fly), zygoptera (damselfly naiad and pyralidae (aquatic moth).

Zooplankton is typically rare in well-shaded fast flowing waterways as planktonic organisms are washed downstream before they have a chance to complete their life cycles. Waterways of interest fall within a rain shadow region of Fiji and therefore absence of regular naturally occurring flash floods which otherwise would have prevented planktonic fauna from establishing populations in the water column.

The most commonly recorded phytoplankton taxa include three Chlorophyta taxa (*Botryococcus*; 16 sites, *Microspora*; 14 sites, and *Spirogyra*; 13 sites), one Cyanobacteria taxa (*Stigonema*; 13 sites) and three Bacillariophyta taxa (*Fragilaria*; 11 sites) and *Cyclotella*; 11 sites and Microcystis; 10 sites). Phytoplankton taxa that were rare (single site) included green algae (*Scenedesmus, Cladophora, Closterium* and *Hyalotheca*), uni-celled diatom *Astrionella* and

Cyanobacteria (*Aphanizomenon* and *Rivularia*). The phytoplankton communities recorded across the three creek system are typical of inland system waterways.

3.6 Macroinvertebrates

TAXA RICHNESS AND ABUNDANCE

A total of 10,120 freshwater macroinvertebrates were collected across 17 sites and identified to lowest taxonomic level possible. A total of 73 distinct macroinvertebrate taxa were collected across all samples and sites during the survey. Macroinvertebrates were distributed among the taxonomic groups shown in Table 2. The most diverse group was Insecta with 51 taxa and representing 70% of the total number of taxa recorded. Of the 51 insect taxa, 13 were caddisflies, 9 were dipterans (true-flies), 7 each were water beetles and water bug, 5 were mayflies, 4 were damselflies, 3 were dragonflies, 2 were aquatic caterpillar (moth) and 1 water cricket. The next most diverse taxonomic group was Crustacea (11 taxa) followed by Mollusca (6 taxa), Annelida (3 taxa) and Nematomorpha and Playhelminthes represented by 1 taxa each. Mollusca were relatively diverse with 11 distinct taxa recorded from edge habitat across sampling sites.

Table 2: number of macroinvertebrate taxa recorded in each of the taxonomic groups across all sites

Higher taxonomic group	Order / class	Common name	Number of taxa
	Trichoptera	caddisfly	13
	Ephemeroptera	mayfly	5*
Insecta	Lepidoptera	moth	2
	Diptera	true-fly	9
	Zygoptera	damselfly	4
	Anisoptera	dragonfly	3
	Coleoptera	beetle	7
	Hemiptera	water bug	5
	Heteroptera	water bug	2
	Orthoptera	water cricket	1
Crustacea	Caridea	shrimp	9
	Dendrobranchiata	prawn	1
	Ostracoda	seed shrimp	1
Mollusca	Gastropoda	snails	6
Annelida	Oligochaeta	worms	3
Nematomorpha	Gordiida	Horse hair worm	1

Platyhelminthes	Tricladida	Flatworm	1
			73

Note: * (+?) = likely to include more species than the number indicated.

The number of macroinvertebrate taxa recorded from sites ranged between 14 taxa from lower Nadrou (LND) and 25 taxa from the upper Wainamau (UWM). The upper Wainamau creek at Koroboya village supported a diverse insect fauna (i.e., 23 insect taxa) dominated by resilient/pollution tolerant species (net-spinner caddis (*Abacaria fijiana*), damselfly naiad (*Indolestes* sp.), purse-case micro-caddis (*Paroxyethira* sp. and *Oxyethira fijiensis*) and the algal grazer aquatic moth (*Nymphicula* sp.). The modified upper Wainamau creek system supported additional micro-habitats such as silt covered macrophyte beds (green charophytic *Chara* sp.), invasive weed vegetation belt at bank and silted streambed which allowed population establishment of resilient species. Lower Nadrou (LND) supported low taxa richness (14 taxa) and reflected agriculturally modified aquatic habitat conditions and overhanging modified streambank vegetation. There was no general trend observed in total taxa richness across catchments most likely due to varying localized disturbance types. Average number of macroinvertebrate taxa across the 17 sites was 20.

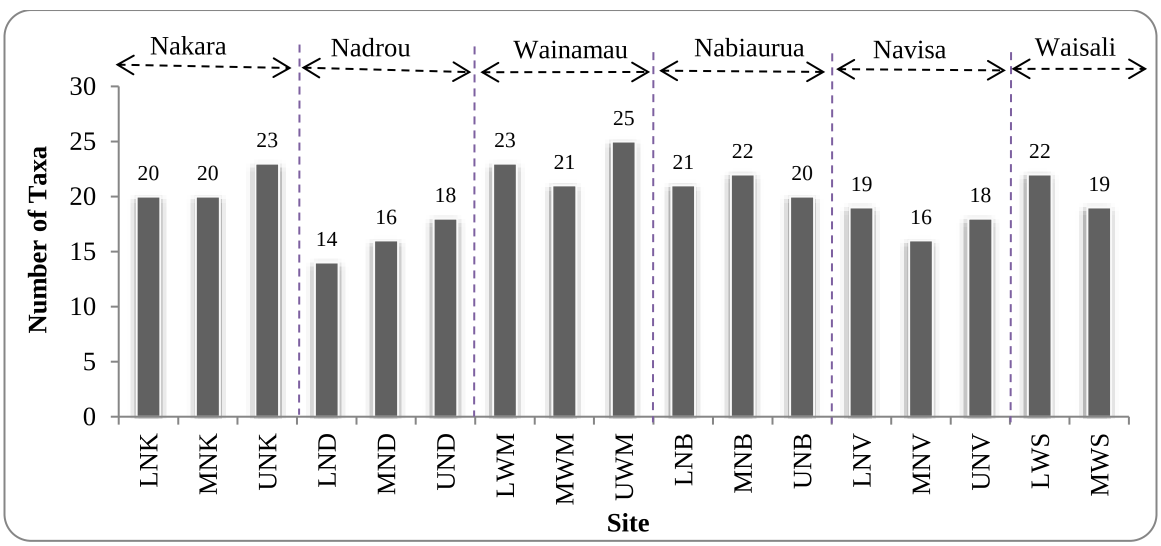

Figure 2: Number of unique taxa across all sampling sites

Note: site code abbreviation= (catchment location (lower=L) + 2 letters of catchment name (Nakara=NK); e.g. LNK

MACROINVERTEBRATE DENSITY

Macroinvertebrate density across survey sites is presented in Figure 3. Macroinvertebrate density was calculated for Surber samples while kick-net samples represent total abundance of individuals collected across multiple habitats. Invertebrate density recorded in riffle habitats ranged between 163 individuals/m^2 at upper Navisa (UNV) and 3,847 individuals/m^2 at upper Nadrou (UND). There was no general trend observed in density across upstream and downstream sites across sub-catchments. Exception was at sites of Nabiaurua catchment whereby invertebrate density decreased downstream. This was due to downstream decline in the abundance of the three dominant taxa; clinging mayfly (*Pseudocloeon* spp), net-spinner caddis (*Abacaria fijiana*) and the weighted-case maker endemic caddis (*Goera fijiana*).

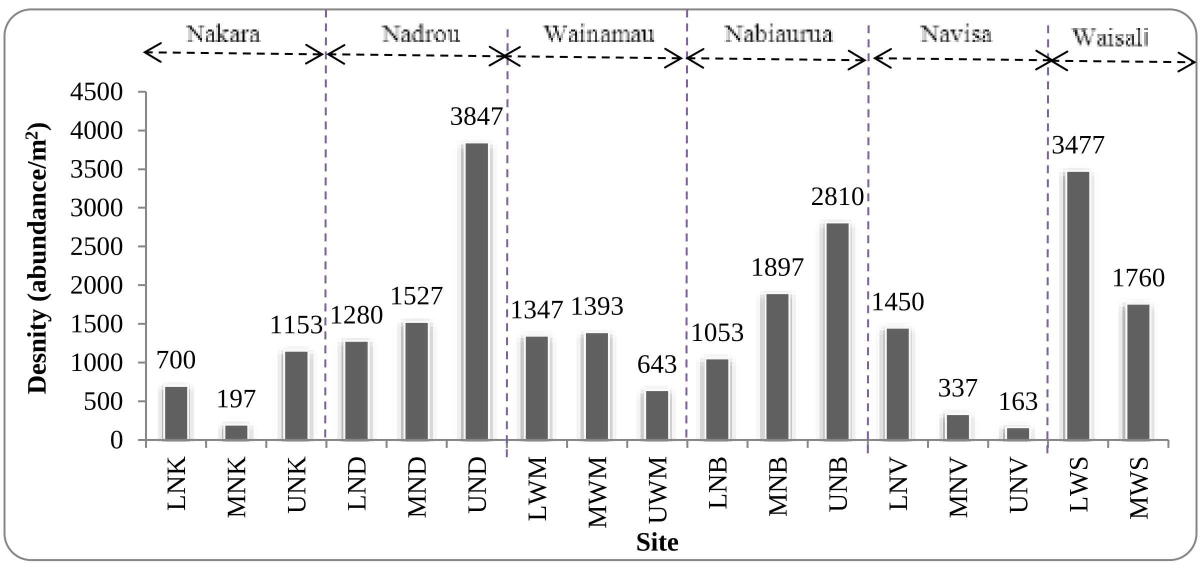

Figure 3: Macroinvertebrate density across all sampling sites

Average macroinvertebrate density across the 17 sites was 1473 individuals/m^2. The relatively low density at upper Navisa (UNV) was due to lack of representatives from certain groups in the riffle habitat; Trichoptera (2 taxa only) and two representatives of odonata (damselfly), zero representatives of odonata (dragonfly), single representative of hemiptera (water bug), coleopteran (aquatic beetle) and zero representative of gastropod and crustacean (prawn, shrimp and crab). The highest densities at upper Nadrou (UND: 3,847 individuals/m^2) and lower Waisali (LWS: 3,477 individuals/m^2) creek sites was due to the large number of Baetid mayfly nymphs (*Pseudocloeon* spp. recorded in riffle habitat representing the largest proportion of invertebrate densities; 42% and 72% of the total macroinvertebrate density respectively. The purse-case micro-caddis (*Paroxyethira* sp.1) contributed to the second largest proportion of invertebrate density at upper Nadrou (UND: 3,847 individuals/m^2); 34% of the total macroinvertebrate density.

STATUS AND DISTRIBUTION OF TAXA

A total of ten of the macroinvertebrate taxa recorded over the survey were endemic to the Fijian Islands and represented 14% of the total number of taxa recorded. Many of the endemic taxa recorded are common throughout Fiji Island streams. These include the five caddisflies (*Abacaria fijiana, Abacaria ruficeps, Anisocentropus fijianus*, *Goera fijiana and Oxyethira fijiensis*), the endemic damselfly*, Nesobasis* spp. (genus endemic to Fiji), a shrimp (*Caridina fijiana*), endemic genus of micro-water striders *Fijivelia* sp., the endemic water cricket (*Hydropedecticus vitiensis*) and spring snails *Fluviopupa* spp. The five endemic caddislfies recorded are common throughout slightly modified to modified streams/creeks.

The most common group were the unconfirmed Fiji endemics represented by 33 taxa (i.e., 47%). Many freshwater macroinvertebrates that has only been identified to genus level and yet to be matched with their respective adults to confirm their species name in order to confirm their status. Hence many macroinvertebrates identified to family/genus level only (eg. Cordullidae or Odontoceridae, *Tipula* sp., Polycentropodidae and *Hydrobiosis* sp.) are unofficially known to be endemic to Fiji but has been placed in the UFE status as of present; which in this survey represented the highest (47%) of the total taxa recorded.

The next most common group were those native to Fiji represented by 18 taxa (i.e., 26%); crustaceans being the dominant taxa. Two taxa were native to the South Pacific region (3%) and two introduced the Pacific region (3%). The remaining 7% of taxa had unknown status (Figure 4).

Figure 5 shows the total number of taxa recorded at each site and status/distribution shown as a proportion of total taxa richness within each community. The number of endemic taxa recorded across the 17 sites ranged between 2 endemic taxa in the upper Navisa (UNV) and eight endemic taxa in the upper Nakara Creek (UNK).

The majority of endemic taxa recorded were insects (eight out of 10 taxa in total). The only other endemic taxa recorded were the small (<4 mm) micro spring snail *Fluviopupa* spp. and *Caridina fijiana* (shrimp). The introduced tropical snail *Melanoides tuberculata* was recorded across 10 sites. Of highest concern is the occurrence of highly invasive leech *Helobdella europaea* which was recorded at upper (UWM) and mid (MWM) Wainamau sites. It is likely that *H. europaea* also occurs in the connecting waterways but was just not recorded during the surveys due to selected sampling site limitation.

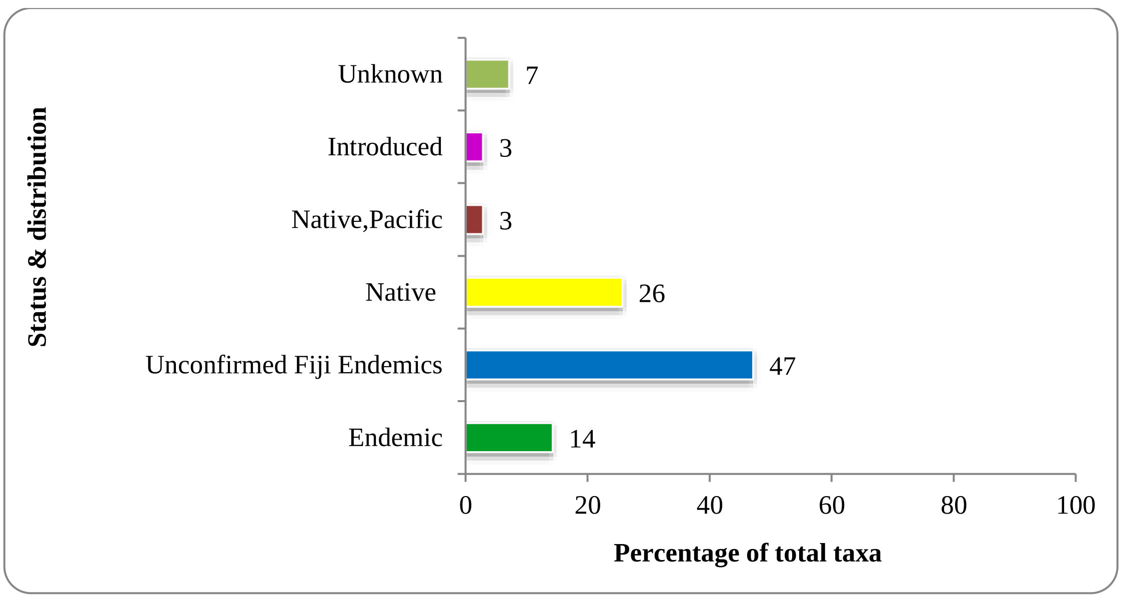

Figure 4: Status and distribution of macroinvertebrate taxa recorded across all sites

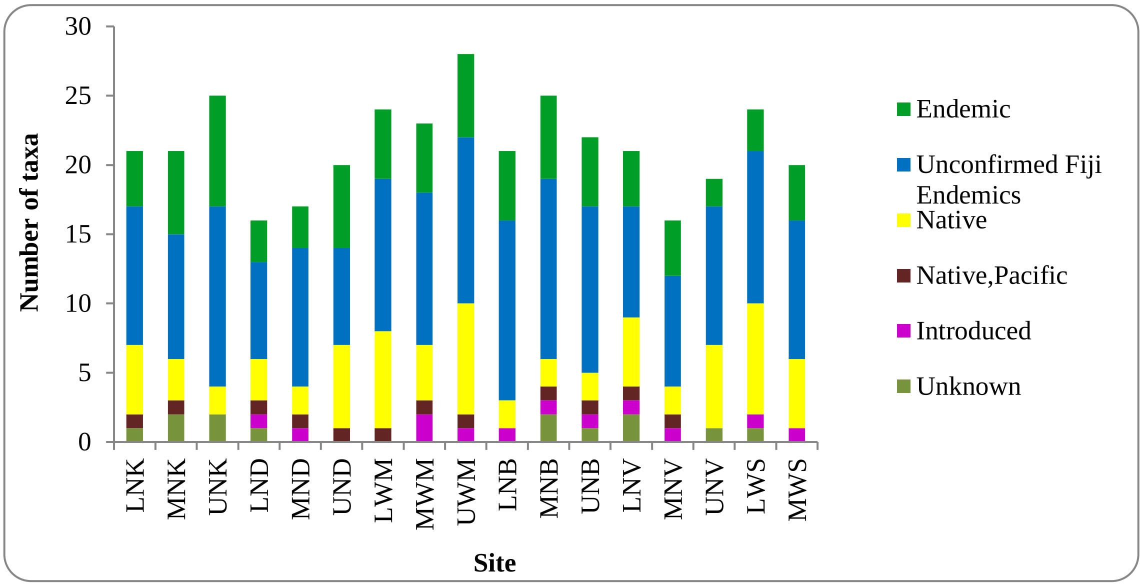

Figure 5: Status and distribution of macroinvertebrate taxa recorded across Individual sites

MACROINVERTEBRATE TAXA OF INTEREST

The only freshwater macroinvertebrates from Fiji that are considered to be threatened and of conservation interest are the endemic gastropods *Acochlidium fijiense* and *Fijidoma maculata*. Haynes & Kenchington (1991) found *Acochlidium fijiense* under stones in shallow (0.06-0.14 m deep) stream sections that were influenced by the tide but upstream of salt water intrusion. *Acochlidium fijiense* is unlikely to be found in any of the waterways of interest given their habitat preferences. *Fijidoma maculata* is endemic to Viti Levu and found in tributaries of major rivers. *Fijidoma maculata* is known to occur in tributaries of the Ba catchment and recorded from the Naidadara creek (Haynes 2004). It is possible that *Fijidoma maculata* occurs within the systems connected to the waterways of interest but were not recorded during the survey. Macroinvertebrate taxa that were recorded during the surveys and are of potential ecological interest are presented in Table 3 The distribution of the invasive leech (H. europaea) which is an ecological concern for Ba waterways and the area endemic spring snails (excellent water quality bioindicators) are presented in Figure 6.

Table 3: Freshwater macroinvertebrate taxa of ecological interest

	Picture	Taxa	Brief details
Freshwater Macroinvertebrate Taxa of Interest		*Helobdella europaea* size: (16mm long)	Invasive *H. europaea* belongs to the family Glossiphoniidae. *H. europaea* is the sole representative of Glossiphonids of Fijian freshwater system. It poses a threat to the native molluscan and annelid fauna as this species is known to feed on haemolymph of aquatic invertebrates. They use their proboscis to suck the insides of molluscs and worms (Kutschera 2004; MÁLNÁS *et al.* 2016). Considering the predatory behavior of the *H. europaea*, this annelid poses a threat to the larval, nymphal and naiad stages of aquatic insects and juvenile stages of endemic and native gastropods. Of primary concern are the area endemic spring snails, the risoodean micro-gastropods of the genus *Fluviopupa* (Family: Tateidae).
		*Nesobasis* spp. size:15mm long	Coenagrionidae is a family of damselflies widely distributed in the Melanesia and Fiji has its endemic genus, *Nesobasis* with 31 aerial adult species. The naiad example presented here cannot be placed into a species level as only the adults have been described so far from Fiji. The naiads collected and observed during the survey are prelimnary collection for the dry side highlands of Viti Levu. New naiad records are possible for the Nadrou and Nabiaurua catchment sites.
		Ostracoda Size: 0.5-0.8mm body length	Freshwater ostracod (seed shrimp) has previously been documented by the author in 2017 from the Qauia creek in Lami (disturbed lowland species) and in 2018 from the Nadarivatu highlands. This is the third record for freshwater ostracod in Fiji and it is an upland forest species. Fijian ostracods are yet to be described and therefore this is a potentially new species for Fiji and new record for Science.

		*Fluviopupa spp.* size: 3mm long	Freshwater Spring snails or Rissoodean snails belong to the family Tateidae (former family Hydrobiidae) with a single genus, *Fluviopupa*, present in the Melanesian archipelago (Haase *et al.* 2006; Haase *et al.* 2010). Fiji holds a record of 28 endemic *Fluviopupa* species, majorly area endemics (Zilke and Haase, 2017). This is the first record of the spring snail in the catchments surveyed. The *Fluviopupa* spp. collected from the six sites are potentially new species as the spring snails are known to evolve in the headwaters of catchments and usually catchment endemic.

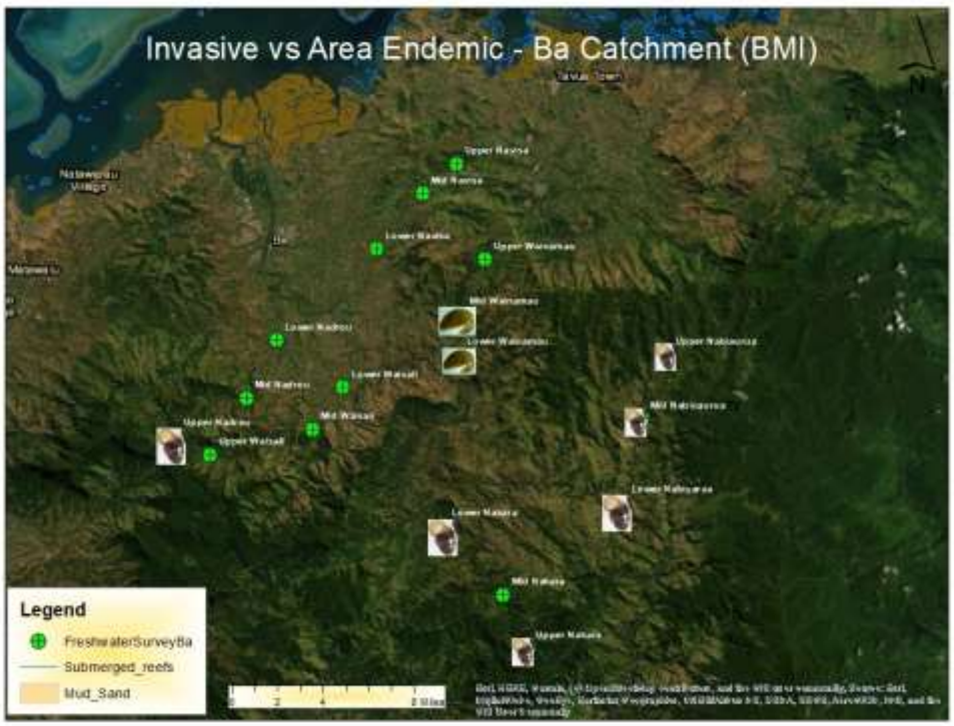

Figure 6: Invasive and area endemic invertebrate species for Ba catchment.

3.7 Fish

ELECTROFISHING CATCH

A total of thirteen species (nine families) were collected by electrofishing from the four sites (**Error! Reference source not found.**). The most speciose family from the electrofishing catch was the Gobiidae family with a total of three species followed by Eleotridae and Signathidae at two species each. The remaining families were represented by one species each. The giant mottled eel *Anguilla marmorata* was the most abundant native fish (19 fish caught across the seventeen sites).

Overall, a total of 159 fish were caught across the seventeen sites. The number of fish recorded at each site ranged from 22 individuals at site 8, followed 16 individuals at site 2. Site 4 recorded the lowest abundance of fish with 2 individuals captured.
Fish abundance was highest at the lower reaches of the six sub-catchments.
Two native fish species were relatively abundant at all sampling stations

- Giant marbled eel (*Anguilla marmorata*)
- red-tailed goby (*Sicyopterus lagocephalus*)

The two families Anguillidae (36%) and Poecillidae *Gambussia affinis* (35%) comprised over 60% of the total fish caught during the survey (Figure 7). The red tailed goby *Sicyopterus lagocephalus* was also abundant at most sites and comprised about 10% of the total catch. Unfortunately the primary sampling tool (LR-24 Smith Root Electrofisher) started to have issues during the survey and resulted in an unstandardized method being employed during the survey. This consequently resulted in no rigorous statistical analyses being carried out to compare the various sub-catchments fish communities.

Table 4: Species abundance across the seventeen sites sampled

Abundance	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Grand Total
Anguilla marmorata	3	6	2	3	2	4	8	3	3	2	0	3	7	2	5	4	0	57
Anguilla megastoma	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Awaous guamensis	0	0	3	0	0	0	0	1	0	0	0	0	0	1	0	0	0	5
Eleotris fusca	0	0	0	5	0	0	0	0	3	0	0	0	0	0	0	0	0	8
Gambusa affinis	7	10	10	4	0	0	0	12	0	5	0	0	0	4	0	1	3	56
Kuhlia marginata	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	4
Kuhlia rupestris	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	2
Oreochromis niloticus	1	0	0	3	0	4	0	0	0	0	0	0	0	4	0	3	0	15
Sicyopterus lagocephalus	0	0	0	0	0	0	0	5	3	0	3	0	0	0	0	0	0	11
Grand Total	**11**	**16**	**15**	**15**	**2**	**8**	**8**	**22**	**10**	**9**	**6**	**3**	**7**	**11**	**5**	**8**	**3**	**159**

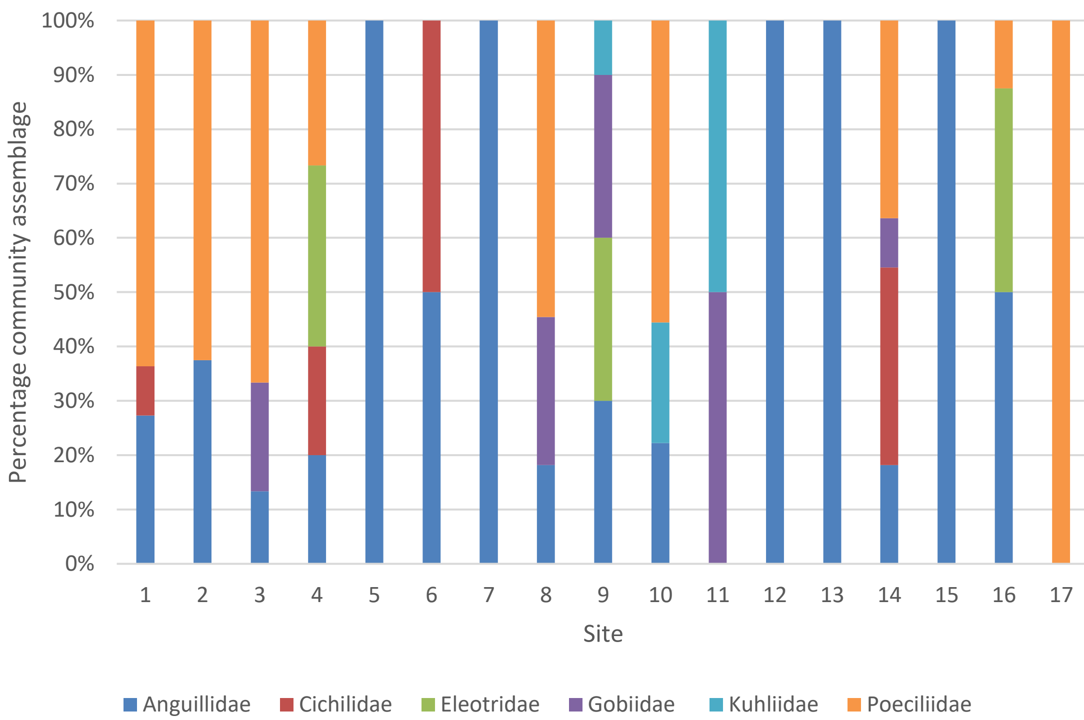

Figure 7: Family site community composition.

4 GENERAL DISCUSSION

Freshwater macroinvertebrates are pivotal in functioning of freshwater ecosystems. They contribute towards crucial ecosystem functions such as nutrient cycling, assisting in litter decomposition and plant community regulation as well as being food for higher-level organisms (MacDonald *et al*., 1991). Higher level organisms such as large prawns and fish (except Gobidae which are algal grazers) are important food supply for the village people. They feed on these macroinvertebrates such as freshwater snails, juvenile shrimps and prawns and insect larvae (Haynes, 2004). Therefore in order to maintain desired number of fish and prawn population in a river/stream, the presence of aquatic macroinvertebrate population is necessary. Higher number of macroinvertebrate diversity increases the number and complexity of aquatic food chains and leads to more stable and resilient freshwater communities.

Macroinvertebrate communities recorded from sampling sites were fairly typical of those expected in western inland streams draining Viti Levu. For the most part, the rivers sampled provided diverse and abundant aquatic habitat in run-riffle-pool habitat sequences, stable stony streambeds (i.e., high proportion of boulder, cobble and gravel), occasional woody debris, abundant leaf litter, streambank vegetation and an abundant source of food (i.e., algae films).

Freshwater survey recorded a total of 73 macroinvertebrate taxa out of 10,120 specimens. An Interesting observation was that the small riffle shrimps that were caught during the survey were all kept by our local guides in Ba for consumption. This clearly illustrates the importance of crustaceans to the diets of villagers in the upper reaches of the Ba catchment.

Many of the freshwater invertebrates found across the 17 sites are the same family as those recorded from other disturbed sites in Viti Levu except the ,Ostracod, new record of the aquatic beetle larva of the family (Spercheidae) and the micro-spring snails (*Fluviopupa* spp.). *Fluviopupa* has undergone considerable speciation and each geographic region has its own species.

The minute (3-5mm shell) freshwater spring snails (*Fluviopupa* spp.) of the family Tateidae snail were recorded from the waterways of interest for the first time for a total of six

sites (35% of the total sites surveyed). This/these species were the only gastropod recorded that is endemic to Fiji during the survey, more specifically they are area endemics and therefore of very high conservation significance. Currently Fiji records a total of 28 *Fluviopupa* species, all of which are endemic and area endemics (Zielke and Haase 2014). A rich density of the *Fluviopupa* spp. collected from mid Nabiaurua suggested that larger populations are thriving well in connected areas of assessment. However their absence in other sites may reflect the intactness of the system as spring snails are highly sensitive to any type of environmental disturbance that affects natural water quality and substrate biofilm smothering. Spring snails are bioindicators of excellent water quality and intact forest systems. The *Fluviopupa* spp. collected from Nakara, Nabiaurua and Nadrou catchments (LNK, UND, MNB, UNB, LNB and UNK) are potentially new species as the spring snails are known to evolve in the headwaters of catchments and usually catchment endemic. Hence, a very high possibility of a total of six new records to science and an increase in the diversity of the area endemic risoodean gastropods for Fijian highlands.
The ostracod (seed shrimp) collected from mid Wainamau (MWM) and mid Nadrou (MND) are first records for waterways of interest and has a very high potential of being a new species to science since and Fiji. There is no literature describing taxonomy of Fijian ostracods and therefore these species are new findings/records for Fiji and need special consideration for micro-habitat conservation and management.

H. europaea is a proboscis-bearing leech (Figure 3) and therefore non-sanguivorous. However it poses a threat to the native molluscan and annelid fauna as this species is known to feed on haemolymph of aquatic invertebrates. They use their proboscis to suck the insides of molluscs and worms (Kutschera 2004, MÁLNÁS et al. 2016). Fiji like other Melanesian countries supports a highly diverse freshwater invertebrate fauna comprising over 61 families (Haynes and Rashni , Ryan 1980, Choy 1984, Haynes 1985, Haynes 1987, Haynes 1988, Choy 1991, Haynes and Kenchington 1991, Haynes 1999, Haynes 2001, Haynes 2001, Jeng et al. 2003, Hasse et al. 2006, Polhemus et al. 2006, Haynes 2009, Rashni 2014, Zielske and Haase 2014), many of which have not been described. Considering the predatory behavior of the *H. europaea*, this annelid poses a threat to the larval, nymphal and naiad stages of aquatic insects and juvenile stages of endemic and native gastropods. Of primary concern are the area endemic spring snails, the risoodean micro-gastropods of the genus *Fluviopupa* (Family: Tateidae). The minute (3-5mm shell) freshwater spring snails are area endemics and known to evolve as new species in intact headwaters and is therefore of very high conservation significance. Secondarily, Naidadara creek of the Ba river headwaters has been known to be home to the Viti Levu endemic gastropod *Fijidoma maculata* which apart from this site occurs only in Wainibuka catchment headwaters of Ra province. The extant population and biogeographical distribution of *F. maculata* is in these areas are yet to be monitored and verified. The likely mode of introduction of *H. europaea* in Fiji remains unknown at the moment however a thorough survey of this invasive species across the connected riverine network of upper and mid Wainamau is recommended. The data gathered will assist in understanding the possible 'cause (s)' of' the leech infestation in the Fijian waterways and the likely impacts on the freshwater biotic communities. It will also feed information to deduce development measures to mitigate any further ecological alterations (e.g. disruption of the trophic interactions) on the affected biotic community and concerned micro-habitats.

Plate 4 to Plate 12 shows some of the important food sources caught during the survey in the Ba watershed.

Plate 4: Berried monkey river prawns

Plate 5: Riffle shrimp

Plate 6: Scissors river prawn

Plate 7: Tilapia

Plate 8: Flag tail

Plate 9: Jungle perch

Plate 10: Marbled eel

Plate 11: Pacific river goby

Plate 12: Riffle shrimps

5 RECOMMENDATIONS

5.1 Community section: Eco-status of Ba catchment riverine systems

This section is compiled to assist with the Ba catchment management plan with a specific focus on the status of riverine systems and recommendations on maintenance of ecological integrity of these systems for continued harnessing of ecosystem services. Ecological status of the Ba catchment riverine systems was developed based on bioindicators of riverine ecological health for Fijian systems. The Eco-status map (Figure 8) shows the ecological status of the freshwater sites surveyed with respective colored keys as indicators of ecological status type. Inland catchments with forest cover associated sites appear to have moderately good to good (green circles) waterways while systems in close distance to coastal areas (less vegetated areas, concentrated agriculture) appear to have moderately degraded to degraded waterways. Despite being impacted by continued agricultural activity over the years moderately degraded sites appear to be receiving good water quality from upstream sites which allow freshwater biodiversity to thrive and thus the shown amber circle per site on the map.

A matrix (Table 5) was developed in association with the eco-status map to reflect the bioindicator community recorded per site, observed threats, mitigation and enhancement measures and site associated villages. It is highly recommended that upstream and down communities work in collaboration to observe the recommendation as per matrix.

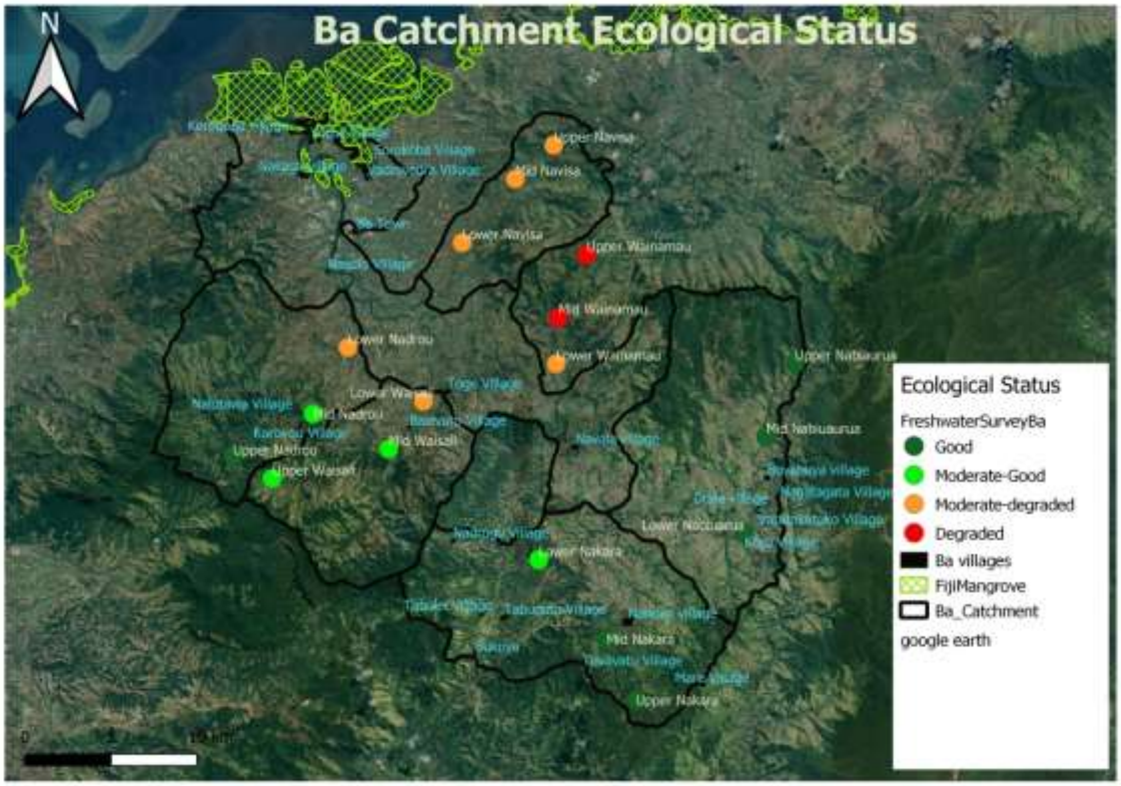

Figure 8: Ba catchment ecological status

5.2 Ongoing monitoring of watershed processes

The importance of conserving the biological resources of watersheds as well as other ecosystem services including clean water supply and fishery resources is now widely accepted (Smith et al., 2003). This recognition has also given rise to a range of new focal points including the integration of watershed-scale considerations with management and conservation planning as well as the ecosystem-based management of aquatic migratory pathways (Jenkins et al. 2010).

5.3 Environmental impact assessments

If consistently implemented and enforced with compliance, Environmental Impact Assessments (EIAs) are another mechanism which could be used to better regulate ridge to reef contexts. Past EIAs in Fiji have covered a range of environmental stressors as well as various infrastructural and industrial developments including dredging in Sigatoka River (Corerega, 2012); EIAs are widely applied in Fiji. However, these EIAs vary in levels of coverage, precision and stringency. This has led to criticisms of EIAs in Fiji. Turnbull (2004) argues that environmental impact assessments, environmental planning and protected areas in Fiji, are often trumped by political and economic processes and interests. Further still, systemic legislative and procedural shortcomings also limit the ability of EIAs in Fiji to reduce the country's vulnerability and exposure to environmental degradation (Turnbull, 2003).

5.4 Gravel extraction

The Ba catchment has several active gravel extraction sites. The Fiji Government has made preliminary decisions to phase out river gravel extraction and a move to rock quarries. Studies have shown the negative impacts of these activities on the environment and to nearby communities. Many communities living along the Ba River depend on it for important services such as drinking water, traditional fishing grounds (Qoliqoli), irrigation and transportation. The transition to supply by a network of hard rock quarries will require a concerted effort by all stakeholders.

5.5 Waste disposal

The issue of waste disposal in many rural villages is an environmental concern that must be addressed. In several villages visited, the river was used as a dumping ground for rubbish. This is perhaps one of the biggest environmental dilemma affecting Fiji and the world. Land-based pollution is a serious threat to many aquatic life.

Table 5: Ecological status matrix

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
UNB	Upper Nabiaurua	*Chimarra* sp., *Hydrobiosis* sp., *Baetis* spp. Chironomidae, *Fluviopupa* spp.	None at site surveyed.	Good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture.	Drala village, Vatutokotoko Village, Buyabuya village, Koro Village & Nagatagata Village
MNB	Mid Nabiaurua	*Chimarra* sp., Polycetropodidae, *Nesobasis* spp., *Dineutus* sp., *Fluviopupa* spp.	None at site surveyed.	Good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope farming is not recommended. 4. Use of Duva (derris	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
					plant) roots and chemicals for fish/prawn harvest is not recommended.		
LNB	Lower Nabiaurua	*Chimarra* sp., *Hydrobiosis* sp., *Apsilochorema* sp., Polycentropodidae, Nesobasis sp., Chironomidae, *Fluviopupa* spp.	None at site surveyed.	Good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture.	
UNK	Upper Nakara	*Chimarra* sp., *Hydrobiosis* sp., *Apsilochorema* sp., *Tipula* sp., *Melanesobasis* sp., *Fluviopupa* spp. and Chironomidae	None at site surveyed.	Good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture.	Mare Village, Tuvavatu Village, Nanoko Village, Bukuya village,

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
					3. Bank/slope farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.		Tabuquto Village, Tabulei Village Nadrugu Village
MNK	Mid Nakara	*Nesobasis* sp., Polycentropodidae, *Baetis* spp. *Abacaria ruficeps* and Chironomidae	None at site surveyed.	Good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture.	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
LNK	Lower Nakara	*Nymphicula* sp., *Abacaria ruficeps*, Chironomidae, *Chimarra* sp., *Baetis* spp., *Tipula* sp. and *Fluviopupa* spp.	Algal covered rocks indicative of excess nutrient leachate.	Moderate-Good	1. Identify point and non-point pollution sources to stream draining the village and farmed areas. 2.To maintain the riparian vegetation on both sides of the bank. 3. Gravel extraction is not recommended. 4. Bank/slope farming is not recommended. 5. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture.	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
UWM	Upper Wainamau	*Nymphicula* sp., *Abacaria ruficeps*, Chironomidae, *Nesobasis* spp., *Apsilochorema* sp., Polycentropodidae, *Helobdella europaea* and *Dineutus* sp.	Unstable stream bank. Vegetation removal next to stream bank. Sedimented streambed harboring inasive leech population. Algal covered rocks indicating nutrient leachates.	Degraded	1. Identify point and non-point pollution sources to stream draining the village and farmed areas. 2. Implement Nature-based solutions (long-term) for Sedimentation Control Plan. 3. Use of engineering control measures (e.g. gabions, straw bale or sandbags) to avoid discharge of contaminated/grey water into the river. 4. Grey water treatement plan. 5. Proper rubbish disposal. 6. Proper fencing for livestock to avoid river access. 7. Be alert to avoid trasporting invasive	1. Proper waste managemeng plan in place (including hazardous wastes). Appoint an Environmental Officer Environmental Management Plan. 2. Define boundaries of the river rehabilitation project for impact (undercutting, bare bank areas) areas to limit socio-ecological disturbance. 3. Consider transplanting (when possible) or replacing weeds/grass covered bank with native/endemic	Koroboya village

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
					leech to other areas via boots or farming tools washed in the creek.	plants (Tahitian chestnut, *Pandanus vitiensis* and Sago palm) seedlings in suitable areas (bare bank/eroded areas). 4. Develop and implement leech eradication plan. 5. Annual biomonitoring of water quality and invasivesin collaboration with forestry, SPC and Ministry of Agriculture.	

ID	Site	Biodindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
MWM	Mid Wainamau	Chironomidae, *Nymphicula* sp., *Abacaria ruficeps*, *Nesobasis* spp., *Apsilochorema* sp., *Harrisius* sp. and *Helobdella europaea*		Degraded	1. Identify point and non-point pollution sources to stream draining the village and farmed areas. 2. Implement Nature-based solutions (long-term) for Sedimentation Control Plan. 3. Use of engineering control measures (e.g. gabions, straw bale or sandbags) to avoid discharge of contaminated/grey water into the river. 4. Grey water treatement plan. 5. Proper rubbish disposal. 6. Proper fencing for livestock to avoid river access. 7. Be alert to avoid trasporting invasive	1. Proper waste managemeng plan in place (including hazardous wastes). Appoint an Environmental Officer Environmental Management Plan. 2. Define boundaries of the river rehabilitation project for impact (undercutting, bare bank areas) areas to limit socio-ecological disturbance. 3. Consider transplanting (when possible) or replacing weeds/grass covered bank with native/endemic	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
					leech to other areas via boots or farming tools washed in the creek.	plants (Tahitian chestnut, *Pandanus vitiensis* and Sago palm) seedlings in suitable areas (bare bank/eroded areas). 4. Develop and implement leech eradication plan. 5.Annual biomonitoring of water quality and invasivesin collaboration with forestry, SPC and Ministry of Agriculture.	
LWM	Lower Wainamau	*Nesobasis* sp., Chironomidae, *Abacaria ruficeps*, Polycentropodidae, *Apsilochorema* sp. and *Baetis* spp.		Moderate-degraded	1. Piggeries to be located far from riverbank Rubbish to be disposed properly in landfill.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture.	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
MWS	Mid Waisali	Chironomidae, *Nesobasis* spp., *Chimarra* sp., *Baetis* spp., *Hydrobiosis* sp. and *Tipula* sp.	1. Eroded bank areas. 2. Modified riparian vegetation.	Moderate-good	1. To rehabilitate and maintain the riparian vegetation on both sides of the bank. 2. Bank/slope farming is not recommended. 3. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended. 4.Livestock to be located far from riverbank 5. Gravel extraction is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	Balevuto village and Toge village
LWS	Lower Waisali	*Nymphicula* sp, *Barbronia* sp., Chironomidae, *Apsilochorema* sp., *Baetis* spp., *Nesobasis* spp., *Caenis* sp. and *Tipula* sp.	Highly modified riparian vegetation.	Moderate-degraded	1. To rehabilitate and maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
					farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.		
UND	Upper Nadrou	*Nymphicula* sp., *Nesobasis* sp., *Chimarra* sp., *Abacaria ruficeps*, *Fluviopupa* spp. and Chironomidae	None at site surveyed.	Good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	Korovou village, Nalotawa village and Nasolo village

ID	Site	Biondicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
MND	Mid Nadrou	*Nesobasis* sp., Polycentropodidae, *Nymphicula* sp., *Abacaria ruficeps*, Chironomidae, *Barbronia* sp., *Hydrobiosis* sp. and *Baetis* sp.	None at site surveyed.	Moderate-good	1. To maintain the riparian vegetation on both sides of the bank. 2. Gravel extraction is not recommended. 3. Bank/slope farming is not recommended. 4. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	
LND	Lower Nadrou	*Nymphicula* sp., *Nesobasis* spp., Chironomidae, *Apsilochorema* sp. and *Nymphicula* sp.	1. Highly modified riparian 2. Eroded bank areas	Moderate-degraded	1. To rehabilitate and maintain the riparian vegetation on both sides of the bank. 2. Bank/slope farming is not recommended. 3. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
					recommended. 4.Livestock to be located far from riverbank 5. Gravel extraction is not recommended.		
UNV	Upper Navisa	*Barbronia* sp., *Nesobasis* spp., *Caenis* sp., Chironomidae and *Hydrobiosis* sp.	1. Highly modified riparian 2. Eroded bank areas 3. Bank farming	Moderate-degraded	1. To rehabilitate and maintain the riparian vegetation on both sides of the bank. 2. Bank/slope farming is not recommended. 3. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended. 4.Livestock to be located far from riverbank 5. Gravel extraction is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	Sorokoba village and Vadravadra village

ID	Site	Bioindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
MNV	Mid Navisa	*Nesobasis* spp., *Nymphicula* sp., *Abacaria ruficeps* and Chironomidae	Modified riparian on the True right bank	Moderate-degraded	1. Plant native trees to enhance bank stability on the true right bank and maintain the riparian vegetation on both sides of the bank. 2. Bank/slope farming is not recommended. 3. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended. 4.Livestock to be located far from riverbank 5.Gravel extraction is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	

ID	Site	Biologindicators (BMI)	Observed Impacts/Threats	Ecological status	Proposed Mitigation Measures	Additional Mitigation / Enhancement Measures	Mataqali landowning units
LNV	Lower Navisa	*Nymphicula* sp., *Barbronia* sp., *Apsilochorema* sp., Chironomidae, *Nesobasis* spp., *Abacaria ruficeps*, *Baetis* spp. and *Atyopsis spinipes*	1. Modified riparian 2. Eroded bank areas 3. Bank farming	Moderate-degraded	1. To rehabilitate and maintain the riparian vegetation on both sides of the bank. 2. Bank/slope farming is not recommended. 3. Use of Duva (derris plant) roots and chemicals for fish/prawn harvest is not recommended. 4.Livestock to be located far from riverbank 5. Gravel extraction is not recommended.	Annual biomonitoring of invasives in collaboration with forestry, SPC and Ministry of Agriculture	

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ANNEXES

Periphyton taxa recorded across sampling sites

	GROUP/ DIVISION	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Dinophyta
CREEK	STATTION / PERIPHYTON TAXA	*Stigeoclonium* (BF)	*Mougeotia* (UBF)	*Microspora*(UBF)	*Spirogyra*(UBF)	*Ulothrix* (UBF)	*Botryococcus* (C)	*Ankistrodesmus* (U)	*Closterium* (U)	*Melosira* (UBF)	*Navicula* (U)	*Fragilaria*(U)	*Achnanthes* (U)	*Nitzschia* (U)	*Cyclotella* (U)	*Pinnularia* (U)	*Actinella* (U)	*Surirella* (U)	*Stauroneis*(U)	*Gyrosigma* (U)	*Eunotia* (U)	*Meridion* (U)	*Frustulia* (U)	*Cymbella* (U)	*Gomphonema* (U)	*Cocconeis* (U)	*Achnanthidium*(U)	*Synedra* (U)	*Stigonema* (BF)	*Oscillatoria* (UBF)	*Lyngbya* (UBF)	*Anabaena* (UBF)	*Microcystis* (C)	*Aphanocapsa* (C)	*Peridinium* (U)
Wainamau	upper			C	C		C			F	A	C	C		A		HA			F			C				C		C					C	
	mid			C	C		C				A	HA	F		A								F		C										
	lower			C			C			C	A	HA	F		A	C									A	A									
Waisali	mid	A		C		C		F			C	C	F		C		C				R				F				C		F		HA	F	
	lower	F	C	C			C				C	HA			C		C	F				C			C					F	F			F	
Navisa	upper		F				C	C		C	C	F	F		C		C							HA	F	F	C		C		R			C	
	mid						C	F		C	C	A	F		F			F					C					R	C			F			
	lower		A	A	C	F	C	F	F		A	HA	C		C		C					C			F		C		F	R	F				
Nadrou	upper		F	F		F	C	F		F	HA	HA	C		HA		A		F						A		C		A	R				F	
	mid		C	C	C		A			C	C	HA	C				F					F			C	F	C		F						
	lower		C		A		A	C			C	HA	F		C				F	F							C	R	C					F	
Nakara	upper		F	F			A	C		C	C		C	C	C		C								F	F	C	R	F					F	
	mid						C				F	F	R		C		C										C		C		F			F	

GROUP/ DIVISION			Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Dinophyta
CREEK	**STATTION**	**PERIPHYTON TAXA**	*Stigeoclonium* (BF)	*Mougeotia* (UBF)	*Microspora*(UBF)	*Spirogyra*(UBF)	*Ulothrix* (UBF)	*Botryococcus* (C)	*Ankistrodesmus* (U)	*Closterium* (U)	*Melosira* (UBF)	*Navicula* (U)	*Fragilaria*(U)	*Achnanthes* (U)	*Nitzschia* (U)	*Cyclotella* (U)	*Pinnularia* (U)	*Actinella* (U)	*Surirella* (U)	*Stauroneis*(U)	*Gyrosigma* (U)	*Eunotia* (U)	*Meridion* (U)	*Frustulia* (U)	*Cymbella* (U)	*Gomphonema* (U)	*Cocconeis* (U)	*Achnanthidium*(U)	*Synedra* (U)	*Stigonema* (BF)	*Oscillatoria* (UBF)	*Lyngbya* (UBF)	*Anabaena* (UBF)	*Microcystis* (C)	*Aphanocapsa* (C)	*Peridinium* (U)
Nabiarua	lower										C					C		C					F				F									
	upper			C				F			A	C				C	C	A					F		F		C		A							
	mid		C			F		C			A	C				A		A							F	F			C		F					
	lower			C		A		A	C		C	HA		F		C				F	F						C	R	C					F		

Site	Zone	Malacostraca	Cnidaria	Crustacea	Annelida	Acarina	Mollusca	Odonata	Diptera	Diptera	Diptera	Diptera	Hemiptera	Trichoptera	Ephemeroptera	Coleoptera	Lepidoptera	Chlorophyta
	PLANKTON	Ostracoda	Hydra	Megalopae	Oligochaeta	Hydracarina	Gastropoda	Zygoptera	Chironominae	Ceratopogonidae	Empididae	Stratiomyidae	Nemphiinae	Trichoptera	*Pseudocloeon*	Coleoptera	Pyralidae	*Spirogyra*(UBF)
Wainamau	U							R	A					C	C			C
	M								C					C	C	C		R
	L								F						C			C
Waicali	M		C						C						C	C		F
	L	C							C						C	C		C
Navisa	U											R			A			
	M		C						R					F	HA			C
	L	C		F	F	A			C				F	C	C		F	C
Nadrau	U	A							C						C			F
	M	C				F			C					C	HA	C		A
	L		C						C						HA	F		C
Nakara	U														C			C
	M														C			
	L								C						C	F		F
Nabiana	U		C		F				F						C			
	M	C							C						C			
	L	F	F						F					F	C			

Site	Zone	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Chlorophyta	Euglenophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta
	PLANKTON	*Botryococcus* (C)	*Scenedesmus* (C)	*Ankistrodesmus* (U)	*Koliela* (U)	*Tetraedron* (U)	*Stigeoclonium* (RF)	*Draparnaldia*(RF)	*Chaetophora* (RF)	*Cladophora* (RF)	*Microspora*(UBF)	*Ulothrix* (UBF)	*Mougeotia* (UBF)	*Prasiola*(UBF)	*Gloeotila* (UBF)	*Closterium* (U)	*Hyalotheca* (UBF)	*Actinastrum* (U)	*Euglena* (U)	*Melosira* (UBF)	*Navicula* (U)	*Astrionella* (U)	*Nitzschia* (U)
Wainamau	U	HA																	A				
	M	C									F						R	R					
	L			F			F	F			C		F					F					
Waicali	M	C					F	C			F	F	F					C					
	L	F					C			C	C		C					F					
Navisa	U	A									C	F											
	M	C					C	C			C		C					A					
	L	F									F		C			C			F	F			
Nadrau	U	C									F			C						F			
	M	C					C				C								F				
	L	C		F			A	F					F					C		C		A	A
Nakara	U	A	F	C	C	F	F		F				F	C	F						F		
	M	C		F				F			F		F					C					
	L	C						C	F		F									C	C		C
Nabiana	U	F						C			C			C				C					
	M	C		C				C			C		F	C									
	L	R									F							F	R				

Site	Zone	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Cyanobacteria	Rodophyta	Rodophyta
	PLANKTON	*Fragilaria* (U)	*Cyclotella* (U)	*Gyrosigma* (U)	*Gomphosphaeria* (U)	*Oscillatoria* (UBF)	*Microcystis* (C)	*Merismopedia* (C)	*Spirulina* (U)	*Anabaena* (UBF)	*Coleodesmium* (UBS)	*Chamaesiphon*(UBS)	*Chroococcus* (U)	*Gleocapsa* (U)	*Stigonema* (RF)	*Aphanizomenon* (UBF)	*Rivularia* (RF)	*Batrachospermum* (RF)	*Kyliniella* (UBF)
Wainamau	U	HA				C													
	M	A	C				F					R		R	F				
	L	A	C												F		C		
Waicali	M	HA	F																
	L	C	F				F					F	HA		C			C	
Navisa	U						C				F	F		F	F				
	M	A	F				C				F	F		F	C				
	L	HA	F				F			R		F	C		C	R			
Nadrau	U	HA	C				HA							A					
	M	HA	C				F								C			C	
	L	HA		F		C													
Nakara	U		C	R		C	A		A						F				F
	M	F	C					R	C			F		F	F				
	L		F			C	F		F						R				
Nabiana	U		A											F	F				
	M				F	C	C		F						F				F
	L	F					C					C		F	F				

List of macroinvertebrates and relative abundance (a) recorded from sampling sites

Higher taxonomic group	Order /class / family	Taxa	Status	Common name			Nakara			Nadrou			Wainamau			Nabiarua			Navisa		Waisali
					LNK	MNK	UNK	LND	MND	UND	LWM	MWM	UWM	LNB	MNB	UNB	LNV	MNV	UNV	LWS	MWS
Insecta	Trichoptera	*Abacaria fijiana*	E	Caddisfly	A	A	VA	A	A	VA	A	VA	A	A	VA	VA	A	C		VA	VA
		Abacaria ruficeps	E	Caddisfly	C	F	F		C	F	F	C	A				C	R			
		Goera fijiana	E	Caddisfly		F	A			C			F	A	A	VA					C
		Anisocentropus fijianus	E	Caddisfly	F			R		R	F	F	F	R			F	R	C	F	C
		Chimarra sp.	UFE	Caddisfly	F		VA			F				F	R	C					C
		Hydrobiosis sp.	UFE	Caddisfly			C		F					R		C			R		F
		Apsilochorema sp.	UFE	Caddisfly			C	F			F	C	C	C			C			C	
		Oxyethira fijiensis	E	Caddisfly			F					C	A		C	F					
		Paroxyethira sp. 1	UFE	Caddisfly				C		VA	C	A	A	F	A	A	A		R	C	R
		Paroxyethira sp. 2	UFE	Caddisfly							C			F	C	F					F
		Paroxyethira sp. 3	UFE	Caddisfly								C									
		Odontoceridae	UFE	Caddisfly	C	R			F		F		F	C	A	F			F	F	C
		Polycentropodidae	UFE	Caddisfly		C	F		A		F		F	F	C						
	Ephemeroptera	*Pseudocloeon* spp.	UFE	Mayfly	VA	VA	VA	VA	VA	VA	VA	VA	C	VA	VA	VA	VA	F	C	VA	VA
		Baetis spp.	UFE	Mayfly	F	C		F	F		R				C	F	F			C	F
		Caenis sp.	UFE	Mayfly															C	F	
	Odonata	*Nesobasis* sp.	E	Damselfly		C		C	A	C	C	C	C	C	C		C	C	C	C	C
		Indolestes sp.	E	Damselfly	F	C		A		C		C	A	F	C	F	C		R	C	
		Melanesobasis sp.	N	Damselfly			F				R		R	F		R			R		

Higher taxonomic group	Order /class / family	Taxa	Status	Common name			Nakara			Nadrou			Wainamau			Nabiarua			Navisa		Waisali
					LNK	MNK	UNK	LND	MND	UND	LWM	MWM	UWM	LNB	MNB	UNB	LNV	MNV	UNV	LWS	MWS
		Anax sp.	N	Dragonfly						F			F								
		Ishnura sp.	N	Damselfly									C								
		Pantala sp.	N	Dragonfly				F					C								
		Libeluliidae	N	Dragonfly								C	C			R	F			F	F
		Nymphicula sp.	UFE	Moth	C	C	C	VA	C	A	F	A	A	C	C	C	A	C	C	VA	C
	Lepidoptera	Crambidae	UFE	Moth														R			
		Hydrophilidae	UFE	Water bug		R															
		Dytiscidae	UFE	Diving beetle	R								F								
		Elmidae	UFE	Riffle beetle														F			
	Coleoptera	Hydraenidae	UFE	Minute moss beetle														R			
		Chrysomelidae	UFE	Leaf beetle														R			
		Dineutus sp.	UFE	Whirligig beetle									R		R						
		Scirtidae	UFE	Marsh beetles															R		
		Chironomidae	UFE	Midge	C	F	C	C	C	F	C	A	C	C	F	C	C	R	F	A	A
		Tanypodinae	UFE	Midge											R						
		Harrisius sp.	UFE	Midge								F									
		Simulium jolli	N	Black fly			VA					C									
		Empididae	UFE	Dance fly			F		C					C						F	
	Diptera	Dolichopodidae	UFE	Long-legged flies	R																
		Stratiomyidae	UFE	Soldier fly		F					R					R					

Higher taxonomic group	Order /class / family	Taxa	Status	Common name			Nakara			Nadrou			Wainamau			Nabiarua			Navisa		Waisali
					LNK	MNK	UNK	LND	MND	UND	LWM	MWM	UWM	LNB	MNB	UNB	LNV	MNV	UNV	LWS	MWS
	Hemiptera	*Psychoda* sp.	UFE	Drain fly										R					R		
		Tipula sp.	UFE	Cranefly	R		C													R	R
		Limnogonus lactuosus	N	Water bug						F											
		Limnogonus fossarum	N	Water bug						R											
		Saldidae	UFE	Water bug								R									
		Fijivelia sp.	E	Water bug		F									F						
		Anisops	UFE	Back swimmer									C								
	Heteroptera	*Tenagogonus* sp.	N	Water bug		R					R	R							R		
		Limnometra sp.	N	Water bug							R		F	C							
	Orthoptera	*Hydropedecticus vitiensis*	E	Water cricket		F					R										
Malacostraca	Decapoda	*Atyopsis spinipes*	N	Shrimp													R				
		Caridina serratirostris	N	Shrimp	C					C										F	
		Caridina gracilirostris	N	Shrimp	R														R	C	R
		Caridina longirostris	N	Shrimp	R			VA			R	C					A	C		C	C
		Caridina fijiana	E	Shrimp												C					
		Caridina typus	N	Shrimp															F	R	
		Caridina sp. 1	U	Shrimp							C				A		F				
		Caridina sp. 2	U	Shrimp															F		

Higher taxonomic group	Order /class / family	Taxa	Status	Common name	Nakara			Nadrou			Wainamau			Nabiarua			Navisa			Waisali	
					LNK	MNK	UNK	LND	MND	UND	LWM	MWM	UWM	LNB	MNB	UNB	LNV	MNV	UNV	LWS	MWS
		Antecaridina sp.	U	Shrimp		C															
		Macrobrachium latidactylus	N	Prawn	F	R					C				F					C	
	Ostracoda	Ostracoda	UFE	Seed shrimp					F			F									
Mollusca	**Gastropoda**	*Melanoides tuberculata*	I	Snail				A	F			A		F	A	C	C	A		C	C
		Melanoides lutosa	N	Snail	A	F			A	C	C		R				C	C	R	F	C
		Physastra nasuta	NP	Snail		R		R		F	C	C	F		C	A	A	F			
		Gyraulus convexiusculus	NP	Snail	R																
		Fluviopupa spp.	E	Spring snail	R		F			F				C	A	F					
		Ferrissia sp.	UFE	Limpet snail													R	R			
Annelida	**Oligochaeta**	Oligochaeta sp.	U	Worm	F	R	C	R							R	R	R			R	
		Barbronia sp.	N	Leech				C	C	C	R	C	C		C		A		C	A	R
	Hirudinea	*Helobdella europaea*	I	Leech								F	F								

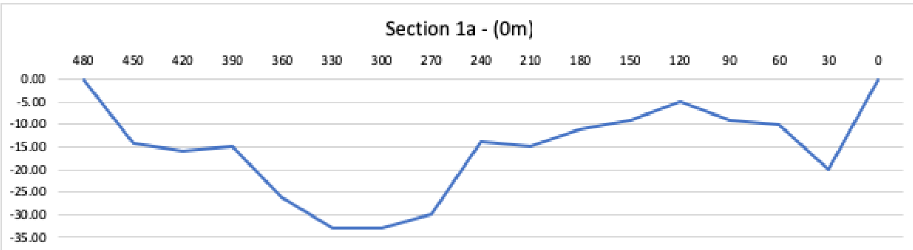
Higher taxonomic group	Order /class / family	Taxa	Status	Common name			Nakara			Nadrou			Wainamau			Nabiarua			Navisa		Waisali
					LNK	MNK	UNK	LND	MND	UND	LWM	MWM	UWM	LNB	MNB	UNB	LNV	MNV	UNV	LWS	MWS
Nematomorpha	**Gordiida**	*Gordius* sp.	U	Horse hair worm			F														
Platyhelminthes	**Tricladida**	Dugisiidae	UFE	Flatworm					C	F	F		F		C	C					

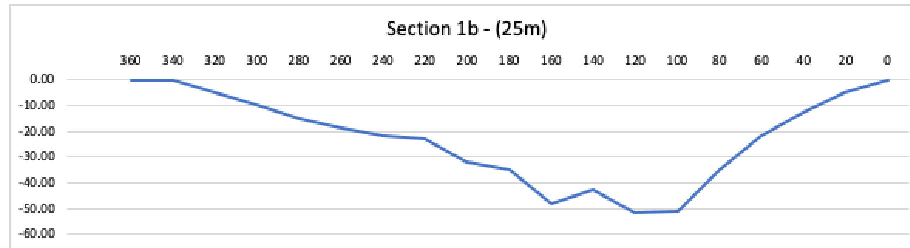
Note: (a) Abundance: VA = very abundant (>100); A = abundant (20-99); C = common (5-19); F = few (2-4); R = rare (1).

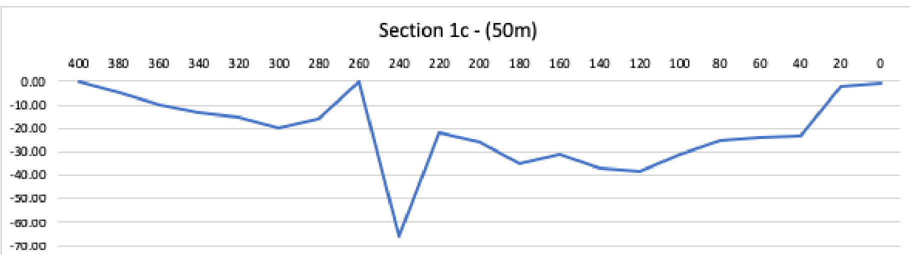
Cross sectional profiles of the seventeen sites surveyed

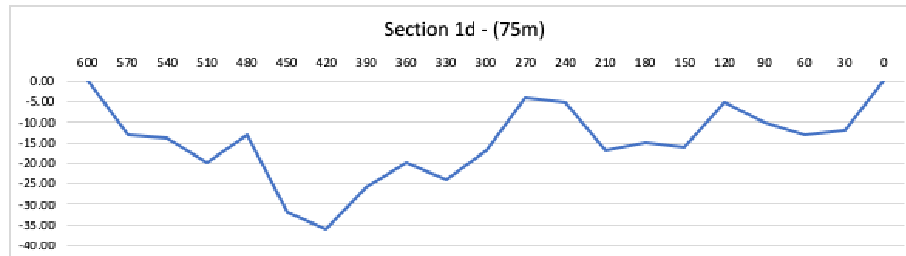
SITE 1

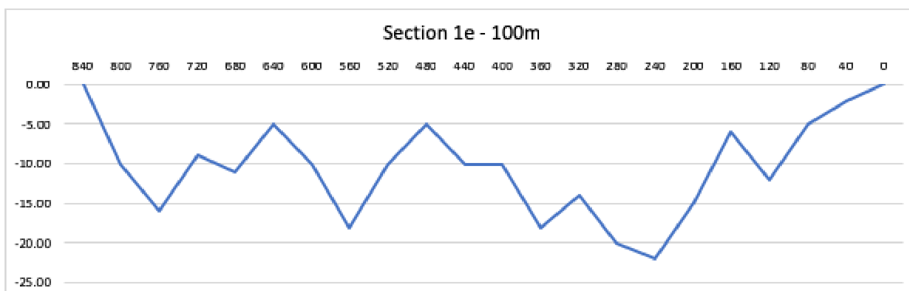
Cross sectional profiles of reach upstream of starting point





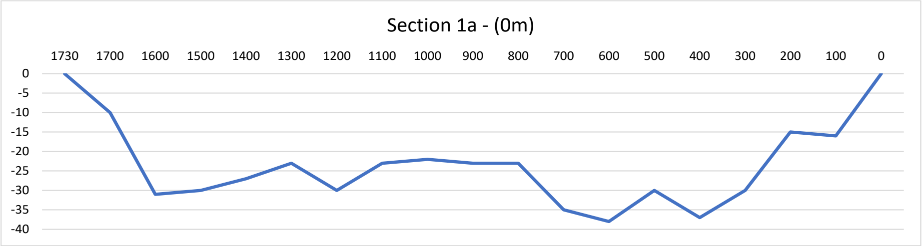


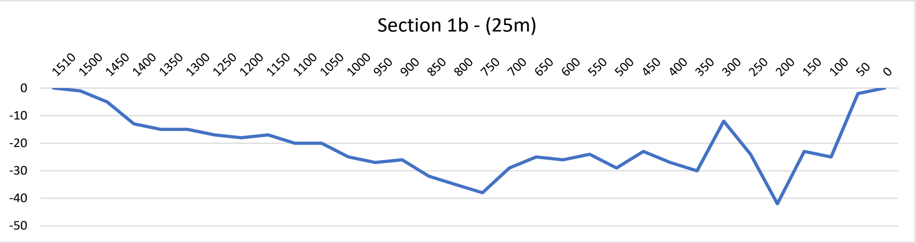


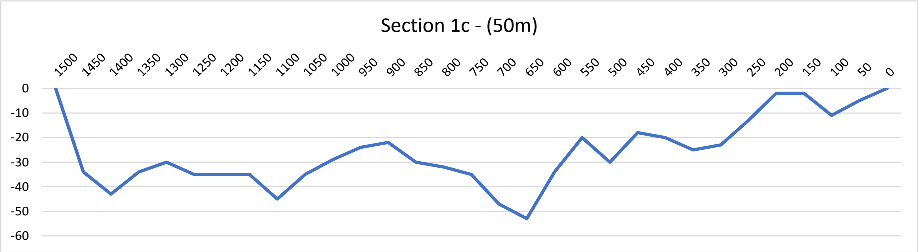


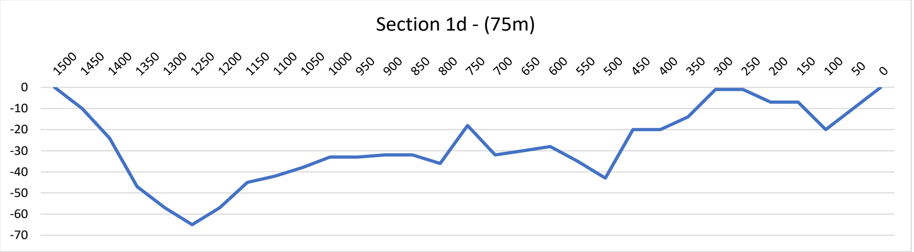
SITE 2

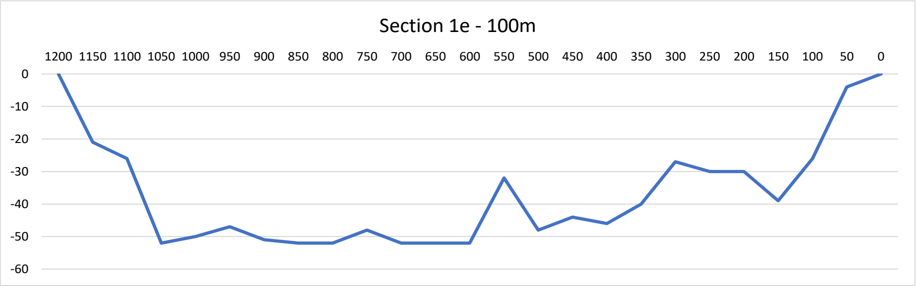
	Mean Velocity	0.50 ms^{-1}
	Mean Cross-sectional area	311.20 m^2
	Mean Discharge per second	156.01 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	1.35×10^4 ML per day





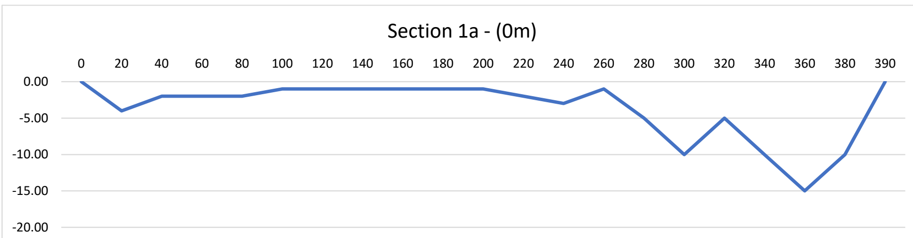


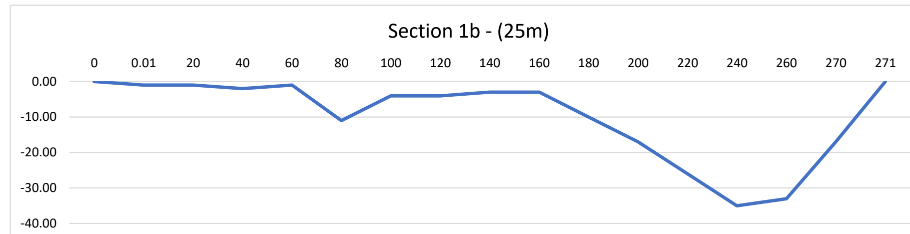


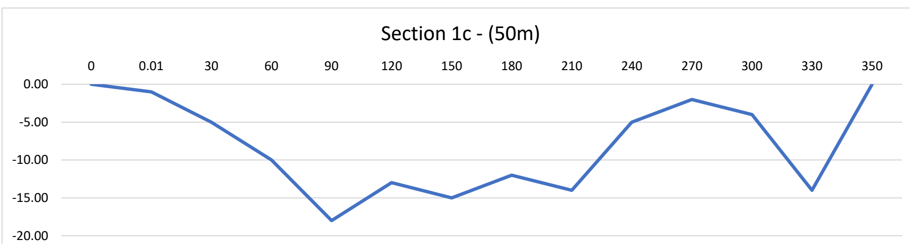


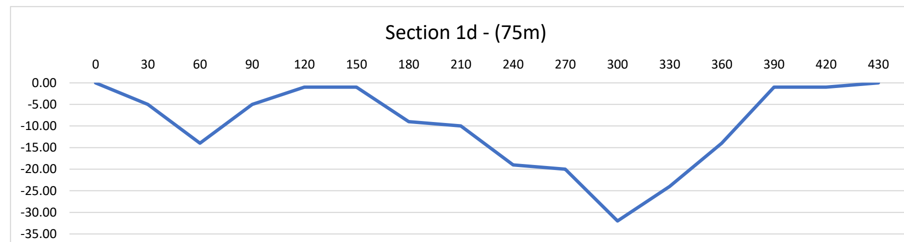
SITE 3

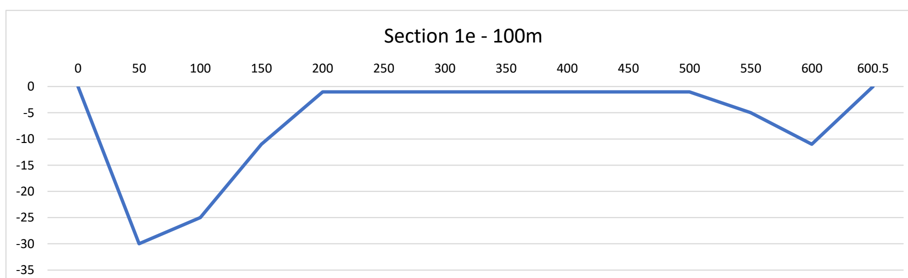
	Mean Velocity	0.23 ms^{-1}
	Mean Cross-sectional area	33.16 m^2
	Mean Discharge per second	156.01 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	6.53×10^2 ML per day





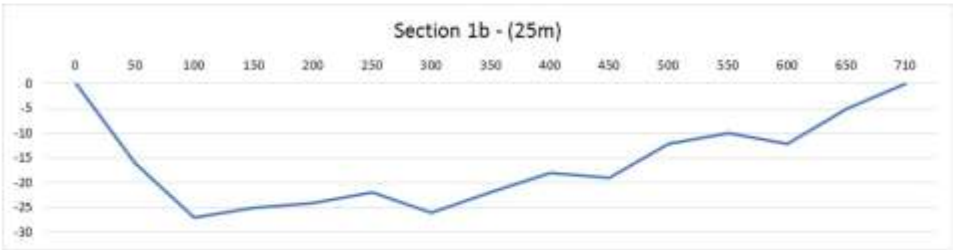


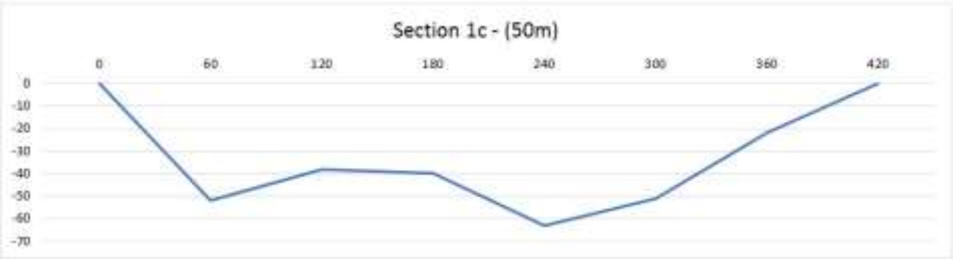


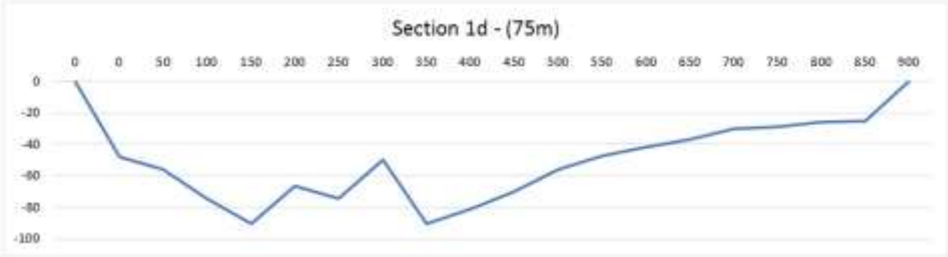


SITE 4

	Mean Velocity	0.46 ms^{-1}
	Mean Cross-sectional area	254.02 m^2
	Mean Discharge per second	116.56 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	1.01×10^4 ML per day

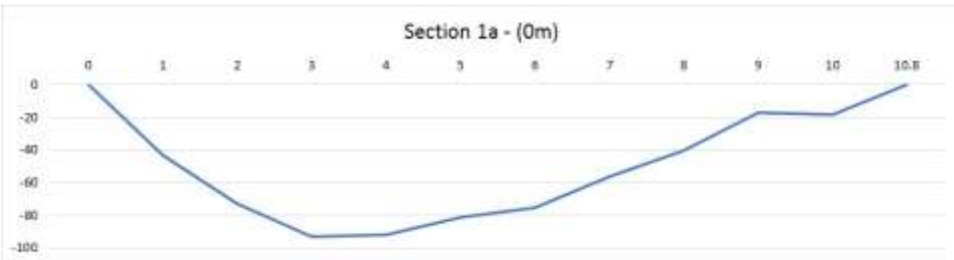


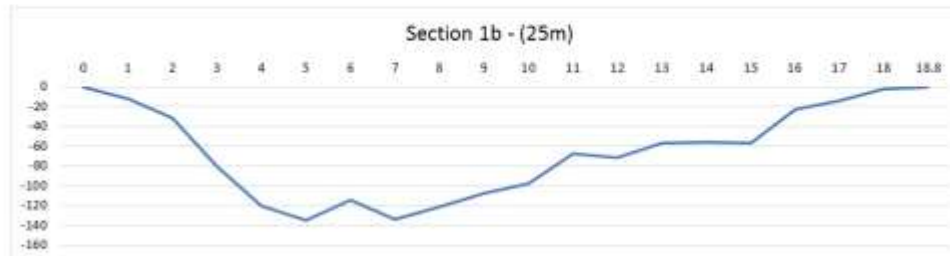


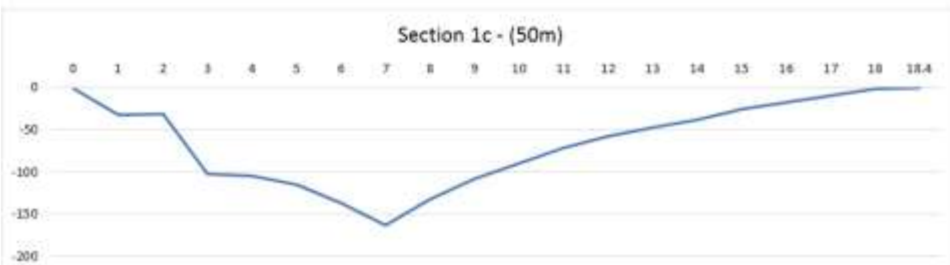


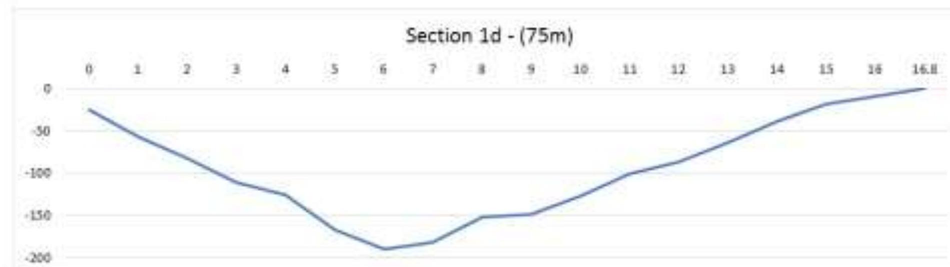
SITE 5

	Mean Velocity	0.60 ms^{-1}
	Mean Cross-sectional area	1209.71 m^2
	Mean Discharge per second	722.09 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	6.24×10^4 ML per day



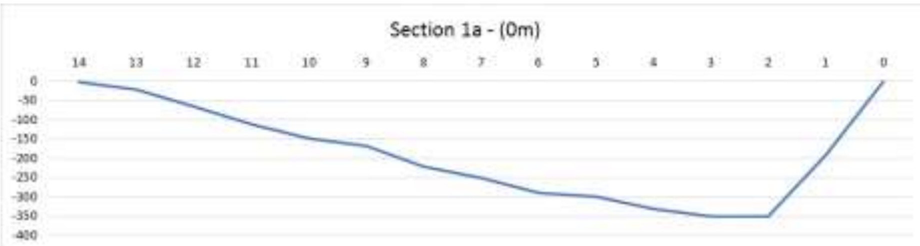


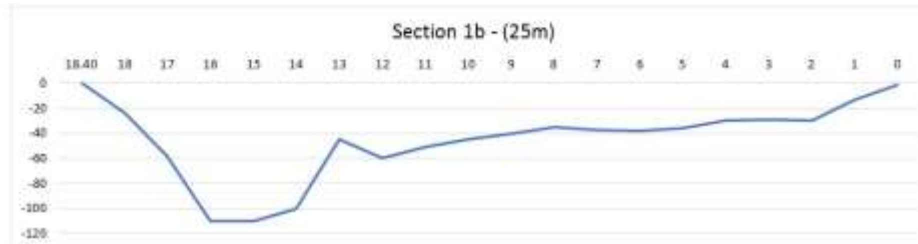


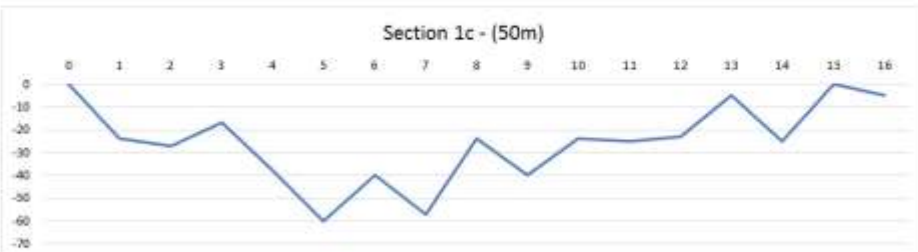


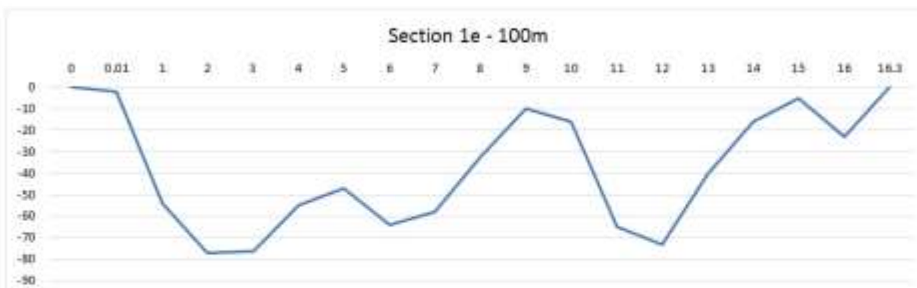
SITE 6

	Mean Velocity	0.40 ms^{-1}
	Mean Cross-sectional area	697.75 m^2
	Mean Discharge per second	276.58 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	2.39×10^4 ML per day



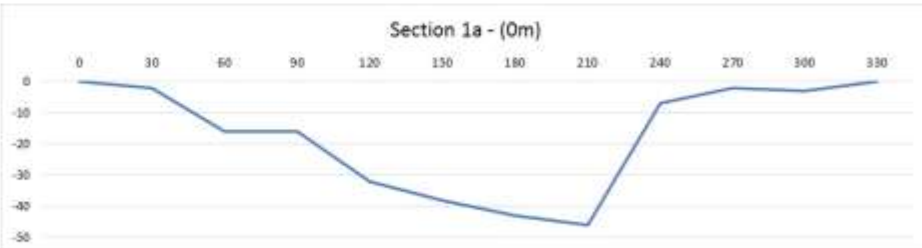


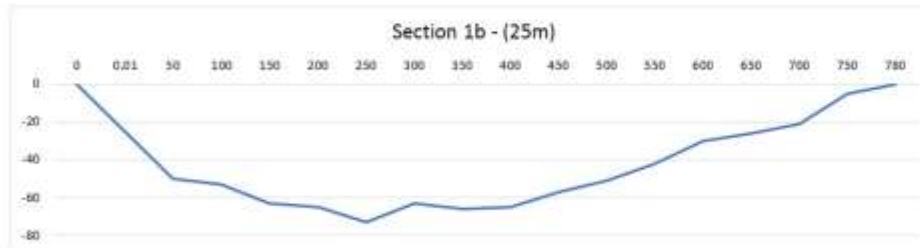


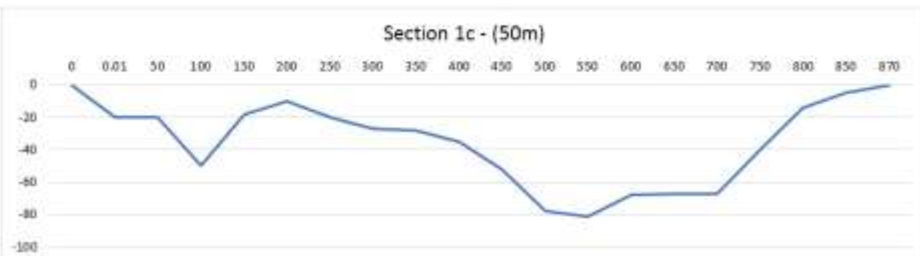


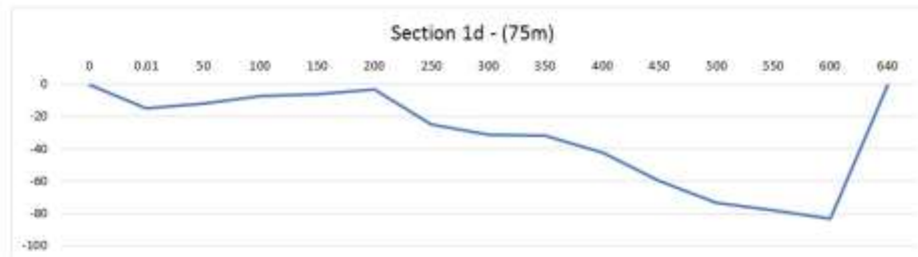
SITE 7

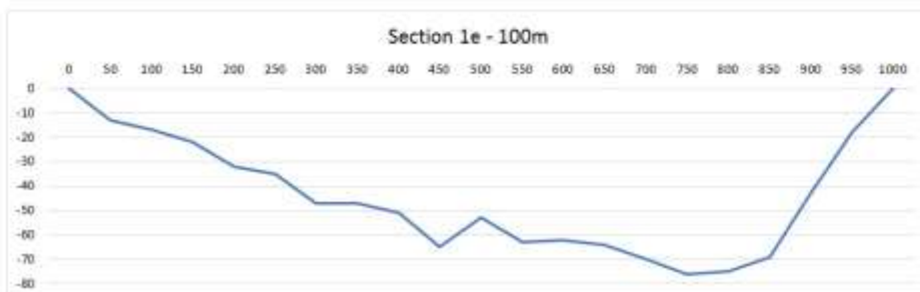
	Mean Velocity	0.50 ms^{-1}
	Mean Cross-sectional area	250.52 m^2
	Mean Discharge per second	125.59 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	1.09 x 10^4 ML per day





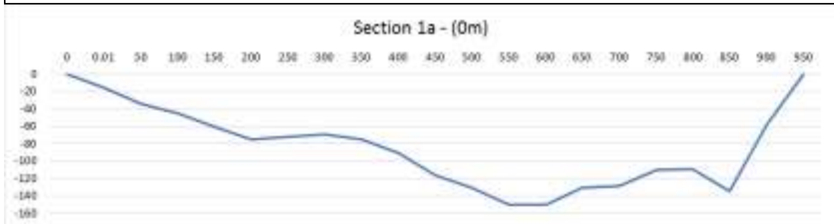


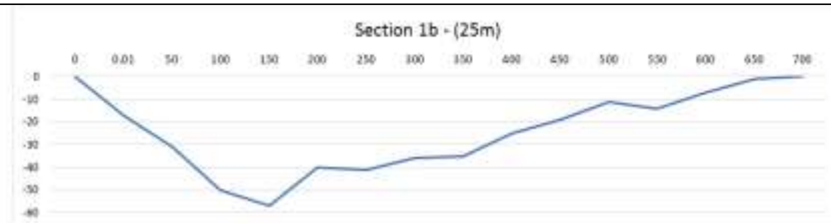


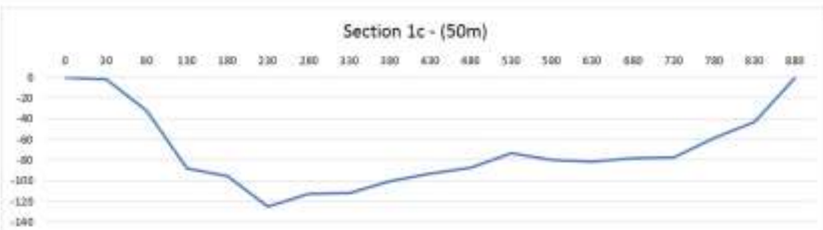


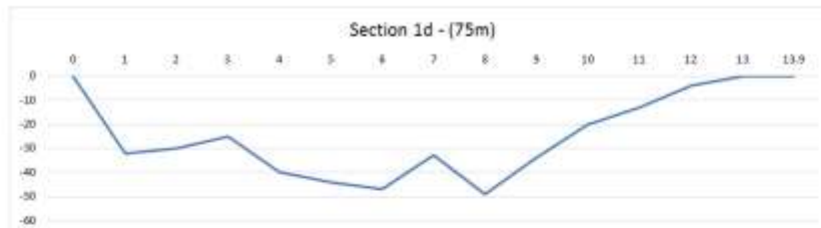
SITE 8

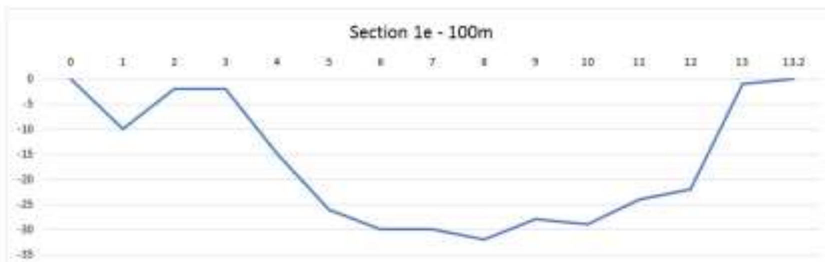
	Mean Velocity	0.50 ms^{-1}
	Mean Cross-sectional area	432.70 m^2
	Mean Discharge per second	216.92 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	1.87×10^4 ML per day





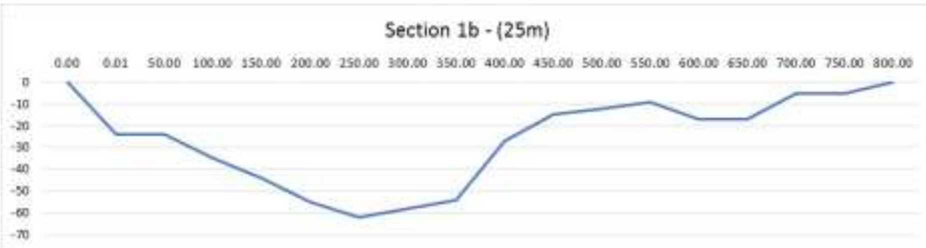


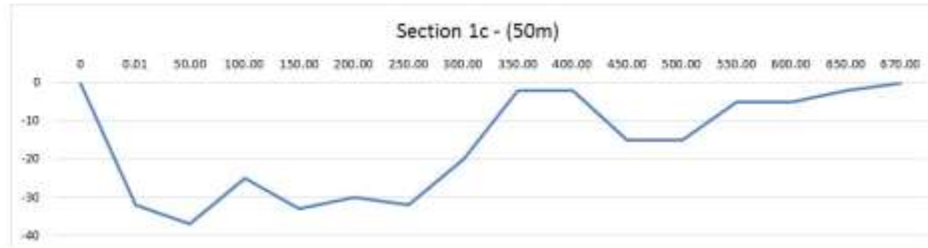


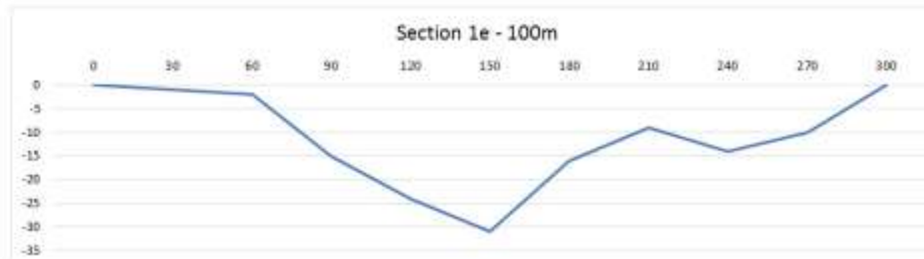


SITE 9

	Mean Velocity	0.36 ms^{-1}
	Mean Cross-sectional area	107.81 m^2
	Mean Discharge per second	38.85 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	3.36 x 10^3 ML per day

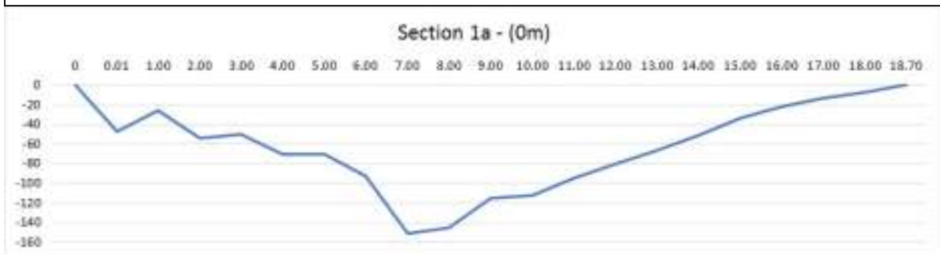


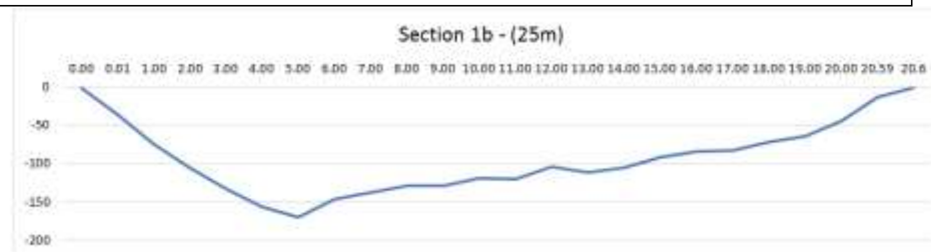




SITE 10

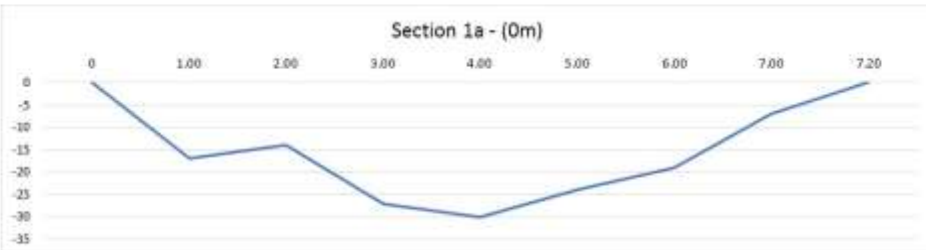
	Mean Velocity	0.08 ms^{-1}
	Mean Cross-sectional area	114.7 m^2
	Mean Discharge per second	91.62 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	7.92 x 10^3 ML per day

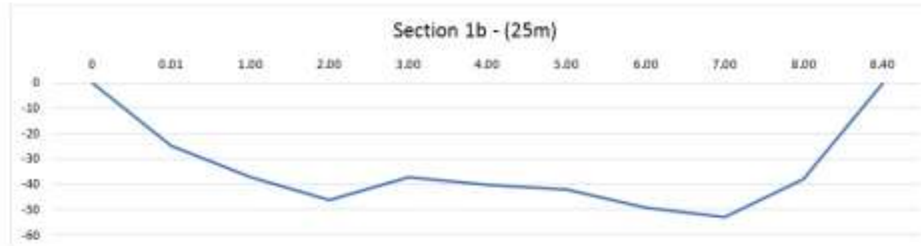


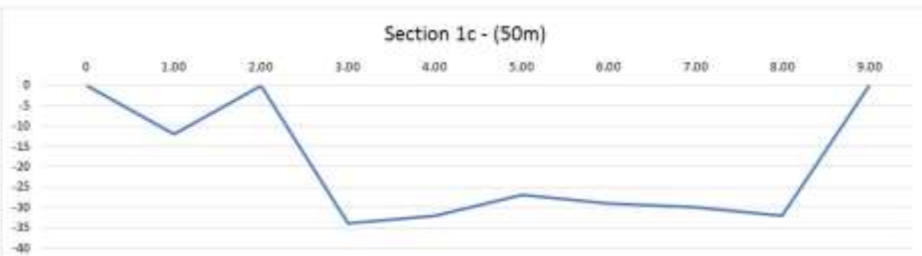


SITE 11

	Mean Velocity	0.23 ms^{-1}
	Mean Cross-sectional area	134.77 m^2
	Mean Discharge per second	30.94 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	2.63×10^3 ML per day

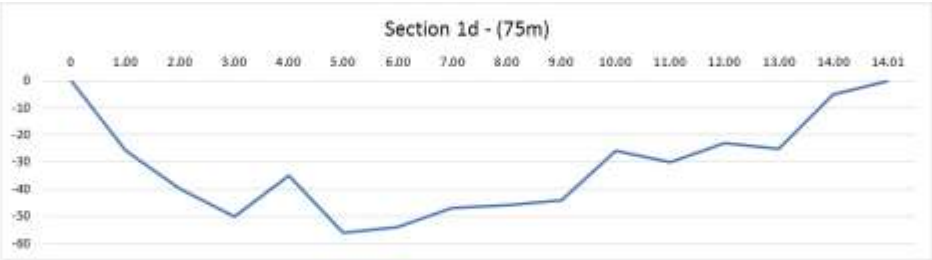


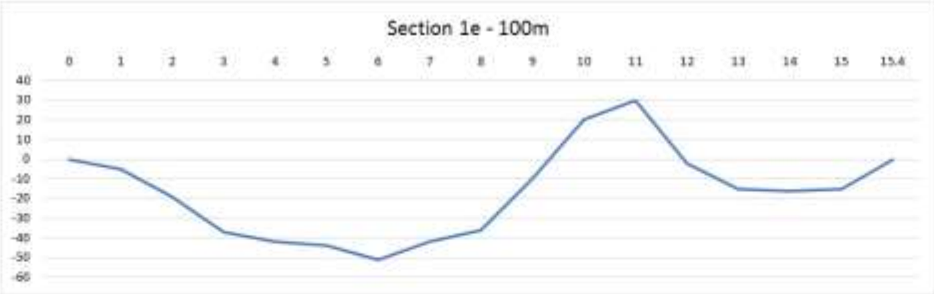




SITE 12

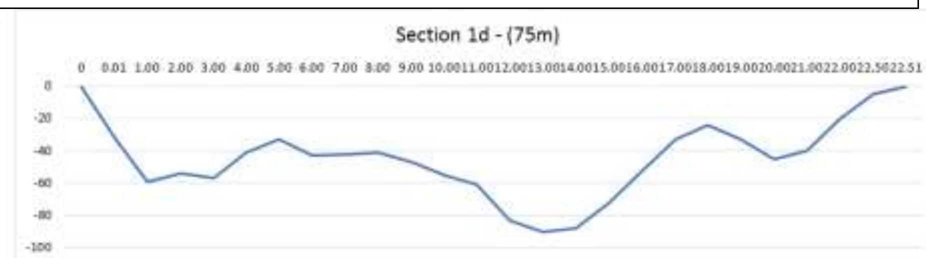
	Mean Velocity	0.95 ms^{-1}
	Mean Cross-sectional area	352.89 m^2
	Mean Discharge per second	335.535 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	2.90 x 10^4 ML per day

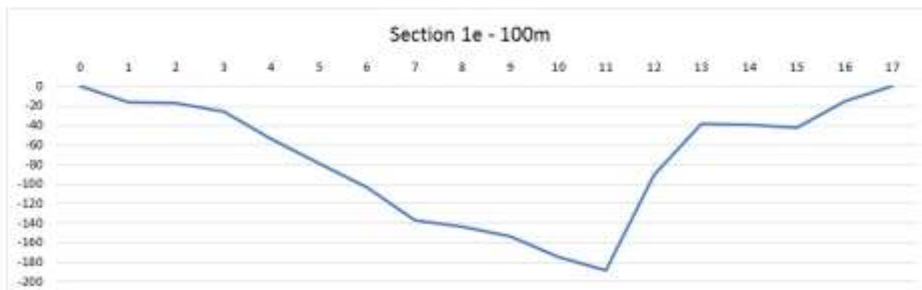




SITE 13

	Mean Velocity	0.24 ms^{-1}
	Mean Cross-sectional area	717.45 m^2
	Mean Discharge per second	174.45 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	1.52×10^4 ML per day

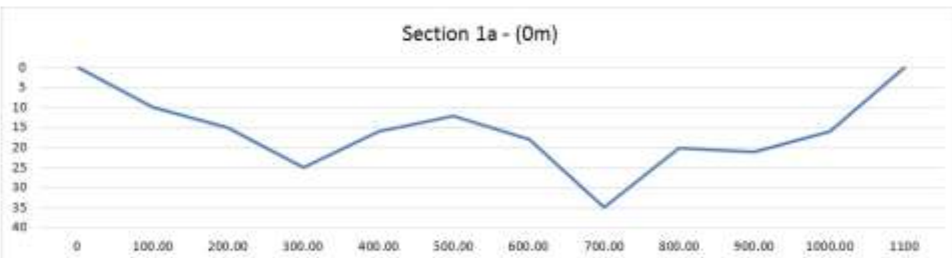


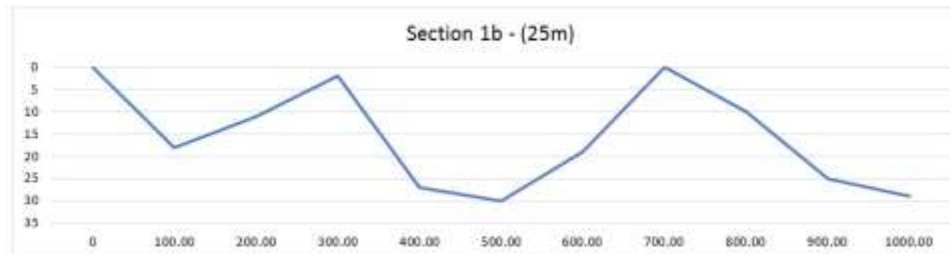


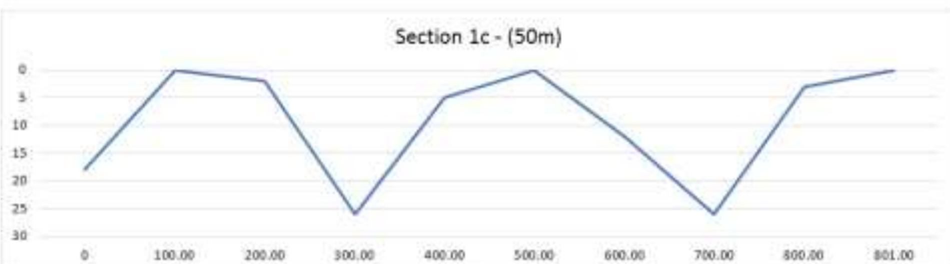
SITE 14

Depth	0.8	0.6	0.2
Mean v	0.11	0.08	0.04
Mean area	134.17	134.17	134.17
Mean discharge	14.7587	10.7336	5.3668
M3/day	1275151.68	927383.04	463691.52
ML/day	1.28E+03	9.27E+02	4.64E+02

Cross sectional profiles of reach upstream of starting point

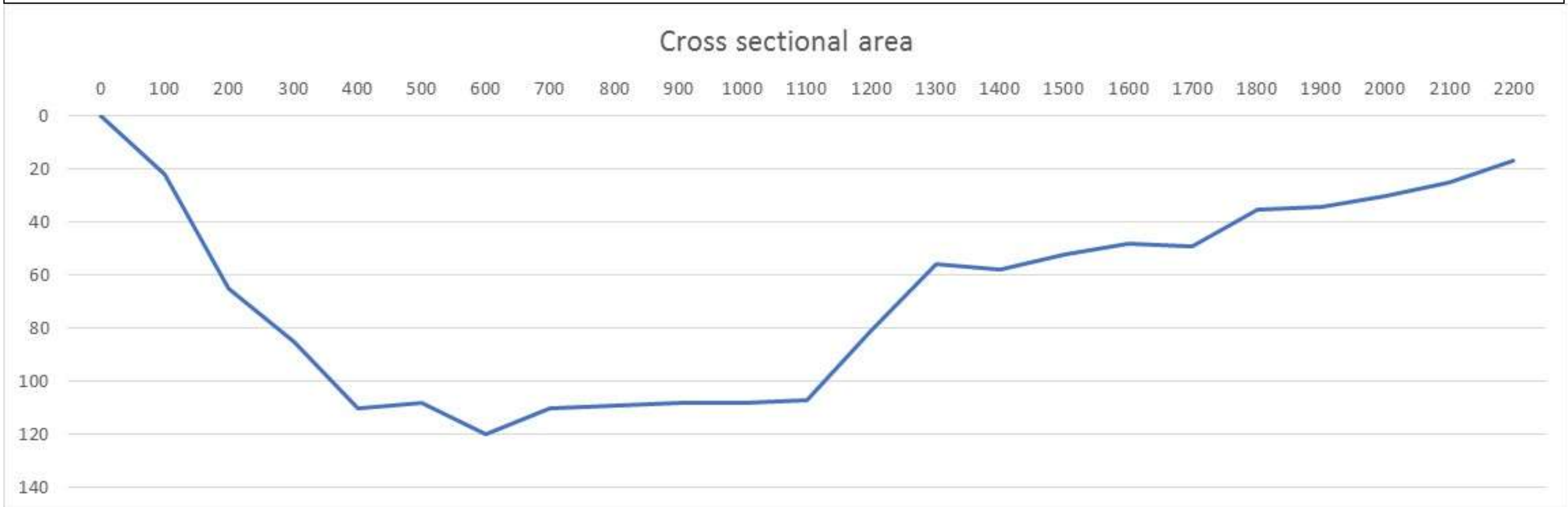






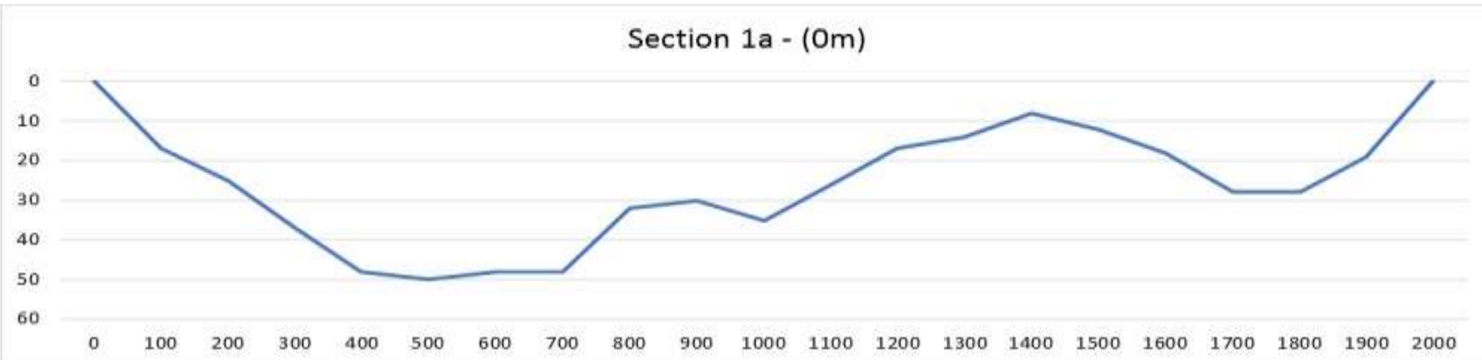
SITE 15

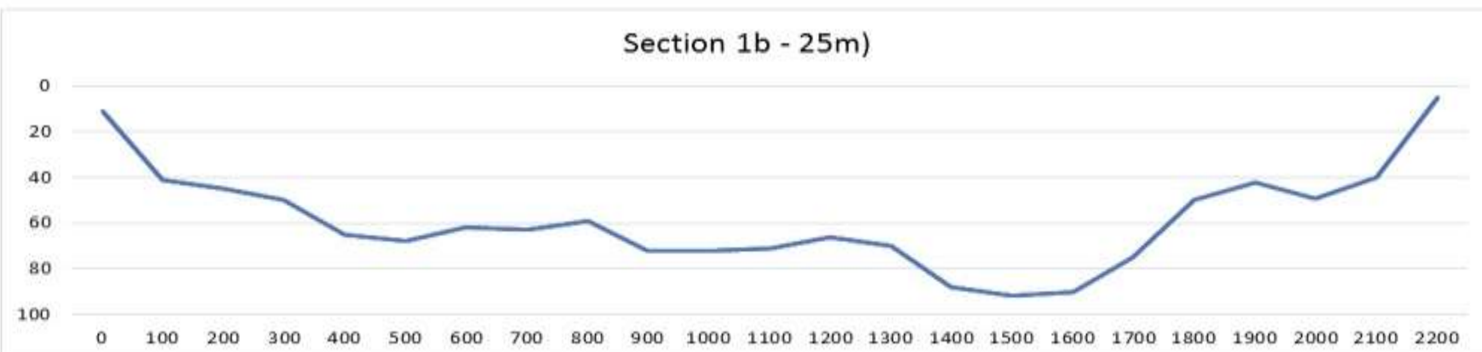
	Mean Velocity	0.95 ms^{-1}
	Mean Cross-sectional area	352.89 m^2
	Mean Discharge per second	335.535 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	2.90×10^4 ML per day



SITE 16

	Mean Velocity	0.94 ms^{-1}
	Mean Cross-sectional area	935.00 m^2
	Mean Discharge per second	878.90 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	7.59 x 10^4 ML per day





SITE 17

	Mean Velocity	0.41 ms^{-1}
	Mean Cross-sectional area	80.93 m^2
	Mean Discharge per second	32.85 m^3s^{-1}
Cross sectional profiles of reach upstream of starting point	Mean Discharge (ML/day)	2.84 x 10^3 ML per day