Environmental and Social Impact Assessment

June 2017

SOL: Tina River Hydropower Project
(Part 6)

Prepared by the Government of Solomon Islands for the Asian Development Bank.

CURRENCY EQUIVALENTS

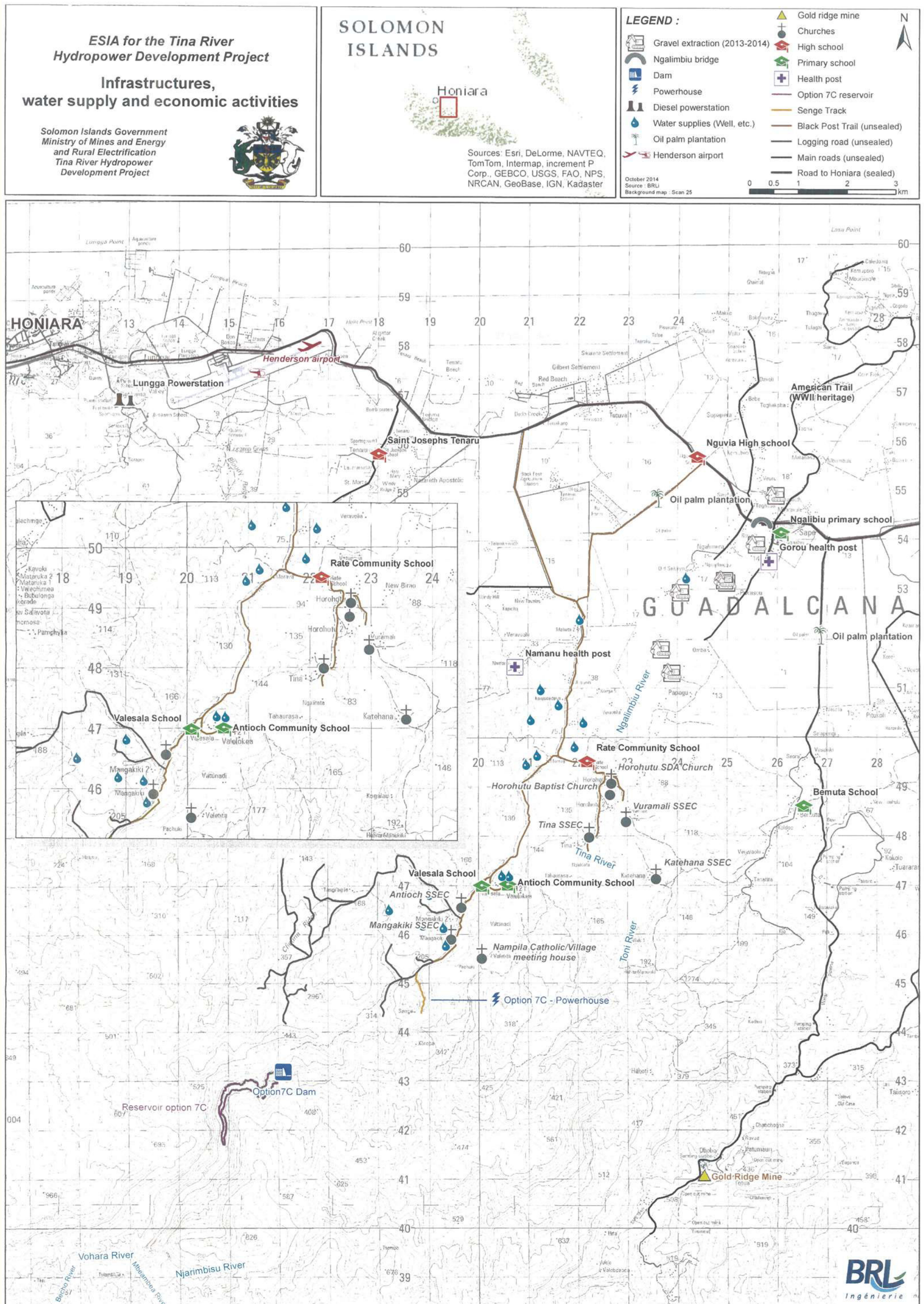
(as of 9 June 2017)

Currency unit	–	Solomon Islands dollar (SBD)
SBD1.00	=	$0.1276
$1.00	=	SBD7.8308

NOTE

(i) In this report, "$" refers to US dollars.

Figure 8-9 Map of local infrastructure



Facing Blank page after 97

8.1.7.10 Household Nutrition

The householder survey included a 24-hour meal recall, for which respondents were asked to recall what they had eaten during the previous 24-hour period. It showed that over the previous 24 hours all the surveyed households in the TRHDP area had eaten breakfast, 90% had eaten lunch of some sort, and 97% had eaten an evening meal. The details of the foods eaten are provided in Annex 6 of the Annex Report.

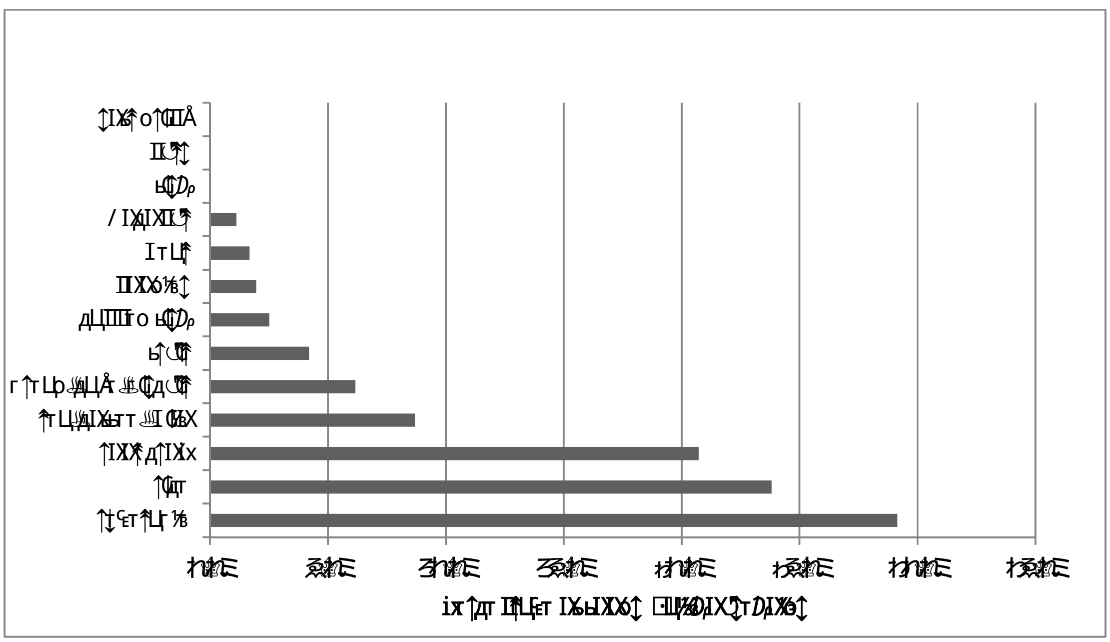
Rice is taking over as a staple food of the Solomon Islands, and for those people of the TRHDP area who can afford it, it is displacing traditional root crops in their diet:

- 43% of households eat rice as part of their breakfast, 41% in their midday meal, and 77% in their evening meal.
- 36% of households eat root crops as part of their morning meal, 42% in their midday meal, and 50% in the evening. These include mainly kumara, cassava, and potato, and occasionally taro or yam.

Figure 8-11 presents the overall picture of foods eaten by households in the project area. Local diets consist primarily of rice and/or root crops, and are eaten with a variety of vegetables, especially green leaves and ferns that are collectively referred to as ‘cabbage’. The main source of protein is canned tuna (domestically produced), and occasionally pork or fresh fish. Meat or fish was eaten in only 12% of meals, mainly in the evening meal. Fruit, mainly banana and pawpaw, is generally eaten at breakfast and as a snack food. While not a major feature, instant noodles are an increasing component of local households’ diets, and are commonly found in local canteen shops.

Based on the limited information available, it appears that the diets of Ghaobata people are generally similar to the people of Bahomea, although, as coastal people, they have greater access to and knowledge of seafood.

Figure 8-10 Foods consumed over 24 hours



Given that subsistence gardening is still the main source for root crops and vegetables for local households in the TRHDP area, changes in work/employment and access to horticultural land and areas where wild foods can be found will have a direct effect on diets and householders’ nutritional status. Past commercial scale logging is reported by local villagers to have had a negative effect on the availability of wild foods, both plant and animal. Also, green leafed food-plants and ferns that are collected from wetlands, and moist areas located adjacent to streams and the river, are negatively affected by drought and floods.

While not recorded as part of the household diets, homegrown tobacco smoking and beer drinking are common among males, and betel nut chewing is common to both males and females. The area is known for its high quality betelnuts, which fetch good prices in the Honiara market.

8.1.8 Physical Capital

Physical capital refers to the equipment, tools, infrastructure, and physical structures used in securing a livelihood. Data was gathered in the TRHDP area householder survey on the goods and equipment owned by the household. This is summarized on Figure 8-12.

8.1.8.1 Household Equipment and Facilities

Regarding the use of toilets, the vast majority of households rely on pit latrines or simply going into the bush. People cite this as one of the reasons for the relatively high incidence of diarrhea, especially among children.

In terms of transport equipment, very few people have their own motor vehicle: 14% reported they had a car and 7% a van or truck, but this appears to be somewhat high given that there are entire villages that have no vehicles. Therefore, the results may be due to sampling bias in the survey.

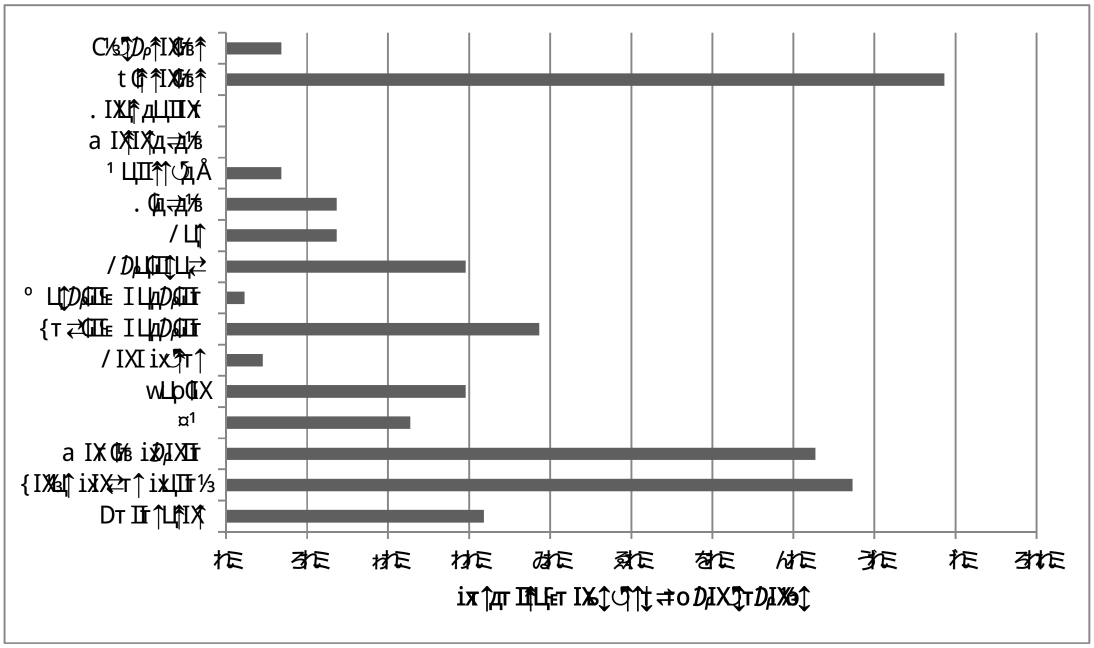
The majority of households have a small solar panel that makes it possible to have a mobile phone. This, in turn, facilitates communication both within the area and with town-based services, suppliers, and family members, and represents a major change for residents of the project area, especially since telephones were completely absent prior to mobile communications technology. Having a solar panel also enables a household to have lighting, albeit at very low power, and small appliances such as a television set, a radio and a computer. However, ownership of each of these items is relatively low. Approximately a third of households report that they have a generator but, again, based on direct observation, this appears to be somewhat high. Generators are typically used for events, such as church and community meetings, rather than for everyday use.

Nowadays, a chainsaw is one of the most important items of physical capital a household within the project area can possess. A chainsaw enables the owner, providing they have resource ownership rights in the area, to fell trees in the forest and, with the addition of a frame, break them down into merchantable timber according to customer need. As noted previously in relation to income, timber milling appears to have become the most important source of income for local households. Being able to produce timber also enables local people to build more durable, modern style houses. However, chainsaws are expensive to buy and, therefore, tend to be owned by people who have access to capital, perhaps derived from logging or mining royalties. Marketing of timber also requires having access to a truck, which few local villagers do. At present, those producing timber rely on timber merchants and hire vehicles to come out from Honiara to collect the materials.

Just less than 40% of households have sewing machines, which are mostly hand powered. These enable women to make clothes and handcrafts for home use and for sale. While not included in the survey, it is apparent that households in the project area lack refrigerators, and, therefore, are unable to store perishable foods, such as meat.

In general, the data indicate that local people lack significant equipment for supporting their livelihoods, in particular, motor vehicles able to transport goods and produce to Honiara for sale. Day to day domestic work could also be made significantly easier with reliable access to power from the main electricity grid, sufficient to run a washing machine, water pump, cooling fan, refrigerator, and household lighting.

Figure 8-11 Household Physical Capital



8.1.8.2 Housing

Local people of the project area live in extended family households, accommodated in several leaf houses depending on household size. Several types of local houses are evident in the villages of the project area:

- traditional one or two room 'leaf houses' made of woven plant material walls, wooden poles, and dirt floors, and sago palm thatched roofs. In some cases these houses are raised on wooden poles. These houses are almost completely made of local materials collected from the forest. They appear to be declining in number.
- traditional style thatched houses with dirt floors or raised on piles, with floors and walls made of sawn timber. These houses are also made of local materials, and appear to be the most common style.
- larger permanent houses with multiple rooms, made of sawn timber, with concrete piles and corrugated iron roofs. Some examples include balconies. These houses incorporate both local and imported materials. It appears that these are a relatively recent introduction into the project area.

Figure 8-13 shows typical house structures observed in the TRHDP study aera at Verakuji (leaf house), Haimane, Habusi, and Marava, the latter of which illustrates the use of more durable building materials.

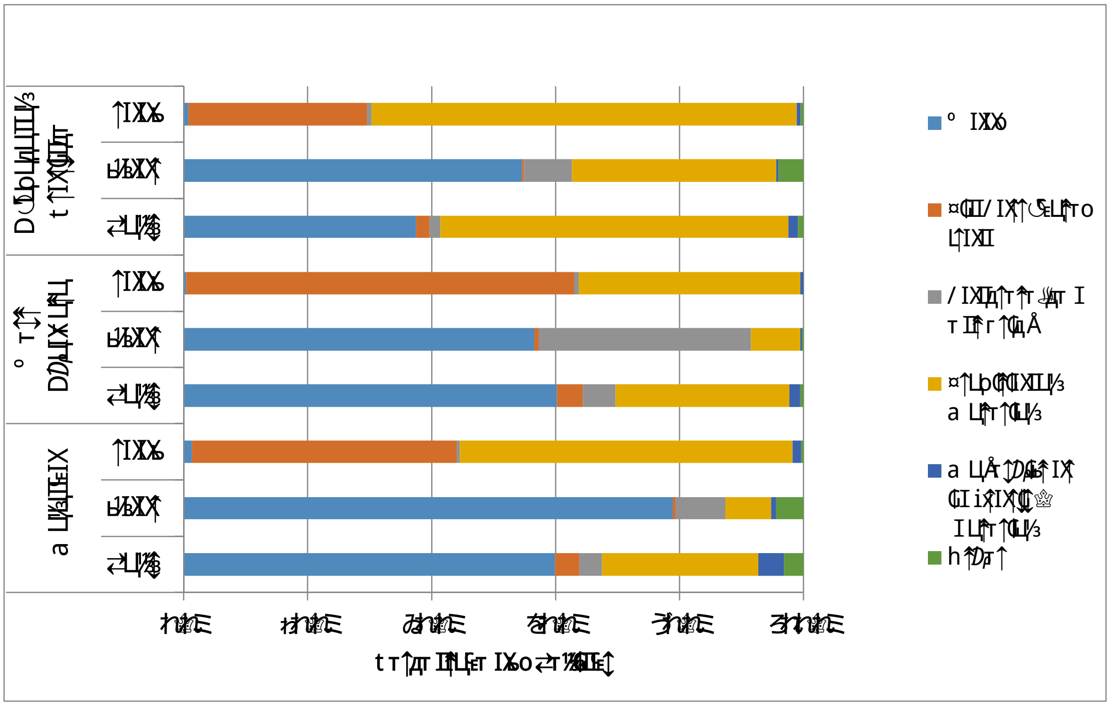
Figure 8-12 Typical house structures in the TRHDP area

The 2009 census recorded 1749 dwellings in Malango ward and 976 and West Ghaobata. Most contained a single household, although 49 of those in Malango ward and 204 in West Ghaobata contained two or more households. This suggests a shortage of housing in the lower part of the catchment.

The Census also records the material used in houses (see Figure 8-14). For the most part Malango houses are constructed of wood or leaf material walls, wooden floors, and leaf-thatch (sago palm) or corrugated iron roofs. This is consistent with field observations made in the project area. Houses in West Ghaobata are generally similar, though they tend to have concrete, rather than wooden, floors.

Malango houses are slightly above average in size for the province, with an average 2.5 rooms each, compared with 2.2 in West Ghaobata and the Province as a whole.

Figure 8-13 House construction materials in Malango & West Ghaobata Wards, 2009



8.1.8.3 Infrastructure

Roads

Physical capital includes local infrastructure. Roads and bush tracks are the most important infrastructure in the project area. These are vital for people and communities to be able to access natural resources, to transport people, goods, and produce to the marketplace, to access services within and outside the area, and to bring home the goods they need. The roads in the area have become vital for people's livelihoods. There are regular minibus services from Honiara right through the project area, wherever there are adequate roads, and they appear to be well patronised. People from the Senge, Pachuki, and Namopila areas who wish to travel to Honiara must ascend out of the river valley along bush tracks. Most villagers in the Tina area have to walk out to the main road to catch the bus.

Unfortunately, all of the local roads are unsealed, lack an adequate or durable surface, are inadequately drained, poorly formed, and badly located in some places. The main road from Black Post (GPPOL plantation) to Marava is a government road, and is only infrequently maintained. Consequently, it is very hard on vehicle undercarriages and suspension problems are common. During periods of heavy rain the roads become deeply rutted, and sometimes impassable. The village side roads are generally poor, and mostly require a 4WD vehicle, and a lot of driving skill. The road from Marava to Mangakiki appears to have been formed as a logging road and is now only maintained as far as Verakuji. Beyond this point, it has reverted to an overgrown track and is not used by local vehicles. The road has a number of culverts that appear to be deteriorating and are likely to fail in the future. In some places, run-off from the roads during heavy rain pollutes local streams and water supplies.

In 2013, some attempts were by the Project to improve the surface of sections of the main Bahomea/Tina Road, as part of its initial development efforts in the area. However, a more serious effort is required. Upgrading of the main road into the area and preparation for the project development was due to begin in October-November 2013, involving correcting creating a proper alignment, improving drainage, and creating a more durable carriageway. If adequately rebuilt, the new road will contribute positively to local people˘s livelihoods, way of life, and general wellbeing.

Water Supply and Use

Despite reports of many promises made by politicians and various agencies, the landowner and settler communities of the project area, and downstream Ghaobata, still have no formal water supplies or water treatment systems, and there is no water or sewerage infrastructure in the villages. This is seen locally as seriously unjust, given that in the nearby capital city of Honiara these services are available to most residents. Popolo/Old Selwyn has a borehole and infrastructure for water conveyance throughout the village, but this is currently inoperative. Several villages in the project area have their own fresh water wells (see Figure 8-15), but most people rely on the Tina River.

Figure 8-14 Covered village wells at Vera˘ande- for washing & laundry

Lack of formal water supply systems is not uncommon in Malango Ward. With respect to drinking water, in 2009 the Census recorded that 38% (i.e. 525) of all Malango houses relied on rivers and streams, and 27% relied on a communal standpipe/well, while only 6% had metered supply from the Solomon Islands Water Authority (SIWA). However, in West Ghaobata 35% of houses had a metered supply, 29% had a communal standpipe, and 23% relied on rivers and streams. For washing water, 57% of houses in Malango Ward (i.e., 1004 houses) in 2009 used rivers and lakes, 17% used a well without a pump, 11% used a well with a pump, and 7% used a private piped supply. The pattern is quite different in West Ghaobata where only 20% use rivers and lakes, 44% used wells, and 26% used either a community standpipe or a shared piped system.

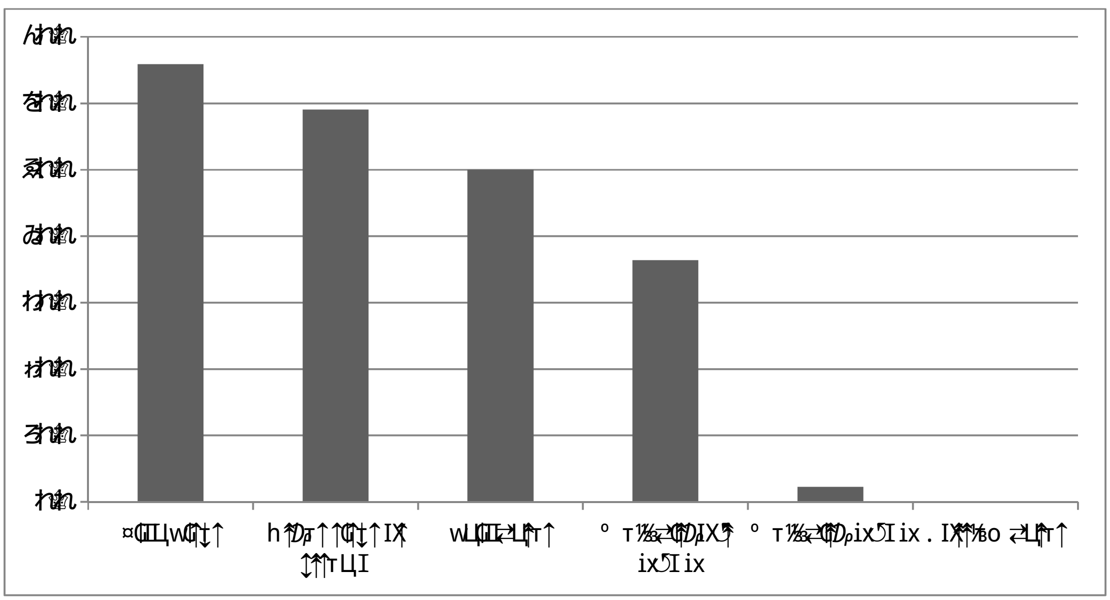
The village workshops and the household survey both enquired into local water supplies. Figure 8-16 presents the household survey findings. Households typically listed two sources of freshwater for drinking and cooking, typically the Tina River or an adjacent stream, and rainwater. Half the respondents said that their household used rainwater. However, there were relatively few rainwater tanks in evidence throughout the villages. Another 39% of households said that they obtained their water from a local well.

Those who take their drinking water from the river use a natural filtration method for ensuring clean water: they dig a hole in the gravel and sand immediately beside the river channel, and water seeps through the sand into the whole from where it is collected (see Figure 8-17). At Senge and the other upstream communities, people take their water directly from the river channel without filtering it. During wet periods or flood events when the rivers and streams are high and discoloured, most villagers collect and store water in anticipation of such conditions, and also collect rainwater in buckets and basins. Only 2% of householders in the survey reported that they used any kind of treatment for their drinking water. This suggests that, generally, the Tina River is of sufficient quality to drink, and most do. As the main source of water for households located in the vicinity, local people and communities are extremely vulnerable to any significant changes in the quality of the water in the Tina River.

Hevalao (2013) has surveyed village water sources in the project area, and provides details of the locations, flow rates and conditions of the Nembo source and Mangakiki, the Rate source for the villages of the Tina River area, and the Antioch source for Antioch and Valesala. In some cases villages have installed small dams and piping to make it easier to access the water.

At Mangakiki, Marava, and Verakabikabi, householders have to walk some distance, sometimes up and down steep hills, to fetch water from local springs or small streams. Several sources are used at Mangakiki, and some villages further down in the valley have proposed that these could be the basis of a piped supply in the valley. Villages at Vera˘ande have several wells close by which are used for different purposes. Villages located on the downstream flood plains tend to have greater access to wells and communal taps, and generally don˘t use the Ngalimbiu River for drinking water.

Figure 8-15 Main sources of drinking and cooking water in the surveyed households



The majority (i.e. 73%) of the surveyed households in the project area do their laundry in the Tina River and 77% use it for bathing.

The people of Malango Ward clearly are at a disadvantage compared with their neighbours, with respect to both drinking water supply and washing water. This disadvantage in lack of basic infrastructure and service availability, which is exacerbated by the additional labour required for collecting water, and in poorer sanitation and health.

Figure 8-16 A water collection hole in the river bed near Tina Village

Sewerage

The lack of sewerage infrastructure and basic toilet facilities in the villages of the project area has been previously discussed. The reliance on pit latrines is common throughout Malango Ward, according to the Census. In 2009 45% of households in Malango used private or shared pit latrines, 13% used a private water seal toilet, 11% had their own flush toilet and 24% had `other_ or no toilet facilities, that is, they use the bush. The pattern in West Ghaobata is slightly different, where 29% used a pit latrine, 30% used a private or shared flush toilet, and 33% had other or no facilities, i.e., they use the beach, sea, or bush.

Energy for cooking and lighting

While the 2009 census recorded that 12% of houses in Malango were connected to the main electricity grid, there is no such electricity supply to the villages in the project area, notwithstanding that this is very much desired by local people. For lighting, the Census records that the vast majority (77%) use kerosene lamps and a small proportion (4%) use solar/PV power. Cooking is almost exclusively done using wood fires (90% of households), with a minority of 8% using gas from compressed gas cylinders. In West Ghaobata, Popolo village was connected to the main electricity supply grid that also serves Honiara, but the overhead power lines were stolen during the period of Ethnic Tension. Other villages in West Ghaobata are connected to the mail electricity supply. The 2009 Census records that 27% of houses were connected to the main electricity grid. However, the majority of households still rely on kerosene lamps for lighting, and almost every household (i.e., 96%) cooks using heat produced from burning wood or coconut shells.

8.1.9 Social Capital

8.1.9.1 Introduction

Social capital refers to the relationships or connections that people and communities have with each other and upon which they can draw while seeking their livelihoods. Being able to access the resources and knowledge of other people and communities requires relationships of trust and reciprocity. Along with natural capital and human capital, social capital is an essential part of local people˝s portfolio of livelihoods assets.

8.1.9.2 Wantoks

Within the project area, kinship or family connection is the most important form of relationship for accessing the resources necessary for life. As mentioned, the indigenous people in the project area see themselves as being part of a :family˜, with a special identity, language, culture and environment. Local people generally live quite close to their extended family members and are able to call upon them to assist with a wide range of tasks necessary to achieve their livelihoods. Likewise they are expected to contribute to other members of the family, clan and community. Those connected by kinship and who are members of the same community are often referred to as `Wantoks¸ and there are strong customary mutual social obligations associated with this relationship. In the project area, it is common for people to call upon relatives and neighbours to help with major tasks such as clearing land for cultivation, house building, transporting produce materials and goods, and assisting in special events such as traditional clan pig feasts. Those who aspire to leadership, draw heavily on their available social capital for the resources and support necessary to succeed.

In addition to kinship and membership in the same community, people use connections with former boarding school mates, workmates, and sports team members to gain access to livelihoods resources that they need.

8.1.9.3 Religion

The second most important basis for social relationships is through membership of the same church.

Most people in villages of the project area are Christians, and actively practice their religion. In some cases, people are also affiliated with the Moro/Gaena˜alu movement. Religious affiliation is a very important basis for community formation and for providing social capital for local livelihoods and activities. The main religious or denominational groups in the communities along the Tina River are the South Sea Evangelical Church, Roman Catholic, Anglican/Church of Melanesia, Seventh Day Adventist, Assembles of God, Bible Way and the Baptist Church. There are also smaller churches such as the Church of the Living Word and Christian Mission Fellowship that are located in communities in the downstream areas. Several villages also have followers of the Moro Movement, centered mainly on Koropa and Namopila. There are twelve Church buildings across the various communities, varying in size, style, and construction.

Church buildings are usually located at one end of the village compound, acting as an `anchor site¸ and important meeting place for a village. They are also the most substantial buildings in the village, and represent considerable investment by the community, in terms of natural resources and materials, labour, and cash. Apart from kinship and clan affiliation, church membership is the main basis for social organisation and action.

Ward-level 2009 Census data show that the South Seas Evangelical Church (SSEC) has the greatest number of adherents in Malango Ward (33%), followed equally by the Church of Melanesia (Anglican) and the Roman Catholic Church (approximately 20% each), and then the Seventh Day Adventist Church (SDA) with 16% of the population. In West Ghaobata Ward, the predominant religion is the Church of Melanesia (with 52% of the population) followed by the Catholic Church (18%). Taken as a whole, Guadalcanal is predominantly Catholic (36%) and Anglican (23%), followed by the SSEC and the SDA.

As noted earlier, day-to-day activities often involve church membership, and along with sports groups, church groups make up the majority of social organisations in the villages of the TRHDP area. The surveyed villages typically have church-focused mothers' clubs and youth groups, Sunday school, and a local soccer, netball or volleyball team. All the larger villages have a church building, and in some cases the church is supported or led by a paid clergyman, religious instructor, and/or youth worker. These churches are also the conduit for church-based aid project work by overseas religious organisations, such as World Vision, Charitas, and others.

Additional details regarding religion, and the Moro Movement, are provided in the Cultural Heritage sections.

8.1.10 Financial Capital

In the context of livelihoods, financial capital refers to the stocks and flows of money or equivalent assets. This includes credit that might be available to the household.

It is clear from the general profile of incomes, work, and other livelihoods assets that the people of the project area are not well endowed with financial capital, although they may have periods where they receive relatively large payments of money from the sale of goods and from royalties. There are no data available on the extent to which local people have bank accounts, loans, or access to credit. Land tenure data from the 2009 Census for Malango Ward suggests that bank mortgages are rare, since 42% of householders were listed as having freehold ownership of their homes, 39% were leasing from a customary or a private owner, 7% were leasing from government, and 12% had some other arrangements.

With customary collective land ownership, and high levels of self-employment and subsistence, it is difficult for indigenous people to get loans for business or other developments from the commercial banks. It is, therefore, easy to see how selling off logging or mineral rights on one˜s customary land to foreign companies may be tempting for those wanting to accumulate a block of financial capital. This seems to be the main means by which capital accumulation among indigenous people has occurred, and why logging and mineral exploration appear an appealing alternative for people of the project area and the wider Malango Ward.

8.1.11 Natural Capital

8.1.11.1 Introduction

Natural capital refers to all the `goods and services_ of the natural environment that people use for their livelihoods. This includes materials and goods that are used directly (e.g., wild foods, and fresh water) or require processing or preparation before they can be used (e.g., forest trees, minerals, and wildlife). In the context of the TRHDP, the most important natural resources for local indigenous people are the land, forests, rivers and streams, sunlight and the cycles of the seasons.

8.1.11.2 Land and Land Use

Land Ownership and Occupation

As described earlier, land is central to the Malango people˜s identity, wellbeing, and culture. Prior to the colonial period the land, including the forests and the living things within them, provided all of the peoples˘physical needs, i.e., food, drink, shelter, weapons, fuel, decoration, and medicine, and the materials required to transform or process products from the land. In modern times, this total dependence on the land and environment has been weakened through participation in the wider economy, including the use of imported food, materials, and technology.

Simultaneously, the land and its resources have been opened up to outsiders and multinational interests for large-scale exploitation. For example, much of the accessible area in Malango Ward has been logged over time, by a number of different companies[66]. This has generated royalty payments for some of the indigenous landowners, and provided roads, but the scale of the forest destruction has meant negative impacts on traditional subsistence uses of the land and forest. Commonly mentioned problems include erosion and sedimentation of streams and rivers, unnecessary destruction of important resources such as sago palm, medicinal plants and food trees, introduction of unwanted exotic plants and animals (e.g., the invasive Giant African Snail), and disturbance to or loss of wildlife habitat, which among other things, has displaced wild pigs into villages garden areas.

To the indigenous people, no land is un-owned or is not connected with a clan, even if it is does not appear to be occupied or utilised. The most important land to local indigenous people is the land that belongs to their particular clan, and the clan can have land in many locations. Sometimes the land is shared with other clans, for example, upland forest where people hunt and gather wild foods and materials. Within the tribal and clan domain, several types of land are particularly important:

- gardening land with soil and conditions suitable for sustained production of a range of crops for both household consumption and for sale in the market;
- well-drained safe flat areas for villages, houses, churches, meeting areas, and recreation, and which have access to fresh water;
- forest land for obtaining both timber and non-timber products (such as thatching, posts, vines, canes, materials for cordage, medicinal plants, decorative plants, fruits, nuts, edible leaves and roots), and for hunting wildlife;
- land that has been formerly occupied and been a home to clan members; and
- land which may contain important cultural sites, graves, or signs of occupation (such as planted food trees).

Full rights to occupy land and use its resources are acquired from membership of one's mother's clan, the matrilineal clan being the land-owing unit in Malango society. As Roughan et al (2011) have outlined in relation to the 'indigenous terrain', clan ownership of particular blocks of land or whole areas depends on having knowledge of the history of that land, its use, and the location of culturally important sites and features to be able prove the connection to others. This knowledge tends to reside with the oldest members of the clan. Over time this knowledge can become lost or uncertain, especially if the knowledge holders and their descendants relocate to other areas, or become deceased, as has occurred throughout Bahomea and Malango.

Since the vast majority of local people occupy, and use unregistered, customarily owned land, it is not always clear today which parts of the landscape belong to which sub-tribe or clan. Hence, there may be claims and counterclaims over particular areas, especially if there are material benefits to be had in the form of royalties or compensation.

With respect to the land in the upper catchment that may be occupied for a hydroelectric dam site and water storage reservoir, it appears that many Malango speaking clans may feel they have a land ownership or land use right over the potential project area since all originate from the

[66] In mid-late 2013, Earthmovers Ltd, who are based at Foxwood on the Guadalcanal plains, were operating elsewhere in Malango Ward, and were seeking to return to Bahomea for more logging. In 2011, Pacific Timbers were logging on the ridges above Choro.

hinterland at the top of each of the river catchments of central North Guadalcanal. A the time of this report, detailed clan ownership was being investigated by the clan leaders of Bahomea[67].

As noted previously, land use rights may be obtained by outsiders, through customary arrangements with the traditional land owning clan, involving the presentation of shell money and pigs. In this way, the original settlers from the Weather Coast were able to take up residence at Verakabikabi. Such arrangement has to be re-established or reinforced when there is a change of leadership among the landowners.

GARDEN LAND

Attempts were made in the village workshops and the household survey to gather information about the location and size of peoples˘garden lands. However, this proved to be difficult. Based on field observations, most garden land is located within relatively close distance to the village, typically within 10-15 minutes walk. Proximity is important for protecting crops from wild pigs and theft, and for convenience. In some cases people cultivate gardens some distance away from their residence, usually in areas and villages where they have land ownership rights. This seems to occur right through the Tina River valley and it is common to see people walking up or down the river or the road to and from their gardens. In some cases such as Choro, where clan land that is suitable for gardens is some distance away, people may build a hut on the land and stay for periods tending their seasonal crops.

The total amount of area used for household gardens depends on the size and needs of the household, the energy of the gardeners, and the extent of their involvement in cash cropping. Also some households may have several plots for different purposes. At Antioch it was said that, nowadays, some households have only small gardens because they are not so dependent on home produced food. At Senge, people said that households typically had two plots under cultivation at one time, each plot being approximately 1600mДin size. At Namopila and Pachuki, where people have access to highly fertile river flats (prior to the serious flood of April 2014), plot sizes were also approximately 1600mД although people may only have one plot under cultivation. At Tina and Haimane, garden plots were said to be typically of a similar size, though there is considerable variation. Householders at Vera˘ande have a large area of cultivated garden land adjacent to the main Tina road, some of which may be encroaching into the road reserve. This garden land, which is also adjacent to a wetland that produces useful plants, and from which groundwater is drawn, also has several pigsties. Generally, pigsties are located on garden land on the edge of the village. Pig keeping is quite common, and is sometimes a community enterprise (such as at Tina). Relatively few households appear to keep chickens and geese. Domestic fowl are usually kept on a free-range system.

8.1.11.3 Water Rights

In Solomon Islands, there are no formal allocations of water rights. Unlike, for example, rights to fish in an area or collect shells, which can be closely held under custom (and recognised by law), the High Court[68] has held that flowing water is a public right, unowned by the owners of the land

[67] This process was subsequently described in a media statement on 24 June 2014 by the `Core Land Tribes of Tina Hydro Project_ as the Bhamoea Land Identification Committee (BLIC) process, It involved investigations and consultations on land ownership by `all the recognised elders and storytellers holding traditional land knowledge_.

[68] Solomon Islands Water Authority v Commissioner of Lands SBHC 58

over which it passes. In making this determination the Court found that the English common law position also reflected customary understandings of water rights:

> In spite of what we may say, it is common knowledge that water is essentially or necessity of the human being. It is always advocated by health officials in public talks and media etc that "water is life". This sum(s) up what I would say on the qualifications as local circumstances render necessaryŭ on applying this common law on water.
>
> And I am satisfied that the common law principles of nobody own(ing) flowing water is not inconsistent with any law or Acts and; its applicability or appropriateness in the circumstances of Solomon Islands is not inconsistent with the Schedule 3 of the Constitution and therefore make a ruling that it is the law in Solomon Islands on the flowing water.

The conclusion in the case also reflects the findings of the 1959 Alan Report that noted that customary rights holders do not ordinarily assert control of water supplies.[69]

8.1.11.4 Crops

The earlier Figure on local people˘s food and nutrition lists the range of food produced from their gardens and adjacent forest areas. As noted, the focus of garden production throughout the villages of the project area is on root crops, especially cassava and kumara, green leafed vegetables, cucumber, pumpkin, tomato, corn, spices, tobacco, fruits (such as bananas, guava, mango, Malay Apple, and citrus), sugar cane, nuts (especially coconut and betelnut), and flowers. Local gardens and nearby areas may also contain small plantations of highly valuable timber tree species such as mahogany, and sago palm. French (2011) provides a comprehensive description of the plants that are frequently grown and/or utilised in the Solomon Islands.

8.1.11.5 Forest Resources

The range of timber and non-timber forest plants to be found on Guadalcanal has been documented in the Solomon Islands National Forest Resources Inventory Project in the 1990s. Google Earth provides a 2010 satellite view of the landscape of the project area. This reveals that the settled areas of the Tina River valley and adjacent hills remain forested, although not as densely as the areas in the catchment upstream of Senge.

The village workshops confirmed that Malango˘s forests are essential to the livelihoods and wellbeing of Malango people, providing:

- timber and non-timber materials for housing (i.e., timber, loya cane, thatch, bamboo, and bark):
- game wildlife for hunting, such as wild pigs, possums, flying foxes, lizards, skinks, frogs, hornbill, pigeons, and ducks ducks):
- plants used for medicinal purposes and magic;
- wild foods such as fruits, wild palm, wild yam, various nuts, and ferns, megapode eggs, and emergency foods when required;
- materials for handcrafts, such as baskets;

---

[69] Allan, C. H. :Customary Land Tenure in the British Solomon Islands Protectorate˘Report of the Special Lands Commission Honiara, Western Pacific High Commission, 1957. Considering customary rights to water the report found :In general, the principle can be stated that the tenure of water supplies is subject to little control˘. This was found to be in contrast to strictly held rights to fishing areas along the rivers in Northern Guadalcanal.

- regulation of run-off from the heavy rains that occur on Guadalcanal especially around the high mountains, and climate regulation; and
- and aesthetic appeal, and places for recreation and relaxation.

The full range of fauna and flora in the Tina Hydro study area, especially that in the upper parts of the catchment where TRHDP is planned, is presented in Section 6 ¯ Biological Environment Baseline - Terrestrial.

8.1.11.6 Timber extraction

Apart from materials for their own homes, people in the Bahomea district use the forests in the upper catchment, including the areas proposed for the hydro scheme options, as a source of timber for sale to the construction sector in Honiara. The main species targeted by locals are vitex (Vitex cofassus), kwila (Intsia bijuga), Calophyllum species, and rosewood (Pterocarpus indicus). Parties of 2 to 3 men work with a chainsaw to fell selected trees, and then mill them on site into timber according to required sizes. The cut timber is then carried to the river, made into rafts,and floated downstream to pick up points with road access, for example, near Tina village. As discussed previously, most villages are involved in timber extraction. Some of the timber extraction is focused on the Toni River and others on forest areas adjacent to the upper parts of the Tina River, especially around Koropa and upstream as far as Choro. The river is, therefore, integral to local landowners˘timber extraction operations.

8.1.11.7 Hunting and Fishing

Most hunting by people of the TRHDP area appears to take place in the uppermost parts of the Tina River catchment, upstream of Choro, and especially around and upstream of the old settlement areas of Tulongu, Tulambirua, and Namoradina on the northern slopes of Mt Popomanaseu. Hunting mostly takes place as `expeditions_ lasting several days to a week and focuses on wild pigs. Hunting and fishing parties commonly base themselves at Njarimbisu at the confluence of the Mbicho and Mbeambea Rivers. Pig hunting is done with dogs, and tends to be the domain of young men, and is mostly done to raise funds for church and other events, as well as when people feel like a `feed of wild meat_.

Fishing is carried out along the length of the Tina River, though nowadays it is focused on the river holes and pools in the upper catchment, upstream of Choro and as far as the Mbicho and Mbeambea Rivers. The main mode of fishing is by spearfishing with mask, snorkel and spear gun, and is sometimes carried out at night. Participants in the village workshops provided long lists of species they said they were catching and eating. The main fish being targeted are eels, helu (Silver fish), valu (Freshwater snapper Lutjanus fuscescenus), kola (Mullets, Cestraeus sp.), and tilapia (in the Ngalimbiu River). People also take prawns (Ura) and a range of small fish. At Senge, villagers named more than 19 species of fish which they said they caught and ate; at Valesala they named 12 species; and at Marava 7 species.

According to PHCG in 2011, some fish species that used to be common in the lower and mid reaches of the Tina River can now only be found in the pools of the upper reaches. Despite the claims made in the workshops, the householder survey shows that fresh river fish only infreaquently feature in people˘s diets, if at all, and canned tuna (`taiyo_) is now the main source of fish protein. Despite local people˘s obvious knowledge of the fish species found in the river, from a livelihoods point of view, it seems that fishing is, nowdays, a minor activity along the Tina River. However, fishing is a significant source of livelihood at the mouth of the Ngalimbiu River, where semi-commercial fishing occurs using mosquito seine net, and gill net gear. Additional information on fishes, and their ecological and economic importance, is provided in Section 7 ¯ Biological Environment Baseline - Aquatic.

8.1.11.8 The River

The Tina River is an important natural resource and feature in the lives of people of the project area. For example it is:

- the main source of drinking and cooking water for the whole district;
- a source of irrigation water;
- a place to bathe, wash clothes, clean vegetables , and recreate;
- a transport corridor and mode of transport;
- a source of food, including fish, crustaceans, and a range of plants found in and around the river and tributary streams;
- a fence and boundary marker (e.g. in some villages pigs are kept on the opposite bank of the river);
- a source of rocks and gravel used in local house building, and sold under royalty by the villages in the West Ghaobata area; and
- a car wash - in its lowest reaches.

Among the Ghaobata people residing in the lower catchment, sale of river gravel to construction companies is a very important source of income, and a significant component of people's livelihoods. Villagers receive royalties for each cubic meter of material extracted from the riverbed. This material originates from the upper reaches of the river, from where it has been washed downstream during periods of high flow, and then deposited in the inside meander bends in the lower reaches of the river, on the Guadalcanal plains.

Importantly, the Tina River is a source of risk to those who live near it or are required to ford it to get to their home villages or gardens. The main risk comes from flooding associated with storms and cyclones, when the river can rapidly swell in volume and, in extreme circumstances, spreade out to inundate and destroy infrastructure, villages, gardens, animals and human life.

Central to people's experience of living in the Tina River area is the unprecedented storms and floods that came with Cyclone Namu in 1986. As noted in relation to the settlement pattern of villages in the Project area, the destruction by the Cyclone Namu floods resulted in a major relocation of many villages to their present-day sites.

8.1.12 Conclusions

In conclusion, the Social survey fieldwork was conducted successfully and in the expected timeframes, covering all of the settled area within the Area of Impact. A high level of participation by the village communities was achieved, with all levels of community members attending focus community workshops and follow up consultations, including adults, youth, women and children. Valuable baseline data and information was collected during the course of the Social field surveys from the village communities, householders, and culturally knowledgeable elders, as well as from various stakeholders, including government ministries and provincial offices, and civil society groups / NGOs.

8.2 CULTURAL HERITAGE AND GENDER ASPECTS

Cultural heritage and gender aspects fieldwork was carried out by Lawrence Foana'ota, a member of the ESIA team.

8.2.1 Survey Methodology

Cultural heritage and gender baseline and assessment data were gathered as part of the social workshops and survey process.

As outlined previously, meetings were held at :core centres˘ either in community buildings or out in the open with members of the participating villages. The meetings generally began and closed with prayers, welcome remarks, introductions and explanation of the purposes of the visits by community representatives and ESIA team members.

During these workshops specific questions were asked about community health, cultural heritage and the role of women, as well women˘s as their views and feelings about the benefits and effects of the project.

In addition to the workshops and the householder interviews, interviews and discussions were conducted with individual chiefs, elders, leaders of youth and women˘s groups regarding cultural heritage matters, and gender aspects of life in the district.

People˘s responses to questions concerning cultural heritage, and the lives of women and children, were recorded in writing during social surveys (see previous section).

Additional information on cultural heritage, gender aspect and vulnerable people was gathered from secondary sources (such as published articles) and from the personal knowledge of Lawrence Foana˘ota, who is a former Director of the National Museum.

8.2.2 Indigenous People

In traditional communities of the Solomon Islands, having specific names for tribes and sub-tribes or clans is by far the most important single factor in the identification of one˘s affiliation in society. Sometimes these names may be used to refer to a particular language group, a people or their geographical location within an island or province. The members of a particular group also use the names to distinguish themselves from other nearby groups of people.

People of Guadalcanal, like all the other communities in different parts of the country, have special names for specific groups of people. The groups of people in the Project area are called the Bahomea People within Malango Ward 20 in Central Guadalcanal.

As far as the whole of Guadalcanal Province is concerned, they have four main descendant groups. As already mentioned earlier in this chapter, they are Manukama, Manukiki, Koinahao and Lasi. The Bahomea people who live in the Tina Hydropower Development Project areas are descendants from the two exogamous moieties known as the Manukama or also known as Garavu and Manukiki. These are big lines and small lines as the people always refer to them.

Manukama or Garave is the big line, which is symbolized by the eagle or Chacha totem, while the small line or Manukiki is represented by the hawk or Roha totem. Sometimes they refer to themselves as big bird or small bird. The name for tribe in the local indigenous Teha language is Vunguvungu. There are reportedly twenty-seven sub-tribes living within the TRHDP area.

According to their custom, men and women of any sub-tribe belonging to these two main tribes can marry each other but not from sub-tribes of the same main tribe. For example, A of a sub-tribe from Manukama is allowed to marry B of a sub-tribe from Manukiki but X of a sub-tribe from Manukama, cannot marry Y of another sub-tribe from Manukama. This also applies to members of other sub-tribes from Manukiki.

8.2.3 Cultural Heritage Sites

In parts of the Solomon Islands, some communities do not impart information or knowledge about their cultural heritage easily, especially when it comes to dealing with cultural and historical sites. There are some sites that are sacred or still considered to have powers that people no longer want to talk about, because they fear of getting sick or dying prematurely. This appeared to be the case in some of the communities the ESIA team visited. Prior to construction of the Project, a culturally accepted protocol has been developed to implement for identifying sacred sites (Tambu sites) (see ESMP).

Cultural heritage is a subject that many communities are not interested in discussing publically. It depends very much on the importance placed on it by the people. During the visits and meetings held with the communities, it was observed that, unlike in the past, members of the Bahomea communities were not always in agreement about what they regard as important cultural heritage. In Tina Village, for example, those interviewed no longer placed much importance on tradition, due to the influence of the Christian religions. Many people have turned to Christianity, and as a result, their cultural practices, sacred sites, and various rituals have lost much of their significance and meaning, including information associated with them.

Throughout the Solomon Islands, these types of sites are usually located either along the coast or high up in the mountains where they are sometimes hard to access on foot. As a result, persons interested in any of the sites may have to walk for a few days to get to them. In some cases, no one is allowed to visit or take pictures of them. This was also the case in the communities along the Tina River.

According to the information provided to date, the main sacred sites, also called tambu sites, located within or near the project area are Tulahi opposite to Koropa Hamlet, Namuloha sacred pool, Aho stream, Vatukotiti and Vatumosa sacred stones (the latter representing a pig), Makara Tavukea (2 stones - one representing a Helu Fish), Babaruhuvia (a cave used before for sleeping when people had no built shelters), Bela hill, Chanjo, Tovu, Choga and Kabi. These sacred sites were all used by the founding families in the past, when they first settled on the land, and are located between Senge and Choro Hamlets. No details of sites upstream of the damsite were obtained.

Some of the sacred sites and objects could be affected by the Project. The Namoloha sacred pool will be affected by flow changes in the by-passed reach of the river. The customary houses built in Koropa where two boxes containing a number of heirlooms are kept will not be affected. Most of the sacred, fishing, hunting and timber milling sites are located within the areas in the upstream catchment.

It was not possible to physically visit these upper catchment sites because they are located in places that are inaccessible by road. The ESIA team only ventured as far as Senge and Koropa

One of the reasons for not speaking about or providing information on these cultural sites, including the whereabouts of grave-sites, during village gatherings is because they are associated with landownership. This kind of response to questions regarding cultural or historical sites is common to many communities throughout Solomon Islands. Chiefs, or those who have the knowledge, fear revealing information in public because someone might use it to claim ownership of land, or use the information in court against them. People from Marava, Vatupaua, Rate CHS, and Ngongoti communities noted that several burial places may be affected if the existing Tina-Black Post Road is enlarged to facilitate construction of the dam.

According to the ESIA Scoping Report, the Njarimbisu River area (upper catchment area) is known to be of significance to local tribes. It is believed that, prior to WWII, Tina Village was located near this site. During the war it is believed that it was attacked and that lives were lost (Entura, 2012).

There are no cultural heritage sites within the project study areas that are formally protected under the Guadalcanal Historic Places Ordinance 1985. So far, based on information gathered by the ESIA team, there are no `critical_ cultural sites or relics to be found within the area that cannot be relocated, or compensated for, if disturbed or destroyed.

There are no WWII sites in the proposed project area. However, some sites were noticed in the downstream area, such as bunkers along the `American Trail_ (see Figure 8-18). These WWII sites will remain unaffected by the Project.

Figure 8-17 WWII Bunker along the American Trail

8.2.4 Christianity

As mentioned in a previous section, there are a total of twelve Church buildings in each of the communities. These structures vary in size and method of construction, using both local and imported materials. An example of the use of modern building materials, are the SSE Churches at Antioch and in Mataruka in the Malango district. Figure 8-19 shows a photograph of the SSE Church at Antioch.

Regarding the location of religious sites, such as Church buildings and cemeteries, these vary from community to community. In some communities, Church buildings are located at one end of the village compound, while the cemeteries are either located near the houses or some distance away from the residential sites. The graves are either surrounded by wooden planks or stone boulders, which hold the soil in place. Some graves were observed next to the families˘dwelling houses or in the center near the Church building (e.g., in Tina Village, Senge, and Pachuki). In some cases, families bury their dead next to their houses (one or two graves), out of concern that someone might disturb or desecrate the graves.

At Tina Village the graves of a notable missionary couple are covered with concrete, whereas at Senge and Pachuki, wooden planks are built around important graves.

Figure 8-18 Antioch South Seas Evangelical Church

8.2.5 Moro Movement

In the Solomon Islands, as elsewhere in Melanesia, there are many stories about various cargo cult movements, which started when people began to experience a new western lifestyle, which was associated with material goods available in large quantities.

The Moro Movement is based on two main objectives: (1) the establishment of a socio-political organization of which the late Moro was the leader; and (2) the launching of a number of co-operative economic enterprises aimed at elevating the standard of living of the followers of the movement. The key premise of the Moro Movement is that the Americans would return and take control of Guadalcanal once more, and that the `Black Americans_ were going to send cargo (i.e., large shipments of American materiel), to which only adherents of the Moro Kastom would be entitled. Ships from America would arrive and then transport the faithful followers of Moro to the USA.

In the late 1960s, Moro sent a deputation to Honiara to see the District Officer. `The deputation consisted of four young girls aged roughly 14 to 16 years, dressed in traditional string skirts and adorned with traditional shell money. They carried a bag containing several thousand Australian dollars to `buy their freedom._ The bag of money was sent back with a message from the District Officer to Moro telling him that they had `freedom_ and that it could not be bought with cash, only by working in society_ (Tedder 2008: 197).

The main headquarters of the Moro Movement is at Makaruaka, on the Weather Coast of Guadalcanal. The Malango branch of the Moro Movement is based at Koropa where Chief Hudson Micah is the main holder of everything related to the movement's beliefs and powers. He has two boxes with three compartments in each one. In the first compartment in each box are traditional objects including some special shell money beads associated with the preservation of the Environment (Hairau). The second compartment contains items related to good health or the wellbeing, style of living, wealth and the way of doing things by Man (Tinoni). The third compartment holds the things used to ensure good yields from the gardens, or for protection from diseases affecting crops and the Land (Pari).

The Movement promotes living a very simple lifestyle (Poua), making sure that the ground (Momoru) is protected and not sold, and adopting a lifestyle based on leading by example (Vuluna), at a time that is, otherwise, characterized by the rich getting richer and the poor getting poorer. To abide by the teachings of living a very simple lifestyle, women and young girls wear twisted string skirts with no top coverings, while men and boys wear tapa aprons or kabilatos (breech clouts) which cover only the front and back also without any top coverings.

According to a leader of the Movement, families living in Senge, Koropa and Choro, and some of those in the other Christian communities downstream of the Tina River, support the Moro Movement and its ideology - especially the core beliefs and teachings about the land, environment and culture. However, the fundamentalist Churches and some of the chiefs are, reportedly, very opposed to their practices and, as a result, any activities or even symbolic buildings such as the custom style built houses that represent the Movement's ideologies, are not permitted within the Christian communities or villages.

The members of some of the fundamentalist Christian Churches view the Movement and its beliefs and practices as evil and uncivilized, because of how the followers dress and the way they live in hamlets with only two or three members of a family, isolated from other communities. In fact, the late Moro was Roman Catholic, and some current followers and members of the Movement also belong to the Roman Catholic Church.

The implication for the Project of the presence of Moro followers is discussed in the impact section.

8.2.6 Gender Aspects

The Solomon Islands national census report of 2009 identifies the total number of women as 251,415 out of a total population of 515,870 - or just over 48.4% (Census Report: 2009).

Women play the very important roles in Solomon Islands society, as mothers, gardeners, sellers of garden products, caretakers of children, and implementers of household chores. In traditional Guadalcanal society, women used to play an important role with respect to land tenure, land management and access to land, and had an impact on wider decision-making in local communities. Women interviewed as part of the social survey, noted that in today's contemporary society, their interests and roles in dealing with land issues, have become marginalised. These communities, like those of other matrilineal societies 'recognize women as legitimate landowners, but there is need for legal recognition through legislation as stated in the Land and Titles Act 1969' (Maetala 2008:39).

During field studies, women's views on issues affecting them and their responsibilities in the communities as leaders of families and women's groups, were recorded (Figure 8-20). Since it was not possible to interview women who belong to the Moro Movement, only those women leaders who belong to different Church groups were interviewed. Even though their views and decisions may be heard during community meetings, either on traditional, contemporary or religious issues, they are often not prioritized.

Regardless, it was interesting and worthwhile to hear about their responsibilities as women, and their views on the Project. During discussions, they were able to speak their minds freely concerning the possible impacts they feel the Project will have on their lifestyle, work, and the use of the water from the river. In addition to using the river for transporting timber and other materials from upstream, and obtaining gravel and sand for building houses, local people use the riverbank for drying their laundry. In other locations, there are special places where children are taken for picnics or camping trips during special events, such as the end of the year when children start their school holidays, or for Sunday School weekend outings.

Even though the communities visited appeared to want the Project to proceed, some women, especially those who are leaders and members of Church groups, expressed some reservations regarding the Project. This is because the river plays an important role in their way of life either every day or occasionally. Some women did not provide an opinion during the meetings because they still did not know what the effects of the Project might be, and because the type and magnitude of the Project is new to the country and, particularly, their region.

Since women are the ones mostly involved in looking after the welfare of the children and, in some cases the whole family, they wanted to ensure that the Project must not interfere with their normal lifestyle. For example, they commented that, presently, they have the freedom to move freely along the river without any fears. However, according to them, free movement will be restricted because no one knows how safe the dam will be when it is completed. Their fear is based on their experience with a huge volume of water, which destroyed some of the communities along the riverbank during Cyclone Namu in 1986.

Figure 8-19 Women at Verakuji and Marava

9. ASSESSMENT OF IMPACTS ON THE PHYSICAL ENVIRONMENT

This section identifies potential direct and indirect construction and operation impacts accruing to the physical environment as a result of the TRHDP. It also identifies mitigation measures, and residual effects and their significance.

9.1 Description of Impact Generating Activities

This section describes the actions and activities of the TRHDP that could potentially affect the physical environment. Potential physical environmental impacts may include induced seismic activity, local slope stability, soil compaction and erosion, hydrology (surface water and groundwater), sediment transport, regional and local air quality, climate change and greenhouse gas (GHG) emissions. In turn, impacts on the physical environment may influence the project's viability or sustainability (see Section 15 Effects of the Environment on the Project).

9.1.1 Pre-construction and Construction Activities

9.1.1.1 Pre-construction Activities

Pre-construction work involves site investigations, including installing a hydrology monitoring station, mapping topography, undertaking geological and geotechnical surveys, and other related activities. Limited drilling and cutting of new tracks to move equipment onto survey sites was required.

9.1.1.2 Widening and Stabilizing Existing Black Post Road

Black Post Road will be widened and improved along its 13.3 km course. This will necessitate bush clearing, surfacing and stabilization with gravel or cement, creation of roadside ditches for drainage and earthworks to build embankments. The width of the right-of-way will be 50m and include the transmission lines.

Between Rate and Mengakiki the upgraded road will be diverted from the existing course of the Black Post Road to take advantage of favourable topography and to avoid the relocation of residents in the Mengakiki Village.

9.1.1.3 Construction of New Access Roads

Black Post Road will be extended from Mangakiki to the project site to serve as the main access road. This will necessitate clearing forest and other vegetation cover, grubbing stumps, removing top soil, completing earth works (cut and fill), stabilizing the roadbed, road surfacing, installing drainage gutters and ditches, and installing watercourse crossings using culverts. This section of road will be gravel or sealed road. The length of this road is about 8.31km. The primary Contractor may subcontract forest-clearing activities to a local logging company, to avoid importing forest clearing and log transport machinery.

Entura's feasibility study (2014) identified two quarry sites both in the reservoir area, which will be connected to the main construction area by access roads. The access roads to the quarry sites will follow topographic contour lines and have the same width as other access roads for which additional width is not required for the transmission line.

9.1.1.4 Construction of Headrace Tunnel from Dam to Powerhouse

The headrace tunnel will be 3.3m in diameter, will run 3.3 km beneath the ground surface, with an 85m shaft connecting to a 130m long power tunnel. The headrace and power tunnel will be built underground using a combination of primarily mechanical excavation (road headers) to excavate rock as well as drill and blast techniques where the geological conditions require this excavation method.

Drilling and blasting above ground will generate noise and vibration due to the use of hydraulic rock drills and explosives. In addition, removal and disposal of spoil material will utilize heavy haul trucks that generate traffic and dust in the dry season. Topsoil removal will be limited to the entrance of the tunnel, surge shaft and tunnel exit. Approximately 1ha of work area for machinery and trucks to operate will likely be necessary at the entrance of the tunnel, and another 1ha will be required for a work area at the exit of the tunnel. BRLi (2013) has estimated the volume of tunnel spoils to be approximately 24,300m^3, based on the dimension of underground infrastructure. These spoils will be used in road construction and in the concrete mix for the power station and proposed tunnel lining.

9.1.1.5 Construction of Dam and Powerhouse

Construction of the dam will require de-watering the river by diverting it through a diversion structure comprised of an upstream cofferdam, a diversion conduit, and a downstream cofferdam. The riverbed and valley walls will be excavated into the bedrock by drill and blast techniques for the dam foundations and dam abutments. Preparation of the dam abutments will affect approximately 2,800m^2 of terrestrial habitat on the right slope of the gorge and 3,700m^2 on the left side of the gorge.

The powerhouse will be built alongside the Tina River 5.7km by river downstream of the dam and will be founded on competent rock using drill and blast techniques to avoid settlement and vibration of the completed structure. A substation will also be constructed. The construction of the powerhouse and substation will necessitate excavation, fill placement, grouting or pilling and will cover approximately 1080m^2 (Entura, 2014).

9.1.1.6 Construction of Work Area

An area of 130m x 90m (11,700m^2) will be required for construction work areas (e.g., staging, fabrication, materials stockpiling, equipment maintenance, etc.) and will involve forest clearing and topsoil removal.

9.1.1.7 Quarrying

Rock quarries will be developed to provide aggregate for the RCC dam. Entura (2014) estimated that 160,000m^3 of aggregate will be required, from two possible quarry sites located in areas that will be occupied by the future reservoir within the Core Area. Where the identified quarry sites are suitable for construction needs, all quarry sites and access roads will be within the Core Area.

In the event that aggregate available from the identified quarry sites in the Core Area is insufficient to meet all construction needs, additional aggregate will be purchased from a licenced gravel supplier. Specific measures for quarry management, including measures applicable to independent suppliers, will be detailed in the Quarry Management Plan to be prepared by the Developer in accordance with the framework provided in the ESMP ‐ Chapter 13.

Quarry exploitation will require the removal of superficial deposits in or close to the river, which may release suspended material into the water.

9.1.1.8 Reservoir Preparation

Prior to reservoir impoundment, trees with a diameter larger than 10cm will be cleared from within the reservoir area up to an elevation of 186.5masl, which corresponds to Maximum Flood Level (11.5m above FSL 175masl). Loose rocks and rubble along the steep faces of the river gorge will be removed where possible.

Reservoir vegetation clearing will be conducted during the latter phase of the construction program, as the dam and powerhouse are nearing completion, just before reservoir inundation is set to commence. The timing is critical so as not to enable vegetation to regrow or become re-established before water is impounded. Depending on the schedule for reservoir filling, vegetation clearing may proceed in distinct phases, with the lowest elevation areas of the future reservoir inundation zone being cleared first, followed by the higher elevation inundation zone. Steep gorges in the reservoir area are covered with ligneous and herbaceous plant species. Due to the steep terrain, lack of access roads and the risk of flash floods, work using machinery will not be feasible. Vegetation clearance will, therefore, be undertaken using manual labour. Sawn timber will be transported by floating it down the river as is currently done from Choro and Koropa. This activity will release organic matter and suspended solids into the river. Reservoir clearing will not involve grubbing (removal of stumps) and soil stripping, since only manual work will be feasible.

9.1.1.9 Construction Traffic

Heavy haul trucks will be required to transport materials and equipment, including excavated material to the crushing plant, spoils from the headrace tunnel, heavy equipment and construction materials, fuel and other products on a regular basis. Light duty trucks and buses will be used to transport workers to and from the Project site.

9.1.1.10 Soil Stockpiling and Spoils Disposal

During the construction of the dam, topsoil spoil will be generated and will be stored (prior to reusing it for rehabilitation or before transporting it outside the Project Area). Storage will either be short term (in case of outside transportation) or long term (in case of rehabilitation of disturbed areas). An estimated 10 ha storage area will be necessary for the generation of 327,900 m^3 of topsoil, using 10 round shape piles of 50m wide and 5m high. It is suggested to use remnant forests of the Core Area to create the 10 ha storage area.

9.1.2 Operation Activities

9.1.2.1 Operation of the Hydropower Facility

The operation of the dam and reservoir will modify the river flow, especially during the night (during reservoir filling) and will create a reduced flow between the dam and the powerhouse. River flow will also be reduced during reservoir impoundment. Operation will also affect sediment transport.

9.1.3 Impact Assessment

9.1.3.1 Impact Identification Matrix

Both the TRHDP construction and operation phases will generate impacts on the terrestrial ecosystem. Table 9-1 identifies impact-generating activities (X mean that there is a foreseen impact).

Table 9-1 Matrix of construction and operation impacts on the physical environment

Foreseen activities	Impact on components							
	Induced seismicity	Local slope stability and geology	Soil compaction and erosion	Surface and groundwater hydrology	Sediment transport	Climate Change	Regional and local air quality	GhG
Construction								
Widening and stabilization of Black Post road including RoW for TL		X	X	X	X		X	X
Creation of a new access road from Black Post road to Project site including quarries and RoW for TL		X	X	X	X	X	X	X
Construction of the head race tunnel from dam to powerhouse		X (minor)		X (groundwater hydrology)			X	X
Construction of dam & powerhouse		X (minor)	X (minor)	X (minor)			X	X
Work area construction		X	X	X	X	X	X	X
Quarry exploitation		X	X	X	X	X	X	X
Vegetation clearance in the reservoir		X (indirect)		X (surface hydrology)			X (burning debris)	X (net positive)
Soil stockpiling and spoil disposal			X				X	X

Foreseen activities	Impact on components							
	Induced seismicity	Local slope stability and geology	Soil compaction and erosion	Surface and groundwater hydrology	Sediment transport	Climate Change	Regional and local air quality	GhG
Operation (including initial reservoir inundation)	X (unlikely)	X		X (surface hydrology)	X (mostly indirect)	X (unlikely)	X (net positive)	X

9.1.4 Assessment of Construction Impacts

9.1.4.1 Induced Seismicity

Probabilistic seismic hazard assessment (PSHA) was carried out by the Seismology Research Centre in February 2014. Although the region is seismically active, the relatively small volume of the reservoir that will be created by damming the Tina River is unlikely to cause induced seismicity that could contribute to slope failures. Additional analysis on seismicity effects on the Project is included in Section 15 ¯ Effects of the Environment on the Project. Conclusions of the seismic hazard assessment will be taken into consideration for the Project Design Report and the Dam Safety Plan.

9.1.4.2 Local Slope Stability and Geology Impacts

The steep slopes bordering the reservoir may be destabilised as a result of reservoir operation, due to the daily fluctuation in reservoir levels and effects that changing pore water pressures may have on soils around the reservoir margin. Given that the slopes above FSL will remain covered with forest vegetation, the potential for slope failure is likely to be confined to the area within the reservoir itself, unless failure of the slope within the reservoir was to trigger a retrogressive failure, one that works its way upslope.

The creation and operation of a reservoir may affect slope stability as a result of the following:

- Saturation of the banks of the reservoir may re-mobilise existing landslides and potentially induce new landslides;
- Deforestation of the storage area will increase landslide activity;
- Construction activity within the reservoir area will alter slope geometry and drainage patterns, thereby increasing potential landslide activity;
- Fluctuation of the storage level may induce slope instability around the reservoir margins;
- Landslides occurring upstream of the reservoir that contribute material which will reduce the available storage volume.

In addition, along the future access road, small landslides are likely to occur, a situation that may be exacerbated with the construction of the road. Retaining structures, such as gabion walls, or the removal of upslope colluvium may be required to minimize the risk of landslides occurring during both access road construction and operation.

Karst geology, which is created by the dissolution of limestone by acidic water, results in formations with cavities and/or caves. The creation of karst formations may be accelerated by the reservoir, leading to significant water leakage from the storage and dam abutments and foundations. Karst formations within the Project area have not created extensive cave systems according to Entura (2014). Therefore, the presence of karst is not considered to be an important leakage pathway. The feasibility study recommended that the maximum storage level be set at 175masl because karst appears to be less extensive below this elevation. In addition, the less stable Suta Volcanics that occur upstream will be avoided by a reservoir operated to 175masl.

9.1.4.3 Soil Compaction and Erosion Impacts

Large projects usually involve extensive land disturbance, involving removing vegetation and reshaping topography. Such activities make the soil vulnerable to erosion. Soil removed by erosion may become airborne and create a dust problem or be carried by water into natural waterways and pollute them. Measures to address the impact of land disturbance on the environment should be included in the planning and design phase of the project, before any land is cleared.

When considering land disturbance and its consequences, priority should be given to preventative rather than treatment measures. To develop effective erosion controls it is necessary to obtain information on the erosion potential of the site where soil disturbance is planned. Erosion potential is determined by the erodibility of the soil (type and structure), vegetative cover, topography, climate (rainfall and wind), and the nature of land-clearing. Erosion potential will also be affected by the type, nature and intensity of earthwork.

9.1.4.4 Surface Hydrology

The construction of the dam will require the excavation of the riverbed and adjacent embankments, and the clearing of the area to be inundated by the storage reservoir. This will introduce sediment to the river, causing significant adverse impacts on downstream water quality likely for the whole period of project construction.

This impact is described in further detail in Section11 ¯ Assessment of impacts on Aquatic Environment.

9.1.4.5 Regional and Local Air Quality

The Project is set within an area that has relatively good air quality, with only periodic localised impacts from emissions caused by smoke from cooking fires in villages and from fires set to clear small patches of understory vegetation for gardens.

During the initial period of project construction, vegetation will be cleared from access road and transmission line alignments, the reservoir area, and the sites where project structures will be built. Non-merchantable vegetation (i.e., non-timber) will be removed and shredded rather than burned. This measure will prevent local air quality impacts caused by smoke generated by burning.

9.1.4.6 Noise and Vibration

The Project is set within an area of low ambient noise levels and minimal or no human generated noise in the vicinity of the tunnel or dam. The use of hydraulic rock drills and explosives at the tunnel and dam site will generate an increase in noise and vibrations. Noise generated by heavy haul trucks transporting equipment and materials will also increase noise levels along Black Post Road.

9.1.5 Assessment of Operational Impacts

9.1.5.1 Hydrology Impacts

9.1.5.1.1 Surface Hydrology

The Project will result in reduced flow in the Tina River between the proposed dam site and the powerhouse. The proposed development is unlikely to have any long-term negative impacts on the availability of fresh water in the Tina/Ngalimbiu River catchment as a whole. The TRHDP PO has indicated that the dam will be operated for :base load˘electricity generation on a daily cycle, with maximum water release from the reservoir during the daytime when electricity demand is highest.

However, during the night, the flow will be reduced downstream of the powerhouse, while the reservoir is being refilled.

To mitigate impact of reservoir impoundment, an environmental flow is to be implemented. One option is to include a low level outlet through the diversion plug for this purpose. It is suggested, that an environmental low (EF) of 1m^3/s be maintained during reservoir filling.

9.1.5.1.2 Groundwater Hydrology

The Project will result in an increase of groundwater table within the slopes at the reservoir area. Reservoir impoundment has to be carried out at a slow and steady rate in order to avoid localized slope failures during initial impoundment. The change in water table due to the change in level based on standard operating range during operation of the hydro scheme is unlikely to cause slope instabilities.

The proposed development is unlikely to have any long-term negative impacts on the groundwater hydrology in the Tina/Ngalimbiu River catchment as a whole.

9.1.5.2 Sediment Transport Impacts

Changes to the Tina River hydrology will, in turn, indirectly affect sediment transport mechanisms. The reservoir will intercept most suspended and bedload sediment, which will be stored behind the dam, until either flushed out through a low level port, or excavated when the reservoir level is drawn down to a point that the accumulated sediments can be accessed. Some sediment transfer will occur during overtopping events, particularly during flood events. Likewise, the significant change to the downstream flows resulting from the operation of the dam, will radically change the process of sediment transport and recruitment to the lower reaches of the Tina/Ngalimbiu River, where it is currently excavated for use in road surfacing and building construction.

The impacts of sediment transport are described in more detail in Section 11 ¯ Assessment of Impacts on the Aquatic Environment.

9.1.5.3 Regional and Local Air Quality

Once the Project becomes operational, there are no anticipated adverse impacts to regional or local air quality, as there will be no significant sources of air emissions. Rather, operation of the TRHDP will have a minor positive impact on regional air quality by offsetting the avoided air emissions that would otherwise be produced from an expanded Lungga Diesel Power Station, during those periods of the day when the TRHDP is generating power.

9.1.5.4 Temperature Change

While some reservoirs are known to affect the climate at a micro level in areas immediately surrounding these bodies of water, as outlined in the study set out in section 7.5.1, the small size of the proposed reservoir means that it is unlikely that it will have any effect on the local climate.

As further outlined in section 7.5.1 the temperature of the dewatered stretch of river between the dam and powerstation may rise slightly.

9.1.5.5 GHG Emissions

Reservoir impoundments emit GHG. Newly impounded reservoirs can emit large quantities of GHG, especially methane (CH_4) as vegetation and organic matter in sediments decays. This is particularly true for reservoirs located in tropical regions if the rain forests biomass is not removed prior to inundation. Ebullition (bubbling) of methane in the reservoir and dissolved methane downstream of the powerhouse, are the main contributors to GHG emissions arising from tropical hydropower projects. However, diluted methane diffusing out of solution is less important in terms of GHG emissions (Deshmukh et al., 2014, International Hydropower Association, 2010). GHG emissions will decrease over time, as the source of decaying vegetation and organic sediments diminishes.

Quantifying impacts is difficult without long term monitoring. However, the International Hydropower Association (2010) has produced a table based on GHG emissions monitoring from several tropical regions. Table 9-2 shows the range of GHG emissions per m^2 of reservoir surface per day[70].

Table 9-2 Range of average carbon dioxide and methane gross emissions from freshwater reservoir in tropical regions

GHG pathway	CO_2 in mmol/m^2/d	CH_4 in mmol/m^2/d
Diffuse fluxes	-19 to 432	0.3 to 51
Bubbling	0	0 to 88
Degassing	4 to 23	4 to 30
River Downstream	500 to 2500	2 to 350

Source: International Hydropower Association, 2010

The unit, mmol/m^2/d means that there are X_ millimoles of the molecule per m^2 of the reservoir released per day. Table 9-3 converts mmol of CO_2 and CH_4 to grams, where 1 mol = 44g of CO_2 and 1 mol of CH_4 = 16g. A negative value means that the reservoir acts a carbon sink.

Table 9-3 Converting mmol of CO2 and CH4 into grams

GHG pathway	CO_2 in g/m^2/d	CH_4 in g/m^2/d
Diffuse fluxes	-0.836 to 19.012	0.005 to 0.818
Bubbling	0	0 to 1.412
Degassing	0.176 to 1.012	0.064 to 0.481
River Downstream	22.005 to 110.024	0.032 to 5.615

If the same ranges are applied to the Tina River and converted to kg, the results shown in Table 9-4 are obtained, considering that the Tina Reservoir will cover an area of 305,200m^2 (30.52ha at FSL).

70 Note: the data does not mention time of monitoring, or whether it was done at the time of reservoir impoundment.

Table 9-4 Estimated daily CO2 and CH4 releases (kg) from Tina Reservoir

GHG pathway	CO_2 in kg/d in Tina reservoir	CH_4 in kg/d in Tina reservoir
Diffuse fluxes	- 255.1 to 5,802.4	1.5 to 249.6
Bubbling	0	0 to 430.9
Degassing	53.7 to 308.8	19.5 to 146.8
River Downstream	6,715.9 to 33,579.3	9.7 to 1,713.7
Total	6,514.5 to 39,690.6	30.8 to 2,541

Using the model `GHG Risk Assessment Tool (Beta Version) 8 (2012)¸ the predicted CO_2 and CH_4 gross flux, following the first years of impoundment for the Tina Reservoir, are much lower, as shown in Table 9-5. However, some of the data used to run the model, such as the amount of rain falling within the Tina River catchment (around 3500mm/yr), are out outside of the calibration range of the model, which makes it less accurate. Table 9-5 shows the gross flux of both CO_2 and CH_4 when the model is applied to the Tina Reservoir. From this model, it is obvious that GHG emissions decrease over time, and stabilise after 20 years of operation.

Table 9-5 GHG gross emissions from the model

Years after impoundment	CO_2 in kg/d applied to Tina reservoir	CH_4 in kg/d applied to Tina reservoir
0	523.1	3.6
1	509. 4	3.4
2	496.3	3.4
3	483.4	3.1
20+	334 (+/-)	1.8 (+/-)

These data provide an approximate indication of the gross fluxes of GHG emissions. Pre-impoundment direct measurements are the only way to precisely assess net emissions.

Modelling of reservoir GHG emissions can be used to inform the assessment of the Projectˇs net GHG emissions. With an installed capacity of 15 MW, TRHDP is expected to annually generate, on average, 78.35 GWh, to displace an equivalent amount of energy generated by current and future diesel generators. Assuming a grid emission factor of 650 tCO_2eq/GWh for a 100% diesel-based system, the net GHG emission reduction potential of the 78.35 GWh Project is 49,500 tCO_2eq on average per year after deducting the anticipated reservoir emissions and emissions of construction and land clearing.

The net GHG emissions abated by the Project represent 8% of the Solomon Islands˘most recent estimate of total emissions of 618,000t per year.[71]

[71] Solomon Islands Draft Report to UNFCCC, 2010, excluding land use change and forestry. A similar figure of 540,000t is adopted by World Resources Institute.

SIG's Intended Nationally Determined Contribution (INDC) commits to reducing GHG by 18,800 tons of carbon dioxide equivalent (tCO_2eq) per year by 2025 and by 31,125 tCO_2eq per year by 2030 with appropriate international assistance.

9.1.6 Mitigation Measures

Mitigation measures are addressed below.

9.1.6.1 Construction Impacts Mitigation Measures

9.1.6.1.1 Induced Seismicity

Given the unlikelihood of induced seismicity from such a small reservoir no mitigation measure is proposed for this potential impact.

9.1.6.1.2 Local Slope Stability and Geology Impacts

Some aspects of this impact cannot be mitigated. Retaining structures, such as gabion walls, or the removal of upslope colluvium are recommended to minimize the risk of landslides occurring during both access road construction and operation.

9.1.6.1.3 Soil Compaction and Erosion Impacts

Ground cover provides the most effective means of preventing erosion. Consequently, sediment run-off and dust controls depend on retaining existing vegetation or revegetating and mulching disturbed areas as soon as possible.

The following mitigation measures are proposed:

- Keep land clearance to a minimum.
- Avoid wherever possible clearing areas of highly erodible soils and steep slopes which are prone to water and wind erosion.
- Use shredded vegetation for production of mulch and revegetate and mulch progressively as each section of works is completed. The interval between clearing and revegetation should be kept to an absolute minimum. Mulch generated from shredded vegetation can be used to stabilize steep slopes along road cuts and fills until revegetation is complete.
- Coordinate work schedules, so that there are no delays in construction activities resulting in disturbed land remaining unstabilised.
- Program construction activities so that the area of exposed soil is minimised during times of the year when the potential for erosion is high, for example during rainy season when intense rainstorms are common.
- Stabilise the site and install and maintain erosion controls so that they remain effective during any pause in construction. This is particularly important if a project stops during the wetter months.
- Keep vehicles to well-defined haul roads.
- Keep haul roads off sloping terrain wherever practical.

- ¿ Designed the slope of a cut to minimise the angle of incline.
- ¿ Cultivating the cut surface will increase infiltration of rainfall and decrease the velocity of water across the slope during rain and therefore reduce erosion.

9.1.6.1.4 Surface Hydrology

Increased suspended sediment load is an unavoidable impact, since most construction work will take place within or adjacent to the river. However, it can be mitigated by implementing best environmental management practices (BEMPs) during construction especially on terrestrial areas. BEMPs for controlling the introduction of sediment into the river include plans for (see Section 13 ¯ ESMP):

- ¨ Reservoir preparation;
- ¨ Point source pollution management, including concrete work;
- ¨ Spoil soil management during earthwork;
- ¨ Forest clearance practices;
- ¨ Stream crossing practices; and
- ¨ Drainage and erosion control.

Notwithstanding that BEMPs will be applied to control sediment entering into the river, moderate residual impacts will continue following application of mitigation measures, since most suspended solids, as measured by TSS, will originate from sources that cannot be fully mitigated. However, due to the effects of heavy rainfall within the catchment and the flashy nature of the Tina River, including tributary streams that enter the Tina River downstream of the damsite, sedimentation will be somewhat masked by the natural situation, as long as best efforts to employ BEMPs are made to prevent soil eroded from the project site from entering the Tina River.

Specific measures for quarry management, including measures applicable to independent suppliers, will be detailed in the Quarry Management Plan to be prepared by the Developer in accordance with the framework provided in the ESMP ¯ Chapter 13. The Quarry Management Plan shall include Good International Industry Practice measures.

Where identified quarry sites in the reservoir are not sufficient for construction needs, additional aggregate will be sourced from a licenced third party gravel supplier. The third party aggregate supplier shall hold all requisite consents for quarry operations including development consent under the Environment Act and consent to extract aggregate under the Mines and Minerals Act.

9.1.6.1.5 Regional and Local Air Quality

To minimise impacts on regional and local air quality, non-merchantable vegetation is to be shredded rather than burned. Shredded materials may be used to produce mulch for use in erosion control. Excess amounts can be used in agricultural areas or shredded and composted to produce a soil conditioner for use on gardens.

9.1.6.1.6 Noise and Vibration

To minimise impacts of noise and vibration the following measures will be employed:

Specific drill and blast methods will be used to reduce noise and vibration. Hydraulic rock drill equipment will be used instead of pneumatic equipment because it produces less noise. Moreover, blasting and drilling equipment will be equipped with silenced masts, which can reduce noise levels by up to 10dBA. Blasting charges will be covered with blasting mats and screens to reduce generation of noise, fly rock and dust.

9.1.6.2 Operational Impacts Mitigation Measures

9.1.6.2.1 Surface Hydrology

The following mitigation measures are recommended to address surface hydrology:

- Environmental Flow of 1m3/s impacts of surface hydrology during operation, to provide water for aquatic life and water for use by downstream villagers;
- Maintaining a flow of 1m3/s during reservoir impoundment;
- Maintaining a flow of 2.4m3/s through the power station during overnight reservoir re-fill;

Section 11 ¯ Assessment of Impacts on the Biological (Aquatic) Environment discusses in more detail the impacts of changed surface hydrology, and the requirements for an EF. Section 12 discusses in more detail impacts of changed hydrology on local inhabitants residing in villages along the Tina River and mitigation measures to ensure continued access to clean water.

9.1.6.2.2 Groundwater Hydrology

As risk level is low and unlikely, no mitigation measures are proposed for this impact.

9.1.6.2.3 Sediment Transfer

Section 12 ¯ Assessment of Socio-economic / Socio-community Impacts also discusses measures for mitigating the potential change to sediment transport mechanisms as it relates to the gravel extraction industry in the lower section of the Tina/Ngalimbiu River.

Section 11 ¯ Assessment of the impacts on the Aquatic Environment also discusses measures to mitigate the potential change to sediment transport as it relates to the aquatic environment.

The following recommendations are proposed for the design of the Project in relation to river sediment transport:

- The storage should be designed to incorporate as much :dead storage˘as possible to accommodate the accumulation of sediment in the reservoir over time;
- The power intake should incorporate a sediment sluicing/flushing structure to ensure that it does not get blocked with sediments;
- Consideration should be given to the impacts of highly turbid water on the headrace tunnel and turbines. Operationally, it may be necessary to close the intake at times of highly turbid flow to prevent deposition of sediments in the headrace tunnel or to prevent any damages to the turbine runner blades, wicket gates, and other parts of the mechanical plant; and

The storage operation should be designed to enable occasional dewatering for the purposes of excavating or dredging accumulated bed load sediments. The design study should consider access to the reservoir to excavate the accumulated bed load, an activity that might help to mitigate impacts on downstream gravel extraction.

Providing an EF during operation will ensure that there is a continuous dry season flow in the 5.7km stretch of by-passed river and beyond to the Tina/Toni River confluence throughout the day. During the dry season, it is expected that up to an additional 1m3/s (or more) of flow will enter the by-passed section of river from lateral tributaries that enter the Tina River just downstream of the dam. During the rainy season, these lateral tributaries will contribute considerable flow. In addition, during heavy rainfall events in the upper Tina River catchment, water will spill over the dam˜s spillway.

The dam will cause a permanent change to sediment transport process of the Tina/Ngalimbiu River. This can be partly mitigated if the reservoir is periodically lowered to enable accumulated sediments to be excavated and trucked to downstream aggregate (sand and gravel) users.

Based on the available mitigation measures, these impacts will persist as low to moderate residual effects that are considered to be not significant.

9.1.6.2.4 Temperature Change

As temperature changes are expected to be minimal, no mitigation measures are proposed.

9.1.6.2.5 GHG Emissions

Mitigation measures recommended for GHG emissions relate to reservoir preparation. Reservoir preparation will primarily involve clearing of vegetation from the inundation zone of the proposed reservoir area. Vegetation clearing will be done involving local communities and local landowners. Machinery will not be used due to the remoteness of the area, the steep topography and the lack of access road upstream of the damsite. The demarcation of the reservoir will be done by spray painting trees to denote the upper elevation limit of vegetation removal, above which the natural habitat is to remain untouched.

As much vegetation as is practical should be stripped off the future reservoir to limit organic matter decomposition in the lower layer of the reservoir that would create anaerobic conditions and generate methane.

This mitigation measure is discussed in further detail in Section 11 ¯ Assessment of Impacts on the Aquatic Environment.

9.1.6.2.6 Regional and Local Air Quality

As positive impacts identified, no mitigation measures proposed.

9.2 CONCLUSIONS ON IMPACTS TO THE PHYSICAL ENVIRONMENT

Table 9-6 - Summary of Impacts to the Physical Environment

	Impact before mitigation	Residual impact
Impact from Construction		
Induced seismicity	Low	Low
Local Slope Stability and Geology	Moderate	Low
Soil Compaction and Erosion	Major	Low
Surface Hydrology	Moderate	Moderate
Regional and Local Air Quality	Low	Not Significant
Noise and Vibration	Moderate	Low
Impact from Operation		
Surface Hydrology	Major	Moderate
Groundwater Hydrology	Low	Low
Sediment Transport	Moderate	Moderate
Temperature Changes	Low	Low
Regional and Local Air Quality	Not Significant	Not Significant
GHG Emissions	Moderate	Moderate Positive

With application of appropriate mitigation, monitoring and management methods, low to moderate direct and indirect impacts will accrue to the physical environment within the project area.

10. ASSESSMENT OF IMPACTS ON THE BIOLOGICAL (TERRESTRIAL) ENVIRONMENT

10.1 BACKGROUND

This section presents the analysis of impacts on the terrestrial ecosystem, including organisms and their habitats. Terrestrial organisms include all wildlife and plants that are not purely aquatic. It includes wetland dependent wildlife and flora. For each identified impact, measures to avoid, mitigate or compensate impacts are presented.

Four types of impacts can be described: direct impacts, indirect impacts, general impacts and cumulative impacts.

- Direct impacts are those that will likely accrue due to the Project footprint. These impacts are habitat-specific or species-specific, and are quantifiable.
- Indirect impacts are those that will take place as a consequence of the Project but with a degree of separation both temporally and spatially. These impacts are non-quantifiable since their extent and intensity are hard to predict.
- General impacts are those that will take place regardless of the Project specificity (e.g., noise from traffic, habitat fragmentation, oil spills, etc.), are not site-specific, and are not quantifiable. Best management practices help to address such impacts.
- Cumulative impacts are impacts arising from the Project that may aggravate existing impacts from other existing or reasonably anticipated projects in the study area. Cumulative impacts are presented in Section 14.

10.2 ASSESSMENT METHODOLOGY

Impact assessment methodology for environmental components (both aquatic and terrestrial) is presented in Annex 19 of the Annex Report. Impacts significance has been applied using a standardized method based on the integration of the following steps:

- Identification of impact sources - the first step of the impact assessment is to determine which activities will have an impact on environmental components. This identification is done using an impact matrix.
- assessment of impacts using the criteria of impact duration, extent, magnitude / intensity, and probability of occurrence. This assessment includes an assessment of fauna species of highest ecological importance;
- application of mitigation measures; and
- determination of post-mitigation residual effects and significance, the latter being determined to be either Not Significant, or Significant.

Where a residual effect is deemed to be Significant, it falls to decision makers within government to determine whether the need for the project outweighs the concerns for potential, non-mitigable, significant impacts.

10.3 ACTIVITIES AFFECTING THE TERRESTRIAL ENVIRONMENT

The section identifies the main project components, and the actions and activities that will affect terrestrial environment components.

Impacts on physical and biological-terrestrial environment arise from the same activities and are listed below for completeness as to each section to be regarded as a standalone section of the ESIA.

10.4 PRE-CONSTRUCTION AND CONSTRUCTION ACTIVITIES

10.4.1 Pre-construction Activities

Pre-construction work involves site investigations, including installing a hydrology monitoring station, mapping topography, undertaking geological and geotechnical surveys, and other related activities. Limited drilling and cutting of new tracks to move equipment onto survey sites was required, with only minor impacts accruing to aquatic habitats and water quality.

10.4.2 Widening and Stabilizing Existing Black Post Road

Black Post Road will be widened and improved along its 13.3 km course. This will necessitate bush clearing, surfacing and stabilization with gravel or cement, creation of roadside ditches for drainage and earthworks to build embankments. In these areas, habitats are no longer natural. Rather, they have been anthropogenically altered for use as oil palm plantations, grazing sites for cattle, grassland, settlements, and other human use. Therefore, there is no forest to clear and exposed soils will be limited. Since the transmission line will follow Black Post Road, impacts related to the transmission line are treated in the same manner as those related to widening the road. The width of the road alignment will be up to 50m, and includes the right-of-way for the transmission line.

10.4.3 Construction of New Access Roads

Black Post Road will be extended from Mangakiki to the project site to serve as the main access road. This will necessitate clearing forest and other vegetation cover, grubbing stumps, removing top soil, completing earth works (cut and fill), stabilizing the roadbed, road surfacing, installing drainage gutters and ditches, and installing watercourse crossings using culverts. This section of road will be paved. The width of the right-of-way will be up to 50m and include the easement for the transmission line. The length of this road is about 8.31km. The primary Contractor may subcontract forest-clearing activities to a local logging company, to avoid importing forest clearing and log transport machinery.

Entura˙s feasibility study (2014) identified two quarry sites both in the reservoir area, which will need to be connected to the main construction area by access roads. As these access roads were not identified by Entura, it has been assumed that they will follow topographic contour lines and have the same width as other access roads for which additional width is not required for the transmission line.

10.4.4 Construction of Headrace Tunnel from Dam to Powerhouse

The headrace tunnel will be 3.3m in diameter, will run 3.3 km beneath the ground surface, with an 85m shaft connecting to a 130m long power tunnel. The headrace and power tunnel will be built underground using drill and blast techniques to excavate rock. Drilling and blasting above ground will generate noise and vibration due to the use of hydraulic rock drills and explosives. In addition, removal and disposal of spoil material will utilize heavy haul trucks that generate traffic and dust in the dry season. Topsoil removal will be limited to the entrance of the tunnel, surge shaft and tunnel exit. Explosives will be stored on site in a secure, purpose built explosives magazine, surrounded by an earth berm, located away from the main areas of activity. Approximately 1ha of work area for machinery and trucks to operate will likely be necessary at the entrance of the tunnel, and another 1ha will be required for a work area at the exit of the tunnel BRLi (2013)_has estimated the volume of tunnel spoils to be approximately 24,300m^3, based on the dimension of underground infrastructure. Tunnel construction will be by drill and blast.

10.4.5 Construction of Dam and Powerhouse

Most impacts of dam construction are related to fish and the aquatic environment. Construction of the dam will require de-watering the river by diverting it through a diversion structure comprised of an upstream cofferdam, a diversion conduit, and a downstream cofferdam. The riverbed and valley walls will be excavated into the bedrock by drill and blast techniques for the dam foundations and dam abutments. Drilling and blasting above ground will generate noise and vibration due to the use of hydraulic rock drills and explosives.

Preparation of the dam abutments will affect approximately 2,800m^2 of terrestrial habitat on the right slope of the gorge and 3,700m^2 on the left side of the gorge.

The powerhouse will be built alongside the Tina River 5.7km by river downstream of the dam and will be founded on competent rock using drill and blast techniques to avoid settlement and vibration of the completed structure. A substation will also be constructed. The construction of the powerhouse and substation will necessitate excavation, fill placement, grouting or pilling and will cover approximately 1080m^2 (Entura, 2014). The total area of terrestrial habitat disturbance is estimated to cover approximately 1.5ha.

10.4.6 Construction of Work Area

An area of 130m x 90m (11,700m^2) will be required for construction work areas (e.g., staging, fabrication, materials stockpiling, equipment maintenance, etc.) and will involve forest clearing and topsoil removal.

10.4.7 Quarrying

Rock quarries will be developed to provide aggregate for the RCC dam. Entura (2014) estimated that 160,000m^3 of aggregate will be required, from two possible quarry sites located in area that will be occupied by the future reservoir. Aggregate will also be sourced directly from the river bed downstream of the dam (Entura, 2014). Where the two identified quarry sites are suitable for construction needs, all quarry sites and access roads will be within the Core Area.

In the event that aggregate available from the two identified quarry sites does not meet all construction needs, additional aggregate will be purchased from a licenced third party aggregate supplier. The Developer will prepare a Quarry Management Plan in accordance with the framework plan provided in the ESMP, incorporating measures to meet GIIP.

Quarry exploitation will require the removal of superficial deposits in or close to the river, which may release suspended material into the water.

10.4.8 Reservoir Preparation

Prior to reservoir impoundment, trees will be cleared from within the reservoir area to an elevation of 175 masl. Loose rocks and rubble along the steep faces of the river gorge will be removed where possible.

Reservoir vegetation clearing will be conducted during the latter phase of the construction program, as the dam and powerhouse are nearing completion, just before reservoir inundation is stet to commence. The timing is critical so as to not enable vegetation to regrow or become re-established before water is impounded. Depending on the schedule for reservoir filling, vegetation clearing may proceed in distinct phases, with the lowest elevation areas of the future reservoir inundation zone being cleared first, followed by the higher elevation inundation zone. Steep gorges in the reservoir area are covered with ligneous and herbaceous plant species. Due to the steep terrain, lack of access roads and the risk of flash floods, work using machinery will not be feasible. Vegetation clearance will, therefore, be undertaken using manual labour. Sawn timber will be transported by floating it down the river as is currently done from Choro and Koropa. This activity will release organic matter and suspended solids into the river. Reservoir clearing will not involve grubbing (removal of stumps) and soil stripping, since only manual work will be feasible.

Vegetation clearing represents important planning in terms of land access and timing, and may also require a government logging permit. The reservoir was acquired as part of the Core Land and will be part of the registered land owned by Tina River Core Land Company (TRCLC) and will be leased to the developer.

10.4.9 Construction Traffic

Heavy haul trucks will be required to transport materials and equipment, including excavated material to the crushing plant, spoils from the headrace tunnel, heavy equipment and construction materials, fuel and other products on a regular basis. Light duty trucks and buses will be used to transport workers to and from the Project site. In addition to issues related to safety and comfort of local communities, the movement of vehicles, especially heavy haul trucks, generates noise and vibration, and presents a risk of wildlife-vehicle collisions.

10.4.10 Worker Accommodation

Entura (2014) and TRHDP Office (personal communication, 2014) indicate that non-local construction workers will reside in Honiara, Lungga or Henderson, likely in existing accommodations, and be transported to and from the project site each day. The estimated number of workers will peak at approximately 175 during the construction of the dam; this number includes experienced expatriate labour and unskilled labour that will be sourced locally. There will not be a workers camp that would be a source of direct impact on terrestrial habitat.

10.4.11 Soil Stockpiling and Spoils Disposal

During the construction of the dam, topsoil spoil will be generated and will be stored (prior to reusing it for rehabilitation or before transporting it outside the Project Area). Storage will either be short term (in case of outside transportation) or long term (in case of rehabilitation of disturbed areas). An estimated 10 ha storage area will be necessary for the generation of 327,900 m^3 of topsoil, using 10 conical-shaped piles of 50m diameter and 5m high. It is suggested to use remnant forests of the Core Area to create the 10 ha storage area.

10.5 OPERATION ACTIVITIES

10.5.1 Operation of the Hydropower Facility

The operation of the dam will modify the river flow especially during the night (during reservoir filling) and will create a reduced flow between the dam and the power station.

10.5.2 Access Road Use

Continued use of the access road to the dam site and powerhouse during operation will have an indirect impact on certain species of fauna, as a result of wildlife-vehicle interactions. However, given the relatively low expected volume of traffic, the impacts upon fauna are likely not significant.

10.6 IMPACT ASSESSMENT

10.6.1 Impact Identification Matrix

Both the TRHDP construction and operation phases will generate impacts on the terrestrial ecosystem. Table 10-1 identifies impact-generating activities (X mean that there is a foreseen impact).

Table 10-1 Matrix of construction and operation impacts on the terrestrial environment

Foreseen activities	Impact on components						
	Flora and habitat	Native Rainforest Rodents	Bats and marsupials	Birds	Amphibian	Reptiles	Wetland dependent insects
Construction							
Widening and stabilization of Black Post road including RoW for TL	X	X	X	X	X	X	X
Creation of a new access road from Black Post road to Project site including quarries and RoW for TL	X	X	X	X	X	X	X
Construction of the head race tunnel from dam to powerstation	X (minor)	X (minor)	X (minor)	X (minor)	X (minor)	X (minor)	X (minor)
Construction of dam & powerstation	X (minor)	X (minor)	X (minor)	X (minor)	X (minor)	X (minor)	X (minor)
Work area construction	X	X	X	X	X	X	
Quarry exploitation	X	X	X	X	X	X	X
Vegetation clearance in the reservoir	X	X	X	X	X	X	X
Soil stockpiling and spoil disposal	X		X	X	X	X	

Foreseen activities	Impact on components						
	Flora and habitat	Native Rainforest Rodents	Bats and marsupials	Birds	Amphibian	Reptiles	Wetland dependent insects
Operation (including initial reservoir inundation)	X (mostly indirect)	X (mostly indirect)	X (mostly indirect)	X (mostly indirect)	X (mostly indirect)	X (mostly indirect)	X (mostly indirect)

10.6.2 Impact Assessment Limitations

The terrestrial ecology impact assessment is lacking supporting scientific literature regarding specific life cycle, breeding and feeding habits of most fauna in the Solomon Islands. Therefore, due to limited scientific data and limited previous surveys, there is little knowledge on the specific impacts that the TRHDP activities may have on many species.

In addition, the terrestrial ecology impact assessment has some limitations due to uncertainties regarding the Project layout:

- Uncertainties regarding the location of the quarry site: the terrestrial ecology impact assessment was based on Entura feasibility report (March 2014), which identified multiple potential quarry sites. The final quarry site locations will be confirmed in the design report.
- Uncertainties regarding right-of-ways of some project components such as access roads to quarries. These are not described in Entura 2014 report.

10.7 Assessment of Construction Impacts

10.7.1 Construction Impacts on Flora

10.7.1.1 Direct Impacts on Flora

This section presents the potential direct impacts on flora during the construction phase of the TRHDP, and proposed mitigation measures, and residual effects and their significance after mitigation is applied. Table 10-2 identifies the potential direct construction related impacts to the terrestrial ecosystem. Man-made habitats (e.g., gardens, settlements, oil palm plantations) have been omitted in the table since the TRHDP will not affect them.

10.7.1.1.1 Identification of Potential Direct Impacts

Construction activities, including clearing vegetation prior to reservoir impoundment, will reduce the biomass of forest and grassland areas. Riparian habitats will be removed or inundated to provide for the access roads, tunnel entrance and exit, transmission lines, quarries, powerhouse and the reservoir.

The assessment of impacts is based on the baseline habitat description of the study area and the proposed project layout at the time the ESIA was prepared. In total, 115.49ha of natural terrestrial habitat will be permanently lost due to construction activities. An additional 10ha will be necessary for the temporary storage of topsoil. However, this area will not be permanently lost and will be regenerated by TRHDP using native vegetation species toward the end of the construction phase.

Although the change in the area of terrestrial flora represents a permanent loss, for undisturbed forest this represents a site-specific (local area) loss of less than 0.2% within the Tina River catchment. For all forest types combined, the Project will result in the loss of only 0.4% of forest habitat. Therefore, the impact on critical forest vegetation before application of mitigation measures is considered to be low-moderate.

Table 10-2 Direct impacts on terrestrial ecosystem habitats

Project component, action or activity	Area of habitat directly lost to construction activities									
	Grasslands (ha)*	Undisturbed forests (ha)	Disturbed forests (ha)	Remnant forests (ha)	Montane forests (ha)	Riparian (ha)	Cliffs (ha)	Garden (ha)	Fallow brush land (ha)	Total Area (ha) affected by Project
Widening and stabilising Black Post Road including RoW for TL	6.09	0	3.90	4.80	0	0	0	0	6.23	21.02
Creation of a new access road from Black Post Road to Project site including quarries and RoW for TL	0	5.27	23.57	7.07	0	3.07	0	0	0.17	39.13
Construction of the headrace tunnel from dam to powerhouse	0	0	0	0	0	2	0	0	0	2 (above ground)
Construction of dam & powerhouse	0	0	0	0	0	1.55	0.60	0	0	2.15
Work area construction	0	0	1.18	0	0	0	0	0	0	1.18
Quarrying	0	4.27	0	0	0	Already calculated in reservoir clearance	0	0	0	4.27

Project component, action or activity	Area of habitat directly lost to construction activities									
	Grasslands (ha)*	Undisturbed forests (ha)	Disturbed forests (ha)	Remnant forests (ha)	Montane forests (ha)	Riparian (ha)	Cliffs (ha)	Garden (ha)	Fallow brush land (ha)	Total Area (ha) affected by Project
Reservoir Preparation	0	0	0	0	0	15	15.52	0	0	30.52
Temporary Soil storage area in the Core Area***	0	0	0	10	0	0	0	0	0	10
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Area by habitat Type in Tina Catchment	59.84	5146.97	295.16	92.40	9013.21	Not assessed**	Not assessed**	4.62	25.38	
Percentage of affected Habitats by type in Tina Catchment	10.18%	0.19%	10.04%	23.66%	0%			0%	25.22%	

* Grassland will only be affected along the access road (15m wide) and not under the transmission line.

**Riparian and cliff habitats where only assessed along the future reservoir, and not in the entire catchment due to inaccessibility of the area.

***An estimated 327,900m^3 of topsoil will be temporarily stored on the project site in 10 conically shaped piles of 50m wide and 5m high, requiring an area of approximately 10ha.

10.7.1.1.2 Mitigation Measures

Reservoir Preparation

Reservoir preparation will primarily involve clearing of vegetation from the inundation zone of the proposed reservoir area. Vegetation clearing will be done involving local communities and local landowners. Machinery will not be used due to the remoteness of the area, the steep topography and the lack of access road upstream of the dam site. The demarcation of the reservoir will be done by spray painting trees to denote the upper elevation limit of vegetation removal, above which the natural habitat is to remain untouched.

Ideally, all plants and topsoil should be stripped fromthe future reservoir to limit organic matter decomposition in the lower layer of the reservoir creating anaerobic conditions.

Due to the high cost of importing logging equipment to the Solomon Islands, the construction contractor may choose to subcontract forest-clearing activities to a local logging company. The contractor in charge of forest clearing will be governed by the commitments and assurances made by the TRHDP and included as conditions in any environmental approvals.

Prior to commencing construction, TRHDP PO should consult with local communities through the Tina Core Land Company to identify possible existing trails along which sawn timber can be transported to the river. Sawn timber could be transported downstream using the river as it is currently done from Choro and Koropa. It would then have to be hauled out at a site immediately upstream of the dam and transported from there downstream again by river, or by truck on the access road.

Prior to commencing construction, a reservoir preparation plan will be prepared by the construction contractor. Preparation of this plan should be based on an assessment of the feasibility of reservoir vegetation clearance, and involve consultation with communities. Key issues that will need to be resolved include:

- Moving logs and sawn timber safely from where they are cut, down to the river in an area that is defined by a steep-sided gorge subject to frequent flash floods; and
- The location of the access road that will be constructed from the dam site to one or both of two possible quarry sites in the reservoir, which could be used to facilitate vegetation clearance.

Trees with a diameter larger than 10cm will be cleared from within the reservoir area up to an elevation of 186.5masl. Loose rocks and rubble along the steep faces of the river gorge will be removed where possible.

Access Road

Once the final access road alignment has been determined, and all areas that require forest clearing have been identified, a botanist will walk the full length of the road (starting from Mangakiki) and other areas where construction will take place to geo-reference and fence environmentally and culturally sensitive areas such as:

- Wetlands;
- Streams;
- Rare, endangered plants and culturally or economically important plants colonies; and

- Large trees that need to be kept to maintain canopy closure to decrease the amount of edge-effected forest.

Fencing will be done using orange plastic construction fencing material supported on wooden or steel pickets. Once fenced, each environmentally or culturally sensitive area will be mapped. The map of these protected sensitive areas will then be presented to a committee comprised of the resident engineer for the dam construction, construction contractors and forest clearing subcontractors, and the independent environmental expert. This committee will discuss potential solutions for protecting each sensitive area identified, including:

- Wetlands located in the right-of-way – these areas will be fenced to denote their sensitivity. If the road alignment potentially bi-sects a wetland then culverts will need to be installed to ensure water exchange continues to occur between both parts of the bisected wetland. If the work areas are located in a wetland, they should be relocated nearby.
- Streams located in the right-of-way – sites where the road will cross streams will be fenced to denote the site of the crossings, the areas outside of which would be 'no go' zones. Work should not occur within the wetted perimeter of any streams. Stream crossings requiring bridging should be clear-spanned. Smaller stream crossings should be equipped crossed using open-bottomed box culverts to enable fish and wildlife to pass under the roads.
- Rare or endangered plants in the right-of-way – fencing will be installed to encircle these areas, and denote that they are to be avoided moving the road alignment or relocating work areas. If measures to avoid endangered plants are not possible, then transplanting plant colonies should be considered an option. Plants that are capable of being transplanted would be relocated as far as possible away from the area of disturbance under the supervision of a botanist, with the help of local villagers.

Large canopy trees – in the interest of maintaining important ground level shade and humidity, that is so important to the ecosystem, large trees that provide canopy cover will be protected from unnecessary clearing, wherever possible. Fencing will be placed around these trees.

Achieving No Net Loss of Biodiversity

Of the 115 ha of land that will be cleared, 50 ha has forest cover, but only 9.5 ha can be considered primary forest. Half of the other 40 ha is disturbed secondary forest, and the other half is remnant forest, i.e., secondary forest formed by natural revegetation of cleared areas.

Cliff habitat and riparian habitat (partially disturbed), approximately 15 ha of each, will be affected by reservoir preparation. The 50 ha represents 0.9% of the total area of non-montane forest and 0.3% of all forest in the catchment. In the context of the assemblage of terrestrial vegetation communities and the wildlife habitats they provide, this permanent loss within the Tina River catchment is not considered to be significant.

The proposed mitigation measures will help to ensure the direct impacts of vegetation clearing are confined to the 115 ha. However, Performance Standard 6 requires that when natural habitat is degraded or converted, measures will be designed to achieve no net loss of biodiversity where feasible. With respect to the potential impacts on critical habitat, PS 6 requires that net gains shall be achieved for the biodiversity values for which the habitat was designated.

To achieve these outcomes, the Project will take steps to protect the upper catchment biodiversity from threats of extractive industries (see Appendix K). The protection of the upper catchment is conceived as a staged approach reflecting the ownership of the land by indigenous customary landowners. Immediate protection measures will include actions of the TCLC and Project Company to restrict access to vehicles (including commercial logging machinery) to the upper catchment through the Core Area, to monitor changes in forest coverage in the upper catchment, to monitor logging truck activity on existing logging roads, and to support SIG to enforce seldom used statutory restrictions on logging at elevations above 400 masl (which if enforced would represent the vast majority of the upper catchment). This protection work will be furthered by Project Office funding for an NGO to facilitate consultations with landowners to seek support for the creation of a protected area in the upper catchment and to conduct mapping and forestry studies, towards preparation of a management plan.

In addition to upper catchment offset activities, the Project Company will implement measures including a post construction rehabilitation plan for disturbed areas, and an offset within the Core Area which will include measures to protect the remaining natural habitat in the Core Area, and to rehabilitate an area of modified habitat within the Core Area of at least 9.5 ha. These measures will be set out in the Biodiversity Management Plan.

Independent Environmental and Social Monitor

To limit habitat clearing to the strict minimum, an independent consultant specialized in environmental and social monitoring will be present on site during key activities to audit all ESMP measures. The consultant will ensure that all mitigation measures are implemented. Special attention will be paid to access road alignment clearing. The consultant will prepare a monitoring report for use by the construction contractor and its subcontractors to inform them of non-compliances. The monitoring consultant will also ensure that corrective measures are implemented (refer to ESMP).

The construction contractor and all subcontractors will also appoint a team of environmental and social specialists with proven qualifications in environmental and social monitoring. They will be responsible for following up on issues raised by the independent monitoring consultant, including ensuring corrective and preventive actions are taken to rectify and avoid environmental and social concerns. Their experience will enable them to make decisions throughout the TRHDP construction program to minimize losses of valuable biomass.

10.7.1.1.3 Residual Effects and Their Significance

Just over 115ha of vegetation cover will be permanently removed from the project area. In the context of the assemblage of terrestrial vegetation communities and the wildlife habitats they provide, this permanent loss within the Tina River catchment is not considered to be significant. The proposed mitigation measures will help to ensure the direct impacts of vegetation clearing are confined to the 115ha.

10.7.1.2 Indirect Impacts on Flora

This section presents the potential indirect impacts on flora during the construction phase of the TRHDP, and proposed mitigation measures, and residual effects and their significance after mitigation is applied. Habitat-specific impacts and residual impacts are also analysed and quantified in this section.

10.7.1.2.1 Identification of Potential Indirect Impacts

Colonisation by Invasive Plant Species

Construction activities, including construction of the access road, will create open spaces and gaps in the canopy. These areas are more prone to colonization of terrestrial invasive plant species, especially if the equipment used carries mud or soils from previous construction sites.

In the Study areas, risk of invasive plant colonization could occur along the access road, quarries and along the transmission line.

Depending on the species, three situations can occur with invasive plants:

- Native plant species may be out-competed by invasive plants with adverse environmental consequences.
- Invasive plant species may adversely affect agricultural and garden plants and pasture, thereby affecting livelihoods.
- Invasive plant species may affect infrastructure, thereby leading to economic consequences for the Project.

Evidence of invasive plant species in the study area was observed, especially within anthropogenically affected areas, including along roads. A good example of an invasive plant is the vine Mikania micrantha (Mile-a-Minute) that can grow up to 1m in a month, and is considered one of the most important weeds of this region of the Pacific. This vine invades subsistence gardens and tree plantations (oil palm) forming thick ground cover that competes with crop plants. It grows from lowland areas up to an elevation of 1200masl, and the seeds are easily dispersed by wind, and by people when seeds attach to clothing (Day et al., 2011). In the study area, the vine is already widely distributed in open areas along Black Post Road and in villages along the Tina River (e.g., Sengue). It not only competes with crop species, but also smothers native vegetation (CABI, 2013).

Mimosa invisa and Mimosa pudica are two invasive plant species from Brazil that have also been observed in the study area and are weeds affecting agricultural and garden plants. They form thickets along road margins and at the edge of cleared forest. They do not colonize undisturbed forests. Their behaviour as weed that competes with native plants is, therefore, limited to grassland areas (CABI, 2013).

Water Hyacinth (Eichhornia crassipes) is by far the biggest threat to any hydropower projects in tropical countries. It is the world˜s worse invasive aquatic plant in dam reservoirs, as it can quickly colonize entire reservoirs, reducing electricity production by clogging water intakes and interfering with reservoir uses (such as fisheries). Water Hyacinth is present everywhere in the South Pacific including in the Solomon Islands (SPC, 2005) and is present in Vella Lavella Island, according to Polhemus et al. (2008). Water Hyacinth have not been observed in the study area likely because of the fast flowing nature of the Tina River. Moreover, if it was to be accidentally or intentionally introduced, it would likely not thrive in the reservoir due to the extreme daily fluctuations in water levels and the expected low concentration of nutrients (see Section 7 ¯ Biological Environment Baseline - Aquatic).

Habitat Fragmentation

Construction activities, especially road construction, may cause habitat fragmentation. Habitat fragmentation effects are more obvious on wildlife than on vegetation. Nonetheless, habitat fragmentation can lead to the `edge effect_along forested areas. The edge is the area where natural habitats come into contact with manmade habitats or infrastructure (e.g., road, transmission line). The edge effect causes abrupt changes in vegetation cover and reduces the true surface of the forest, leading to the colonization of heliophitic shrub and vine species. The edge effect also leads to local changes in soil characteristics from a cool, dark and moist to a warm, exposed and dryer environment due to solar radiation. This change can lead to a higher rate of tree mortality along the edge.

In tropical rainforests, the edge effect can affect forests and plant composition up to 100m into the forest (Laurance et al., 2009). Fragmentation increases local erosion as slopes and small landslides are created at the edge of the forests. Therefore, habitat fragmentation can lead to changes beyond the line of contact with the construction activities. The edge effect is diminished when the canopy stretches across the clearing (Goosem, 2007). In terms of edge effect on habitat, forested areas are more vulnerable than grasslands.

Local Hydrological Changes

Some plant habitats can be indirectly fragmented when local hydrologic conditions are changed by construction activities. For example, many small tributary streams within the Tina River catchment area are free flowing perpendicular to the future access road (see Section 5 ¯ Physical Environment Baseline). These small streams are conveying water to micro wetlands and cliffs habitat (waterfalls) where hydrophilic and epiphytic plants thrive. The construction of the access road could change local small stream hydrology leading to disappearance or displacement of micro wetlands. Such changes could come from soil deposited in cut-and-fill approaches, earth works, and access road construction, blockage of water flow due to poor dimensioning of culverts or absence of culverts.

Point Source Pollution

The presence of machinery during construction activities can lead to oil spills and to the spread of other pollutants that could result in either the mortality of plants in adjacent areas along roads, or in bioaccumulation of the food chain (Goosem, 2007). Concrete wash waters, with their high pH, and high concentration of suspended solids could leak into the Tina River during the construction thereby affecting riparian habitats and forests. Suspended solids released from earthworks could also affect the vegetation. Workers may also be tempted to use the river as an open defecation area.

Impacts on Topsoil and Vegetation Regeneration

Earthworks will locally modify topsoil leading to three type of impacts: increased erosion and sedimentation of surface runoff, disturbance of soil nutrient cycles, and delayed natural regeneration due to invasive species colonization.

In the Solomon Islands vegetation regeneration is vigorous. According to a study of vegetation regeneration in Papua New Guinea (Hartley, 1991 quoted by PNG LNG Project, Coffey Natural Systems, 2009), regeneration is quick in disturbed soil in the region. Regeneration is poor to non-existent in areas made out of hard limestone pavement or compacted limestone, especially for ligneous species. This study of vegetation regeneration involved regeneration follow-up from 1991 to 2005. For the Project, most of the access road will be built on conglomerate formation. It is, therefore, difficult to qualitatively assess the rate of vegetation recovery based on this study. However, based on field observations made for previously disturbed areas, such as logging roads and on observations of the Project area, it appears that vegetation regeneration is vigorous, especially mainly in areas where the topsoil has been retained.

According to Coffey Natural Systems (2009), factors influencing vegetation regeneration include:

- Whether the topsoil remains in place or not - when the topsoil is left in place it enhances vegetation regrowth as the seed bank remains on site.
- Whether the soil is compacted or not - a compacted soil may prevent rooting of woody (e.g., tree) species.
- Length of time soils are disturbed - the longer the soil is disturbed, the higher the chances of seed bank losses due to erosion and colonization by invasive species.
- Vegetation type prior to disturbances - the richer the plant composition, the richer the seed bank in the soil.
- Rainfall pattern - the higher the rainfall, the faster the topsoil erosion will take place.
- Topography - steep slopes are prone to gullying, causing unstable surfaces for rehabilitation, erosion and loss of topsoil.
- Altitude - disturbed lowland forests are quicker to regenerate that montane forests because of their cooler climate.

10.7.1.2.2 Mitigation Measures

During the TRHDP construction phase, good international industry practice (GIIP) will be implemented by the construction contractor, to mitigate indirect impacts on flora.

<u>Colonisation by Invasive Plant Species</u>

The following actions will be implemented to protect against encroachment and colonization by invasive species:

- Machinery will be checked by designated project staff before the equipment is allowed to enter the project area, to ensure that wheels, tracks, buckets and other parts of machinery that may have come into contact with mud or soil, are clean of these materials. A washing station will be installed just outside the project area at Veroande (see Section 6.4.2.1 ¯ Invasive and Feral Species) to ensure that all machinery that enters the work area is clean. Drainage water from washing stations will be diverted away from water bodies.
- Importation of soil from outside work areas will be prohibited.

- Soil stockpiles in the construction area will never be permanent in order to avoid colonization by invasive species. Soil stockpiles will be covered with geofabric tarps or revegetated with native plants. The soil management plan (see ESMP) will be amended by the construction contractor: to assess the amount of spoils from road cuts; to assess the need for road embankment and future use of excess soil; and to locate stockpiles.
- Topsoil will be left on site and will be reused as much as possible.
- Chemical and biological control of invasive plant species is not recommended as the extent of the impacts will be limited spatially.
- Local population will be sensitized regarding the threat posed by Water Hyacinth and the consequences should it find its way into the area.

To mitigate indirect impacts of the terrestrial habitat fragmentation and the edge effect, the following actions will be implemented:

- Construction activities will be favoured in already affected areas (such as along the existing access road) and in disturbed and remnant forests rather than undisturbed primary forests.
- Where possible, impact-causing activities will be spatially concentrated to limit any encroachments.

<u>Local Hydrological Changes</u>

To mitigate indirect impacts of local hydrological changes, the following actions will be implemented:

- Small tributary streams in the vicinity of the access road will be identified and geo-referenced prior to the construction of the access road.
- All identified tributary streams in the vicinity of construction activities will be protected by fences to avoid any encroachments.
- Culverts will be installed along the access road to enable water to flow freely. More measures are detailed in Section 13 – ESMP.
- A watercourse crossing management plan will be produced by the construction contractor prior to commencing the TRHDP construction.
- Depositing soil outside the limits of access road earthworks will be prohibited within 100m of nearby streams.

<u>Point Source Pollution</u>

To mitigate the indirect impacts of point source pollution, the following actions will be implemented:

- The presence of on-site toilet facilities for workers will be mandatory.
- All sanitary wastewater will be regularly transported outside of the study area for treatment.
- Oil management will be clearly defined prior to commencing construction and secondary containment will be required for all hydrocarbon products (fuel, oil, lubricants) used on the Project. Hydrocarbons will be stored at least 100 meters from any water body or wetland. Any hydrocarbon storage tanks or oil/fuel drums will be free of rust and cracks. The Project will provide and maintain bund walls around the fuel storage areas within the Site. These bund walls will be of a sufficient height to contain a volume equal to one and one half (1.5) times the entire contents of its fuel storage facilities. Fuel dispensing areas and machinery maintenance areas will be built with concrete hard standing surface, which will drain to oil separators. The oil will be pumped by a tanker and sent to Honiara for treatment. A hydrocarbon (fuel, oil, lubricant) management plan will be prepared and implemented by the construction contractor(s) prior to commencement of construction.

- All necessary means will be taken to reduce sediment loads in the river, especially when earthwork activities are being undertaken for dam construction. (see Section 13 – ESMP).
- Wash water from concrete works will never be directly or indirectly released in waterbodies or wetlands. Instead, it will be reused, stored and treated on site or collected and transported by road tankers for treatment in Honiara. A designated impermeable containment area must be used for concrete activities. To treat concrete washout onsite, a combination of settling ponds can be useful:
  - Coagulants or flocculants will need to be added before discharging the water into the first or primary pond. This will help to reduce the size of ponds. Water must flow over small weirs from one basin to the next until the quality is good enough to be reused as plant water (closed loop system). The first pond will require periodic cleaning. The hardened concrete that is removed can be crushed and sent to a landfill in Honiara or reused on site as non-structural aggregate for road ballasting or surfacing works yards. The capacity of each pond must be greater than a full day supply of wash water and will take into account that the area often receives considerable rain. Due to the sensitive nature of the area, wash water will never be released in the Tina River.
  - Each settling pond could allow for seepage and evaporation. For seepage, the water table needs to be low enough so that the water can be filtered without escaping. Settling ponds will need to be well sealed to limit any risks of infiltration of groundwater.
  - Water levels of settling ponds will be inspected daily. Before intense rain, the water levels will be lowered. Suitable cover will be installed to cover the pond in the event of intense rain (e.g., folding tarps). Tarps will cover the pond at night to keep birds and bats from drinking unsafe water. When excess water becomes a disposal issue, its pH will be adjusted with automatic pH neutralizer using $C0_2$ gas (the use of acids for that purpose is prescribed) prior to a potential discharge off-site in Honiara.

<u>Impacts on Topsoil and Vegetation Regeneration</u>

It is assumed that all excavated soil will be reused for restoration of construction work areas no longer required as the project moves into operation. Therefore, soils will be stockpiled in an area roughly 10ha in size, which will be developed with limited encroachment on natural habitats.

To ensure good soil management and revegetation, the following mitigation measures will be implemented during any earthworks conducted in forested areas where rich organic topsoil is present.

- Salvaging topsoils with high organic content, and mineral soils (i.e., subsoil not capable of supporting plant growth) - prior to commencing construction of the access road, the contractor will be required to do soil coring to assess the depth of organic soil in the right-of-way in cleared forested areas, from Mangakiki to the dam and quarry sites. This will determine the depth of soil stripping that is required. Collection of soil cores, and the management of soil stripping, will be done under the supervision of a soil expert. The aim is to conserve the topsoil for future use in rehabilitation of disturbed areas and to reuse subsoil for road embankments.

  Usually, machinery will be used to strip topsoil layers to a depth of 1m. With an access road length of about 21.86 km and a width of roughly 15m, it is estimated that approximately 327,900m^3 of topsoil will be removed from the access road right-of-way. Measures taken during earthworks to protect waterbodies are presented in Section 13 – ESMP).

- Storage of topsoil – topsoils having a high organic matter content, that have good potential for plant regrowth, will be stored within a soil stockpile area. Topsoil storage will be done away from all water bodies on a flat terrain, and close to work areas. Stockpiles will be compacted and covered with geo-fabric tarps to avoid unwanted prolific plant growth. Another option is to seed soil stockpiles with indigenous herbaceous plant species to maintain the organic content of piles. If the supply of native plants to vegetate piles is limited then stockpiles will be covered. In both cases, stockpiles slopes will not exceed a horizontal to vertical ratio of 5H:1V, and will be surrounded by sediment control structures, such as deeply anchored sediment fences, ditches, or berms around the stockpiles.

  In addition, stockpiles and all disturbed areas, including those adjacent to road alignments, will be drained to enable sediment control structures, such as settling ponds, to prevent sediment laden runoff flowing into water bodies. Stockpiles of topsoil will be maintained at a pH of greater than pH5.5, since a lower pH may lead to reduced organic matter content. With pH below 5.5, many essential nutrients may leach from the topsoils, and toxic elements may become available to plants, which in turn, will affect future plant regeneration. If necessary, agricultural lime could be spread onto the stockpiles to maintain a stable pH level.

  Monitoring of stockpiles will be done throughout the construction phase. An estimate of 10 conical stockpiles each 5m high, and 50m wide, will be necessary to store 327,900m^3 of topsoil. Stockpiles will be located within the Core Area, with the exact location being determined by the construction contractor, a botanist, and the independent consultant. It is recommended that spoils be stored in the remnant forest habitat to minimize forest clearing and because this habitat is located close to the access road (see Figure 6-12 – Study area habitat types and land use).
- In addition to soil spoils, non-organic (mineral subsoil spoils) and rock will also need to be removed and disposed, or reused, as follows:
  - Subsoil spoils - the Project access road will be located in steep terrain, and will require excavation of high cuts, placement of high fill embankments, and construction of retaining walls. Some soil spoils produced by cuts will be reused for fill embankments and unsuitable soil spoils will be transported outside the Project area to a designated disposal site.
  - Rock spoils - Construction of the tunnel (headrace tunnel, surge shaft, power shaft) will produce approximately 24,300m^3 of spoils. Spoils may be used either for road construction as aggregate base, or for river diversion works downstream of the dam and adjacent to the powerhouse tailrace. Excess rock spoils will be disposed of in the reservoir.

10.7.1.2.3 Residual Effects and Their Significance

By applying the mitigation measures recommended above and GIIP, the indirect impacts on flora during construction can be reduced to an acceptable level of low residual impacts and are, therefore, considered to be not significant.

10.7.1.3 Conclusions Regarding Impacts on Flora

10.7.1.3.1 Conclusions Regarding Direct Impacts

Construction activities will necessitate clearing approximately 115.49ha of natural vegetation, mainly forests, to create an access road and to prepare the reservoir area. Measures to mitigate impacts include conducting a pre-construction road alignment survey to delineate environmentally sensitive areas where valued or protected species are to be avoided or, where avoidance is not possible, transplanted where feasible. Changes in road alignment may be necessary based on this survey. Good international industry practice (GIIP) will be implemented by the construction contractor that is responsible for forest clearing, to minimize impacts. Some natural habitat will be disturbed beyond the road alignment and footprint of other project components, as a result of colonization by invasive species and fragmentation of habitats.

10.7.1.3.2 Conclusions Regarding Indirect Impacts

With application of appropriate mitigation, monitoring and management methods, minimal indirect impacts will accrue to flora within the project area.

10.7.2 Construction Impacts on Fauna

Impacts on fauna arising from construction activities will generally be of short-term duration. Long-term changes and impacts resulting from operation of the dam are discussed in Section 10.5.3 – Operation Impacts on Fauna).

10.7.2.1 Direct Impacts on Fauna

This section identifies potential sources of direct impacts on valued species or group of animals. These groups have been classified according to their habitat requirements. In the Solomon Islands, the lack of scientific research on many species does not enable precise assessment of how each species will react to the construction and operation of the Project. Therefore, professional judgment of biologists and ecologists based on experience from other projects on similar species has been used to predict impacts.

The following table (Table 10-3) provides an assessment of the species specific and direct impacts that could potentially accrue to fauna as a result of project construction, and includes the following analysis:

- Fauna that could potentially be affected;
- Value within the ecosystem and as a resource utilised by local communities;
- Potential impacts;
- Impact significance, based on magnitude, extent, duration and probability of impacts;
- Mitigation measures, and
- Residual impact and significance after mitigation has been applied.

Table 10-3 Assessment of potential direct impacts on fauna resulting from construction

Fauna type	Native forest rodents				
Ecosystem or resource value	The Emperor Rat is probably extinct (IUCN, 2013), while the King Rat is endangered. Both species are, therefore, highly valued.				
Potential Impact(s)	The extension of Black Post Road into the forest will follow the 160masl to 200masl topographic line, thus avoiding montane forest areas. Since both species seem to prefer forests in higher altitudes (600masl), they are unlikely to be directly affected by the Project or indirectly affected by noise or vibration. Studies in tropical Queensland Australia have shown that movement of native rodents fell by 67% to 90% across narrow forest clearing (6m to12 m), and by 90% to 100 % across larger forest clearings (20m to 60 m) Laurance (2009). However, the access road will not be located within the native home range altitude of the native rodent species. Some King Rat could be impacted at lower altitude. With most habitat in the area likely to be unsuitable this impact is considered to be of low significance and low probability.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Not in range	Short term	Unlikely	Low
Mitigation measures	None required.				
Post-mitigation residual impacts and significance	No residual impacts. Not significant.				

Fauna type	Bats & marsupials				
Ecosystem or resource value	Endemic bat species are threatened and, therefore, have a high ecosystem value. The only marsupial in the Solomon Islands (Cuscus) is widely distributed and is of moderate resource value.				
Potential Impact(s)	The marsupial known as the `Northern Common Cuscus_, as well as fruit eating bats, may be adversely affected by project construction, as they inhabit all kinds of forests, including remnant forests and gardens. Extension of Black Post Road into forested areas is the area that will be primarily affected. The Cuscus tolerates degraded forested areas (IUCN, 2013). The species feeds on fruits, leaves and seeds and dwells in Ficus trees. It forages at high canopy but also in gardens. Cuscus requires shade, moderate temperatures and humidity (Pikacha, 2008). Areas that will be totally cleared, such as the access road, will no longer provide suitable habitat for this species. Impacts include disturbance from forest clearing, leading to species displacement, exposition and vulnerability to opportunistic hunters, noise and vibration disturbance from drilling and blasting, and vehicle-wildlife interactions. Fruit-eating bats are adaptable to disturbances and degraded areas as long as artificial light is kept to a minimum. The main threat from project construction will come from blasting, carried out close to caves, and destruction of roosting trees by forest clearing. Many fruit eating bats roost in the daytime in the inland hills and forage in coconut groves along the coast (Campbell & Beecher, 1947). Project construction activities will probably temporarily disturb this daily migration pattern, and bats will probably become disoriented if their roosting areas are destroyed. In addition, forest clearing may destroy fruit trees used as sources of food.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Moderate	Localised	Short term	Likely	Moderate

Mitigation measures	Fauna-friendly underpasses at stream crossings will be installed to provide safe crossing opportunities during dam construction. Speed limits will be imposed on all construction traffic along access road. The use of artificial light during construction will be kept to a minimum, Lights to be of low intensity and orientated towards the ground to avoid disrupting bats in flight. Specific drill and blast methods identified in the ESMP to be used to minimise blasting noise and vibration. Measures to mitigate for habitat loss, such as the creation of shelters or nest boxes, would lead to opportunistic hunting from local villages.
Post-mitigation residual impacts and significance	Low impacts will persist in project affected area and are considered of low significance due to wide spread availability of suitable habitats throughout Guadalcanal.

<table>
<tr><td>Fauna type</td><td colspan="5">Forest-dependent birds (e.g., pigeons, doves and ground birds)</td></tr>
<tr><td>Ecosystem or resource value</td><td colspan="5">Many of the forest-dependent birds are endemic to Guadalcanal and are not found anywhere else in the world. Some are threatened. Therefore, they have a high ecosystem value.</td></tr>
<tr><td>Potential Impact(s)</td><td colspan="5">Extension of Black Post Road into the forested area is the main location of impacts. According to a study on the edge effect in Malaysia (Hossein, et al, 2009), abundance of many bird species decreases at forest edges. Forest clearing for the access road and truck traffic during construction activities will adversely affect forest-dependent birds in forested areas because the forest canopy will be completely or partially uncovered. Forest-dependent birds find shelter in the dense cover of the forest and in tree cavities. The access road will only fragment a small patch of forest, the extent of fragmentation is, therefore, somewhat localised. The intensity of the impact is moderate since there will only be a limited number of truck trips per day (e.g., roughly 40). Trucks will generate noise and vibration, which further startles birds. Impact duration, although temporary, may lead to permanent changes in bird composition in the vicinity of the new access road, where it passes through forested areas.
Forest dependent birds will also be impacted by noise and vibration from machinery works and blasting. Other impacts will include loss of habitat through clearance of construction work area. Impact duration will be temporary.</td></tr>
<tr><td rowspan="2">Impact significance rating</td><td>Magnitude</td><td>Extent</td><td>Duration</td><td>Probability</td><td>Overall Rating</td></tr>
<tr><td>Moderate</td><td>Localised</td><td>Short term</td><td>Highly likely</td><td>Moderate</td></tr>
<tr><td>Mitigation measures</td><td colspan="5">Forest canopy shall be `sealed_ where possible by minimising large tree clearing and maintaining canopy connectivity to reduce edge effect. Botanist to identify large canopy trees for retention.
Construction work area to be rehabilited as part of no net loss of biodiversity measures.
Specific drill and blast methods identified in the ESMP to be used to minimise blasting noise and vibration.
Additional measures, such as the creation of shelters or nest boxes would lead to opportunistic hunting from local villages.</td></tr>
<tr><td>Post-mitigation residual impacts and significance</td><td colspan="5">Low impacts will persist and are considered to be of low significance due to temporary and localised nature of impacts and wide spread availability of alternative habitat</td></tr>
</table>

Fauna type	River dependent birds

Ecosystem or resource value	Most of the river-dependent birds are widespread and none are endemic to Solomon Islands.				
Potential Impact(s)	All construction activities along the river that are associated with the project, including dam and powerhouse construction will have an adverse effect on river dependent birds, as noise and vibration from machinery and shock waves from blasting will startle them. During construction of the dam and mining of quarries, the water of the Tina River will become turbid. This will reduce visibility which, in turn, will make it difficult for fish-eating birds, such as kingfishers, to locate their prey. During construction, the affected areas will likely not be utilized by birds. Impact duration, although moderately long, will be temporary. Impact magnitude will be low, since construction is not likely to cause any bird casualties.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localized	Short term	Likely	Low
Mitigation measures	Mitigation will not appreciably reduce impacts on river dependent birds. However, to mitigate encroachment on riparian habitats, work areas will be clearly delineated prior to commencement of work. Specific drill and blast methods identified in the ESMP to be used to minimise blasting noise and vibration.				
Post-mitigation residual impacts and significance	Low impacts will persist, but are considered to be not significant.				

Fauna type	Grassland & widely distributed birds				
Ecosystem or resource value	As most of these species of birds are widely distributed they have moderate ecosystem value.				
Potential Impact(s)	Grassland and widely distributed birds, such as forest edge birds, roost along the forest edge and forage in grassland and forest clearings. Birds that inhabit areas of grassland along the portion of Black Post Road that will be enlarged and improved and where the transmission line will be installed, will be adversely affected. Over the long-term, forest located openings along the access road will most likely favour some bird species that are accustomed to open spaces. However, it is expected that during construction the areas adjacent to the access road will not likely be utilized by most bird species, due to noise and vibration impacts. The traffic along the existing access road will affect grassland birds that use this area, as the access road will be see traffic from heavy haul trucks, light duty trucks and other vehicles, that will generate noise and vibration. The intensity of the impact is low since grassland species can easily find other suitable habitat in the vicinity of the access road during construction. Impacts will be moderate but the duration is temporary.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Short term	Likely	Low
Mitigation measures	To mitigate impacts on grassland dependent birds, it is recommended that as many trees and shrubs be left standing as possible along the existing Black Post Road, as they offer good roosting sites for birds.				
Post-mitigation residual impacts and significance	Low impacts will persist, but are considered to be not significant.				

Fauna type	Amphibians

Ecosystem or resource value	A number of amphibian species are deemed ecologically important due to their endemicity, or threatened status and, therefore, have high ecosystem value. They are further threatened by the introduced cane toad.				
Potential Impact(s)	Access road construction will be the most affected site. Amphibians will be adversely affected by project construction in a variety of ways, including: being confined to small territories or home ranges; their restricted mobility and speed limits their ability to escape from construction activities, making them vulnerable to physical damage and pollution; they are highly sensitive to changes in humidity and vulnerable to the edge effect, and some, like tree frogs, are highly dependent of dense forest cover; increased predation by feral cats and dogs might reduce their numbers; and improved access may facilitate further encroachment into the area by cane toads. Habitat in the vicinity of the access road is largely modified habitat and is marginal habitat for high value amphibian species. The density of high value amphibian species is relatively low due to the presence of invasive cane toad populations. Blasting and construction noise and vibration would result in temporary adverse impacts to amphibians. High value amphibians identified in the baseline surveys inhabited upper forest habitats and riparian habitats unaffected by the majority of construction activities.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Short term	Likely	Low
Mitigation measures	It is not possible to limit the incursion of new amphibian species along the extension of Black Post Road, including the cane toad, which is already present in the area. To mitigate habitat fragmentation consideration was given to installing frog-friendly crossing culverts beneath the access road to facilitate crossing the road without being hit by moving vehicles. However, since the volume of traffic is expected to be light during operation, and local species of frogs are not known to migrate end mass between hibernation and breeding wetlands in the Solomon Islands, access road traffic will not represent a serious threat to frogs. Rather it is recommended fauna-friendly underpasses be installed at stream crossings (see Figure 10-1), as these would also be beneficial to amphibians. Specific drill and blast methods identified in the ESMP to be used to minimise blasting noise and vibration.				
Post-mitigation residual impacts and significance	Low impacts will persist				

Fauna type	Reptiles
Ecosystem or resource value	A number of reptile species are deemed ecologically important due to their endemicity, or threatened status and, therefore, have high ecosystem value. They are further threatened by the introduced cane toad.
Potential Impact(s)	The access road will be the most affected site during construction. Some reptiles will probably be favoured by the Project in the long-term, since partial opening of the canopy will create more favourable conditions (i.e., sunny and drier environment) for them. This positive impact is further discussed under operation impacts. In the short term, during forest clearing for access road construction, reptiles will be adversely affected in the same manner as amphibians. Reptile mortality will occur because of their limited mobility and small home ranges. Many reptiles found in the study area rely on trees. Therefore, forest clearing will probably lead to diminished productivity. In addition, snakes may suffer from persecution by construction workers.

	Reptiles will also be impacted by noise and vibration from machinery works and shock waves from blasting. Other impacts will include loss of habitat through clearance of construction work area. Impact duration will be temporary.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Short term	Moderate	Low
Mitigation measures	It is recommend fauna underpasses be installed at stream crossings (see Figure 10-1). Some species of reptile will probably be favoured once the access road is finished since they thrive in sunnier and dryer environments. In addition, during construction, workers will be prohibited from harming any wildlife. They will receive wildlife awareness training informs them of the requirement to request the project˘s environmental specialist capture and remove animals that are either in danger or are dangerous to construction workers. Construction work area to be rehabilited as part of no net loss of biodiversity measures. Specific drill and blast methods identified in the ESMP to be used to minimise blasting noise and vibration.				
Post-mitigation residual impacts and significance	Low impacts will persist, but are considered to be not significant.				

Fauna type	Wetland dependent insects				
Ecosystem or resource value	A number of wetland dependent insect species are deemed ecologically important due to their endemicity, or threatened habitat status and, therefore, have high ecosystem value. They are further threatened by activities such as timber harvesting that threaten wetland habitats, and by the introduced little fire ant.				
Potential Impact(s)	The site of powerhouse construction is the most affected site. Many micro-wetlands are created by flash floods along the Tina River, especially where low relief topography occurs adjacent to the Tina River. Around the dam site, the topography is very steep and, therefore, does not support micro-wetlands. At the powerhouse site, some micro-wetlands will be destroyed leading to localized loss of wetland dependent insects, such as dragonflies and damselflies.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Short term	Moderate	Low
Mitigation measures	Specific measures for mitigating the production of wetland dependent insects are limited. Best Environmental Management Practices will be implemented.				
Post-mitigation residual impacts and significance	Low impacts will persist, but are considered to be not significant.				

10.7.2.2 Indirect Impacts on Fauna

10.7.2.2.1 Identification of Indirect Impacts

This section identifies potential sources of indirect impacts on fauna.

<u>Habitat Fragmentation and Barrier Effects</u>

As previously stated, access roads will have adverse impacts on flora. The following discusses how fragmentation may affect wildlife. According to Laurance (2009), wildlife habitat fragmentation is particularly acute in tropical rainforests, including rainforests of the South Pacific, due to road development because:

- Many tropical species are adapted to moist, dark and stable microclimates provided by forest understories;
- tropical forests sustain species with microhabitats which are sensitive to slight changes of light and humidity;
- Sediments eroded from access roads and small stream blockages at road crossing points can alter habitats;
- Waterborne pollutants, such as oil spills on roads, can easily be flushed into water courses and, in turn, may affect amphibians living in adjacent wetlands,
- In developing countries, access roads have been known to induce increase hunting pressure, settlements and population growth.

Two types of habitat fragmentation can take place:

- Fragmentation caused by roads that bi-sect wildlife habitats and cause populations to become isolated or separated. This can result from vehicle-wildlife interactions (i.e., road kills), and from species that are easily startled and, therefore, hesitate to cross roads; and
- Fragmentation that results from improved access to predators, such as birds of prey and snakes, which are provided with improved foraging along newly exposed forest edges for species such as amphibians, native rats and Cuscus.

The potential impacts of habitat fragmentation on wildlife may be:

- Decreased species adaptation to change due to genetic isolation causing population decline;
- Reduction in home range surfaces and an abandonment of the habitat by species when habitat surface thresholds are crossed;
- Change in microclimate and increase predation, leading to an abandonment of the habitat by species;
- Increased encroachment of opportunistic wildlife species.

Ultimately, habitat fragmentation leads to reduction in wildlife diversity.

In addition to contributing directly to habitat fragmentation, linear clearings such as access roads, and transmission line rights-of-way can create a barrier to wildlife movement. Many species adopt an avoidance behaviour when confronted with linear clearings (Laurance, 2009). As noted above, this behaviour can ultimately contribute to wildlife habitat fragmentation.

Most species that adopt an avoidance behaviour are those that are usually not affected by road kills. The barrier effect has been reported even in cases of narrow clearings. Species at risk are those that:

- Are strictly arboreal;
- Are adapted to fly short distances in dense forested environments;
- Are easily startled and dazzled by light, traffic noise, pollution and dust and human presence. For example, bats are disturbed by artificial lighting, especially when installed along river corridors, and forest edges;
- Align their territories with forest clearing boundaries (Laurance, 2009).
- Whose means of communication will be interfered by traffic noise (Goosem, 2007)

- Are physically unable to cross when roads include deep drainage channels, gabion baskets or when roads are built with a cut-and-fill approaches. In this case, road construction represents an impassable obstacle that leads to permanent habitat fragmentation and permanent genetic isolation of small patches of population. This issue is particularly significant in the case of the access road extension to the dam, because many cuts and embankment fills are foreseen.

Species that are of greatest concern are insects, rainforest amphibians, reptiles (such as skinks), forest-interior birds, bats and other small mammals.

Vehicle-Wildlife Interactions

Any access road represents a risk of vehicle-wildlife interactions leading to wildlife mortality (i.e., road kills). Laurance (2009) identifies species at risk as being those that:

- Require wide habitat ranges;
- Are less mobile, slow or freeze when faced with danger, such as ground dwelling species (mainly amphibians but also some reptiles, ground and understory birds and small mammals) (Goosem, 2007). The highest casualties occur when these species find good hunting or breeding ground near roads and when the activities of the crepuscular species coincide with traffic peaks;
- Are predominantly arboreal and are less agile when required to move on the ground;
- Birds and bats with low flight paths; and
- Species with poor eyesight.

Feral and Invasive Species

The access roads will have an indirect effect on native wildlife by providing improved access for feral and invasive species into new areas, and the associated predation on native species. Islands around the world are particularly vulnerable to invasive species. In the case of the Solomon Islands, dogs and feral cats are known to represent a threat to native rats and the Cuscus.

Fire Ants

In Guadalcanal, logging roads have opened the way for invasive insects such as the little fire ant (Wasmannia auropunctata), which is native to South and Central America. This species was introduced in the Solomon Islands as a biological control for a nut fall bug (IUCN, 2012). This species, because of its plundering behaviour, reduces insect diversity. The access road will lead to the colonization of fire ants of new undisturbed areas. Proliferation of the little fire ant in rainforests occurs approximately 60 times faster with the presence of roads, than in undisturbed forests (Polhemus et al., 2008).

Feral Animals

Cats, non-native rats (Polynesian Rat and House Rat) and dogs are known to move along roads (Goosem, 2007). In the Solomon Islands, they threaten the survival of many native small mammals and ground birds such as pigeons. Feral cats are the most dangerous introduced predator of native species in the Solomons Islands, and are a threat to native rats and the Cuscus (Pikacha, 2008). Goldridge fauna surveys revealed the presence of introduced rats in disturbed and degraded areas. The TRHDP construction phase may create new ecological niches for, or facilitate the spread of, non-native rat species, which might compete with - or spread disease to - native rats (if these are still extant).

Cane Toad

The cane toad (Bufo marinus), which is native to Central and South America, is an introduced species that is found throughout the Solomon Islands. In the Project area, the cane toad was found as far as the upper catchment area along the Vohara River. According to Pikacha (2008) and IUCN (2013), cane toads are a threat to snakes and native frogs that eat the tadpoles and die from the toxic poisons present in the Cane toad glands. Cane toads are more successful in open areas such as roadsides (Urban et al., 2007). In tropical Australia, a recent study has shown that cane toads colonize new habitat moving along roads and cleared fence lines, avoiding heavily vegetated habitat (Brown et al., 2006). Forest clearing for the access road will, therefore, facilitate the continuing encroachment of cane toads into the project area. Evidence of cane toad presence was observed (juvenile toad and tadpoles) on 12 May 2016 in the reach of the Tina River just upstream of the powerhouse site (see Figure 10-1).

Figure 10-1 Photo of juvenile Cane Toad caught just upstream of proposed powerhouse site

Source: Scott Hanna photo (2016)

Giant African Snail

The Giant African Snail was introduced into the Solomon Islands, probably as eggs and juvenile snails within soil that was adhered to imported logging equipment. The snail competes with native species and damages food crops. During the mitigation workshops, it was mentioned that this species has already reached Veraande village (along Black Post Road).

<u>Noise, Vibration and Light</u>

In addition to the fragmentation of habitat, noise, light and vibration can have adverse impacts on wildlife. However, dust will not be a significant problem thanks to the rainy climate in Guadalcanal. During the TRHDP construction phase, noise and vibration from blasting and drilling (during the tunnel construction or the quarry exploitation) and from vehicle traffic will startle many wildlife species. In addition, artificial light may disorient bats. In tropical regions, artificial light alters the foraging behaviour of fruit-eating bats (Lewanzik and Voigt, 2014).

10.7.2.2.2 Mitigation Measures

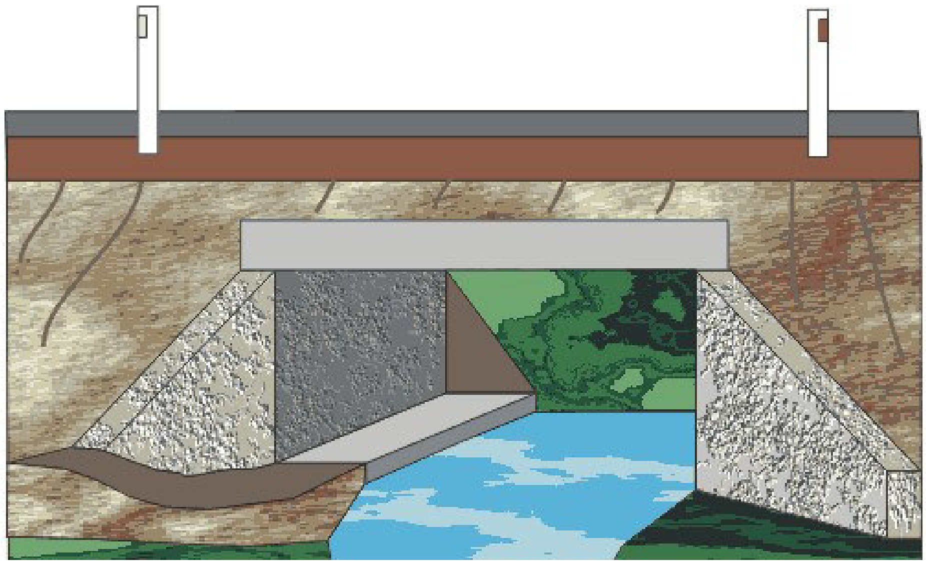
<u>Habitat Fragmentation and Barrier Effects, and Vehicle Wildlife Interactions</u>

To mitigate habitat fragmentation and barrier effects, and vehicle-wildlife interactions, the following measures will be implemented:

- Best Environmental Management Practices will be implemented by the Construction Contractor during the TRHDP construction phase;
- Faunal underpass - culverts (or bridges) across small stream will allow terrestrial species to underpass the access road. These culverts will be large enough to allow the water flow and to ensure permanent dry passage using ledges (see Figure 10-2). The dry passage will provide suitable cover such as rock piles, logs, and brush. For example, ledges will be large enough to allow Cuscus to cross (with a width of 1m).

However, these corridors can also pose a risk to prey species if predators learn that these underpasses are a source of prey. Notwithstanding, compared to the numbers of fauna that could be killed crossing the access road, the use of wildlife underpasses will likely more than make up for the number of road kills.

Figure 10-2 Faunal underpass in open bottom culvert



Source: Main roads, Western Australia, 2014

- The forest canopy will be kept intact wherever possible to maintain ground level shade and humidity levels, and to minimise creating an edge effect; and
- Vehicle speed limits will be controlled along the access roads, to ensure that drivers are able to prevent running over wildlife that may be lying on, or crossing, the access road.

Feral and Invasive Species

Only intensive long term trapping or control could attempt to stop further encroachment of feral and invasive species such as fire ants, cats, dogs, and cane toads that are already known to have entered the project area. However, to mitigate the spread of the Giant African Snail, the following actions will be implemented:

- An equipment cleaning station, employing pressurized steam, will be installed at Veraande. This location was chosen because the Giant African Snail is already located there. All wheels, tracks, excavation blades and buckets, as well as other pieces of machinery that could have come into contact with soil, will be cleaned prior to entering the project site. This measure will provide an opportunity to create small jobs for local communities; and
- Soil will never be imported into the project area.

Noise, Vibration and Light

To minimise impacts of noise, vibration and light, the following measures will be employed:

- Specific drill and blast methods will be used to reduce noise and vibration. Hydraulic rock drill equipment will be used instead of pneumatic equipment because it produces less noise. Moreover, blasting and drilling equipment will be equipped with silenced masts, which can reduce noise levels by up to 10dBA. Blasting charges will be covered with blasting mats and screens to reduce generation of noise, fly rock and dust; and

- The number of artificial lights will be kept to a minimum, while still maintaining a safe working environment. Light intensity will also be limited, where possible, and the lights will be oriented toward the ground to avoid disorienting bats in flight.

10.7.2.2.3 Residual Effects and Their Significance

By applying the mitigation measures recommended above and GIIP, the indirect impacts on fauna can be reduced to an acceptable level of low to moderate residual impacts and are, therefore, considered to be not significant.

10.7.2.3 Conclusions Regarding Construction Impacts on Fauna

Table 10-4 summarises impact significance on fauna during construction. Forest clearing is the main impacting activities. It will disturb fauna and fragment their habitats. Forest clearing will potentially lead to diminished numbers of less mobile species, such as amphibians and reptiles, but given the short duration, localised nature of the impacts, they are considered overall to be not significant.

Table 10-4 Summary of construction impact ratings on fauna

Group of animals	Pre-mitigation Impact Rating	Opportunity for Mitigation	Residual Effect
Native Rainforest Rodents	Low	No	Not significant
Bats and marsupial	Low – Moderate	Yes	Low Significance
Forest-dependent birds	Moderate	Yes	Low Significance
River-dependent birds	Low	No	Not significant
Grassland and widely distributed birds	Low (positive)	Not required	Not significant
Amphibians	Low	Yes	Low Significance
Reptiles	Neutral	Yes	Not significant
Wetland dependent insects	Low	No	Not significant

10.8 ASSESSMENT OF OPERATION IMPACTS

10.8.1 Operation Impacts on Flora

10.8.1.1 Direct Impacts on Flora

10.8.1.1.1 Identification of Direct Impacts

Project operation will necessitate vegetation control under the transmission line. Herbicides such as glyphosate will not be used for vegetation clearance, due to the potential toxic effects on amphibians and reptiles, as well as on fish and water quality. Instead, manual vegetation control methods will be employed for the Project to maintain the right-of-way.

10.8.1.1.2 Mitigation Measures

Other than vegetation control, there will not be any additional work involving forest clearing during operation. The transmission line will mainly pass through grasslands, and will most likely only require minor vegetation control. This will be accomplished using manual or equipment vegetation control techniques. No herbicides will be used to manage vegetation growth along the transmission right-of-way.

10.8.1.1.3 Residual Effects and Their Significance

During project operation, direct impacts to flora are considered to be not significant, as most of the impacts will have already occurred as a result of project construction.

10.8.1.2 Indirect Impacts on Flora

This section identifies and rates portential indirect impacts on flora that will result from project operation. Most indirect impacts are related to the presence of the access road through the forest, which will could act as an agent of change in the area, leading to a gradual degrading of surrounding ecosystems.

10.8.1.2.1 Identification of Indirect Impacts

<u>Ongoing Encroachment by Invasive Species</u>

Once the dam and the hydropower plant is in operation, improved access will facilitate increased presence of people in the area around the dam, which could in turn, lead to colonization of invasive, vine and pioneer species leading to local displacement or disturbance of native plant species. The primary concern is the accidental or purposeful introduction of invasive plant species. As noted previously, Water Hyacinth colonization does not represent a significant risk for the Project, if accidentally or intentionally introduced, given the daily fluctuations in reservoir water levels and the expected low concentration of nutrients.

Opening of forested areas along access roads will create on-going opportunities for invasive species to settle.

Changes in Vegetation Induced by Changes in River Hydrology

Impacts can arise from changes in the Tina River hydrology downstream of the dam. Changes could have an effect on riparian habitats and small wetlands located along the river between the dam and powerhouse. The dam will provide flood attenuation but does not provide flood control. A major effect of flood attenuation will be a reduction in flow variation. This reduced variation will lead to a reduction in littoral wetland habitats that will be most pronounced in the low flow region (there will be diurnal variation/generation related variation below the powerhouse). There will also be additional littoral wetland habitats created by variable exposure water levels in the reservoir.

Changes in the Accessibility to Forest Products

Wood and non-wood products will be under increased human pressure if the new access road facilitates access into areas presently covered by undisturbed forest (primary forest) or regenerating forest (disturbed forests) this is particularly true for the Core Area.

Improved access to the dam and reservoir area provided by the access road could lead to development of settlements in upstream areas by landowners who wish to take advantage of better access available forest resources such as fruits, nuts, medicinal plants, wild game, timber for construction, fuel wood, aggregates at the upstream end of the reservoir, and other resources. Therefore, the extent of road related impacts on habitats is not limited to the width of the access road but to newly accessible forested areas.

Improved access afforded by the new access road could also lead to increase logging activities in upstream areas. This impact has been well documented in the Gold Ridge area (Ross Mining, 1994).

Land Use Dynamics on Natural Habitats

Over the long term, the access road will allow people to modify land use since it will promote rapid deforestation and transformation to gardens. Vegetation composition will gradually change in proximity to the access road. In addition, the 4.288km^2 Core Area will probably be under increasing development pressure. The extent of modification is impossible to predict. However, development of gardens and increased use of timber for house construction will inevitably modify the forest and create openings in the canopy leading to modification of ecosystems.

10.8.1.2.2 Mitigation Measures

Ongoing Encroachment by Invasive Species

To mitigate impacts of ongoing encroachment by invasive plant species, the following actions will be implemented:

- Monitoring of Water Hyacinth will be undertaken to assess its presence in the reservoir and to ensure quick response in case it becomes established. This monitoring will be done twice each year and will include surveys of the entire reservoir. In the event that Water Hyacinth does become established in the reservoir, immediate removal of the plant and its roots will be carried out to limit the ability for it to propagate further.
- Site restoration using native plant species will be undertaken in affected areas, including the Core Area (see Section 13 – ESMP). As discussed in Section 13, native vegetation species are expected to become quickly established if planted in good quality soils.

Changes in River Vegetation Induced by Changes in River Hydrology

To mitigate impacts, an environmental flow (EF) must be implemented downstream of the dam. Details on the determination of the EF are presented in Section 11 ¯ Assessment of Impacts on the Biological (Aquatic). This environmental flow is, however, not sufficient to mitigate impacts and long term changes in vegetation along the river banks.

Changes in the Accessibility to Forest Products, and Land Use Dynamics on Natural Habitats

To mitigate the impacts of changes in the accessibility to forest products and increased development pressure on natural habitats, the following action will be implemented:

Management of access - during mitigation workshops, local communities requested that access to the Core Area by non-local settlers be prohibited, and that the extension of Black Post Road be declared a private access only. Control of access would be done by the Tina TCLC, which will own the Core Land, including the access road from Marava Village to the dam site. The access road to the dam will be gated to prevent access to logging companies. Access would only be granted to the local population and hydropower facility operator. The TCLC will not permit anyone to live or construct housing within the land leased for the project, except where strictly necessary for project activities, including housing fort rangers or security staff. A settlement policy will be developed and implemented with the assistance of the TCLC and incorporated into the Biodiversity Management Plan. The settlement policy will include enforcement measures to prevent the use of the land for a workers camp. It will also address restrictions on the use of the private project road through the Core Area by people seeking to build new settlements beyond the Core Area.

10.8.1.2.3 Residual Effects and Their Significance

By applying the mitigation measures recommended above and GIIP, the indirect impacts on flora during operation can be reduced to an acceptable level of low residual impacts and are, therefore, considered to be not significant.

10.8.1.3 Conclusions Regarding Impacts of Operation on Flora

Impacts on flora during project operation are mostly indirect, and will accrue due the presence of the access road that will allow communities to access better forest resources in upstream areas, and move deeper into the forest in areas bordering the road. The access road will be an agent of change in the area. Land use along the access road could also change with the arrival of new settlers.

10.8.2 Operation Impacts on Fauna

10.8.2.1 Direct Impacts on Fauna

The following section discusses direct species-specific impacts on wildlife, proposed mitigation measures, and examines residual impacts and significance following the application of mitigation measures. This section studies the same group of species as presented in the construction section to analyse whether the situation for these species will worsen, improve or stabilize with the Project operation. Impacts accruing from operation are permanent, as the Project will permanently modify some ecological function and habitats.

The following table (Table 10-5) provides an assessment of the species specific and direct impacts that could potentially accrue to fauna as a result of project construction, and includes the following analysis:

- Fauna that could potentially be affected;
- Value within the ecosystem and as a resource utilised by local communities;
- Potential impacts;
- Impact significance, based on magnitude, extent, duration and probability of impacts;
- Mitigation measures, and
- Residual impact and significance after mitigation has been applied.

Table 10-5 Assessment of potential impacts to fauna resulting from operation

Fauna type	Native forest rodents				
Ecosystem or resource value	The Emperor Rat is probably extinct (IUCN, 2013), while the King Rat is endangered. Both species are, therefore, highly valued.				
Potential Impact(s)	No direct impact due to operation. Indirect impact due to presence of an access road, relatively close to montane forest could increase human and invasive species (e.g. cats, rats) presence in previously pristine montane forest, leading to potential impacts on native rodents.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Moderate	Localised	Long term	Likely	Low
Mitigation measures	Access to private road through Core Land to be limited. No human habitation of Core Land to be permitted.				
Post-mitigation residual impacts and significance	Low				

Fauna type	Bats & marsupials (i.e., Cuscus)				
Ecosystem or resource value	Endemic bat species are threatened and, therefore, have a high ecosystem value. The only marsupial in the Solomon Islands (Cuscus) is widely distributed and is of moderate resource value.				
Potential Impact(s)	Forest areas adjacent to the access road will be the main areas affected. Progressively, this impact will extend into the forest interior away from the road. Project operation and ongoing use of the access road will create on-going impacts on mammals as hunting activities and the presence of new settlers create additional pressures on wildlife. In addition, if the transmission line is constructed using wooden power poles, there is a risk that cuscus may climb the poles and be electrocuted, causing power outages as circuits are tripped.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Long Term	Highly likely	Low - Moderate
Mitigation measures	Metal shields will be installed on wooden power poles in forested areas to prevent Cuscus from climbing poles and becoming electrocuted.				
Post-mitigation residual impacts and significance	Not Significant				

Fauna type	Forest dependent birds (e.g., pigeons and ground birds)				
Ecosystem or resource value	Many of the forest-dependent birds are endemic to Guadalcanal and are not found anywhere else in the world. Some are threatened. Therefore, they have a high ecosystem value.				
Potential Impact(s)	Majority of operational impacts will affect modified forest habitats with limited suitability for forest dependent birds especially ground birds. There is current evidence of wide spread presence of feral animals particularly cats throughout the area. According to Laurance (2004), edge effect can lead to reduction in forest-dependent bird species extending up to 70m away from road margins in Amazonia. Predation by feral animals could continue. As for construction, forest near the access road will be the main impacted site. Progressively, this impact will reach forest interior away from the road. Dependent on design, the transmission line may present collision or electrocution risks to larger-bodied species, such as birds of prey, parrots and hornbills.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Moderate	Localised	Long term	Highly likely	Moderate
Mitigation measures	Natural habitats within the Project Area to be protected and 9.5 Ha of modified habitat will be rehabilitated to forest habitat. These measures are to be set out in the developer's Biodiversity Action Plan. Forest canopy shall be 'sealed' where possible by minimising large tree clearing and maintaining canopy connectivity to reduce edge effect. Botanist to identify large canopy trees for retention. Transmision line design and mitigation will follow well-established global best practice (e.g., from the Avian Power Line Interaction Committe and BirdLife International) to minimise the risk of both collisions and electrocutions. Other mitigation measures not feasible as the access road will create a clearing in the canopy and associated edge effect.				
Post-mitigation residual impacts and significance	Low impact, not significant				

Fauna type	River dependent birds				
Ecosystem or resource value	Most of the river-dependent birds are widespread and none are endemic to Solomon Islands.				
Potential Impact(s)	River dependent birds will be affected by the low flow conditions created by operation in the reach between the dam and the powerhouse, where water levels will be reduced. Floods, which are known to create and feed small riparian wetlands, will be attenuated by the dam. There will be some reduction in wetland habitats in the reduced flow section; less or no reduction in wetland habitrats downstream of the powerhouse, and some increase in habitats on the margins of the lake. Environmental flow conditions are expected to increase fish density from baseline medium flow conditions. . Impacts may be felt in the upper catchment, should fish numbers decline if fish passage provisions are not effective. Lower flows in the affected reach could also expose fish making them easier prey for some fish-eating species of birds.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Long term	Likely	Low
Mitigation measures	Key mitigation measures will be maintenance of environmental flow and trap and haul fish passage.				

Post-mitigation residual impacts and significance	Not significant				

Fauna type	Grassland and widely distributed birds				
Ecosystem or resource value	As most of these species of birds are widely distributed they have moderate ecosystem value.				
Potential Impact(s)	Bird species that utilize forest edge and grassland habitats, and bird species that are otherwise widely distributed across many different types of habitats, might benefit by the extension of Black Post Road, which will create additional habitats for these species.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low (positive)	Localised	Long term	Likely	Low (positive)
Mitigation measures	No mitigation measures required.				
Post-mitigation residual impacts and significance	Not significant				

Fauna type	Amphibians				
Ecosystem or resource value	A number of amphibian species are deemed ecologically important due to their endemicity, or threatened status and, therefore, have high ecosystem value. They are further threatened by the introduced cane toad.				
Potential Impact(s)	The river reach between the dam and the powerhouse is the main affected riparian habitat. A reduction in wetlands in this area may reduce habitat for the San Cristobal Treefrog (the only Solomon Islands˘frog with a tadpole stage) while the creation of a dam may improve habitat in the reservoir area. Habitat of other high value amphibians is above the project affected area in the upper catchment. Cane toads and feral animals will continue to exert pressure on native species of amphibians where disturbed areas (e.g., access road, and along the low flow river reach).				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Periodic	Highly likely	Low
Mitigation measures	The steady 1 m^3/s environmental flow will not be sufficient to recharge riparian wetlands. Floods, which are known to create and feed small riparian wetlands, will be attenuated by the dam. There will be some reduction in wetland habitats in the reduced flow section; less or no reduction in wetland habitats downstream of the powerhouse, and some increase in habitats on the margins of the lake.				
Post-mitigation residual impacts and significance	Low significance				

Fauna type	Reptiles				
Ecosystem or resource value	A number of reptile species are deemed ecologically important due to their endemicity, or threatened status and, therefore, have high ecosystem value. They are further threatened by the introduced Cane Toad.				
Potential Impact(s)	The extended access road will modify habitat quality for reptiles. Some reptiles will be positively affected by the new access road, as this road will create additional open habitat along the forest edge and will bring more solar radiation to the ground. Which species will benefit is difficult to				

	assess. However, snakes will likely benefit the most by forest openings. However, all reptiles could also be affected by the ongoing arrival of feral animals and by potential vehicle-wildlife interactions where reptiles try to cross the road or lay on the road to absorb residual heat given off by the surface of the road during the cooler parts of the day.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Neutral	Localised	Long term	Highly likely	Neutral
Mitigation measures	No specific mitigation measures can be implemented for reptiles.				
Post-mitigation residual impacts and significance	Not significant				

Fauna type	Wetland dependent insects				
Ecosystem or resource value	A number of wetland dependent insect species are deemed ecologically important due to their endemicity, or threatened habitat status and, therefore, have high ecosystem value. They are further threatened by activities such as timber harvesting that threaten wetland habitats, and by the introduced little fire ant.				
Potential Impact(s)	Micro-wetlands along the by-passed reach are the most affected sites. ‛Wetting_ of these sites by floodwaters will be reduced due to the flood attenuation effects of the dam, however the reservoir will not have flood control storage and impacts will be short lived. Simulation of the hydro operation indicated that floods or freshets would occur on average every 6 weeks, and their average duration would be between 4 to 6 days. Additional aquatic terrestrial contact zones (ATCZ) along the shores of the reservoir are expected to provide additional habitat for wetland dependent insect species. There is therefore expected to be a minimal reduction in the number of wetland dependent insects.				
Impact significance rating	Magnitude	Extent	Duration	Probability	Overall Rating
	Low	Localised	Periodic	Likely	Low
Mitigation measures	No specific mitigation measures can be implemented.				
Post-mitigation residual impacts and significance	Low significance				

10.8.2.2 Indirect Impacts on Fauna

10.8.2.2.1 Identification of Indirect Impacts

Some of the indirect impacts on wildlife that will occur during construction activities will continue during operation of the Project,as the access road could facilitate increased access through the Core Area. Measures to restrict vehicle access to the new section of Black Post Road above Mengakiki will be instrumental in minimising this impact. No residences, settlements or workers˘camps are to be permitted in the Core Area other than limited accommodation necessary for the Project (eg. security guards or on-call engineers).Terrestrial ecology will adapt over the long term, and ecological functions of the affected area will be redefined. Some species types will probably be favoured by road presence, but most will be disadvantaged. During operation, the access road will be a low-volume road used only for Project activities, including implementation of environmental mitigation measures, with impacts being related less to vehicle-wildlife interactions, and more to ecological modifications brought about by opening of the canopy. .

Changes in Accessibility to Bush Meat

Several studies have shown that newly created access roads in forests bring negative indirect impacts on forest products (wood and non-wood products) and wildlife, when access roads are not controlled. These impacts are generated because access roads greatly facilitate human encroachment into areas that would normally be difficult to access, thereby leading to development of new economic activities along roads (Young, 1994). Even when access is controlled by the local population, indirect impacts are still significant. Suarez et al. (2012) has demonstrated that, in Brazil, despite access along new roads being controlled by Indigenous communities, wildlife depletion accelerates due to increased hunting pressure and the establishment of new settlements along the road. Similar studies have not been carried out in the South Pacific region. However, settlements along the access road, and associated impacts on bush meat, are likely to occur over the long term.

Access provided to the local population along the road is a key issue that was discussed with local populations during mitigation workshops. Local communities indicated that the new extension of Black Post Road past Mangakiki should be controlled by local communities. However, it will not be accepted by local communities that this road be strictly prohibited to new settlements. It is also possible that some local chiefs will take advantage of the access road to sell access to logging companies to newly accessible areas. Therefore, impacts as described above are expected.

It has been decided that the TCLC will own the Core Area, including the access road from approximately Marava to the dam site. TCLC, which is a joint venture between customary landowners and government, will be subject to the terms of the lease agreement between the TCLC and the TRHDP, and will control who can access the land. Management of access as a means of mitigating impacts is presented in Section 13.2.1.4.

On-Going Habitat Fragmentation

Once the dam is in operation, the access road will be used less by heavy haul trucks. However, its presence will continue to contribute to permanent habitat fragmentation, increased human presence along the road, local population uses of forest products, land transformation into gardens, and other activities. This is particularly true in the Core Area and around the reservoir. Wildlife that is affected by the access road and the Core Area will not fully recolonize their initial habitat once the Project is in operation. Moreover, human encroachment will spread to a certain extent out into forest areas.

On-Going Feral and Invasive Species Encroachment

The permanent access road will allow for feral and invasive species to continue encroaching into new areas. Most feral animals follow human settlements. With new settlers, impacts occurring during construction will continue during operation of the Project. However, regardless of whether the Project was to proceed, or not, the feral and invasive species that currently threaten the region will continue to encroach into new areas, given enough time.

10.8.2.2.2 Mitigation Measures

The new access road will locally modify the environment and change ecological dynamics. To minimize human presence in previously undisturbed areas, it is suggested that workshops be held with local communities to raise awareness about the need for protecting the ecosystem and for applying practices aimed at the sustainable use of forest products. The TRHDP will also meet with local Chiefs to raise awareness regarding the need to sustainably use forest products, and to avoid selling access to logging companies. Raising awareness will also include discussions aimed at reducing opportunistic hunting of bats and Cuscus.

10.8.2.2.3 Residual Effects and Their Significance

During project operation, direct impacts to fauna can be mitigated by implementing measures to raise awareness of local communities and their chiefs. If these measures are put into effect, the impacts will be considered to be not significant, as most of the impacts will have already occurred as a result of project construction.

10.9 Overall Conclusions Regarding Impacts on Terrestrial Ecosystem

The operation of the hydropower facility will not directly affect terrestrial biodiversity, which will already have been adversely affected as a result of project construction. However, there may be some indirect effects, especially on wildlife species due to the improvements of access and possible river ford crossing opportunities to new habitats on either side of the river between the dam site and powerhouse, under the low flow conditions that will prevail.

Operation of the reservoir will not impact terrestrial wildlife, since there is no known diurnal or seasonal migration of terrestrial wildlife species across the area defined for the reservoir. The reservoir will occupy a steep-sided gorge that presently acts as a natural barrier to the movement of ground dwelling wildlife, but is not pose a physical impediment to avifauna, such as birds or bats, that are able to fly from one site to the other.

Some of the potential construction impacts will continue to affect terrestrial ecosystems during operation. These impacts are related to the access road and the advantages that it will bring for local communities. The access road will allow villagers and feral animals to move into the project area placing additional pressure on natural resources and wildlife. New impacts will also arise due to the presence and operation of the dam, such as shortage of water in riparian micro-wetlands along the Tina River, which will affect both amphibians and water dependent insects. Whether the access road will be beneficial to reptiles is difficult to assess. Some species such as snakes could benefit from forest openings while smaller species might be more vulnerable to feral cats and mortality from vehicle-wildlife interactions. Grassland birds will be able to colonize areas along the access road.

Mitigation measures are limited to raising awareness of with local communities, which could help to reduce pressure on natural resources along the access road.

Table 10-6 summarizes pre-mitigation impact ratings and post-mitigation residual impact significance determinations on fauna resulting from construction and operation.

Table 10-6 Summary of impacts on fauna from construction and operation of the Project

Group of animals	Construction		Operation		Species situation with Project operation
	Impact before mitigation	Residual impact	Impact before mitigation	Residual impact	
Native Rainforest Rodents	Low and improbable	Not significant	Low	Not significant	Species could be affected by human encroachment in newly accessible montane forest areas
Bats and marsupial	Low - Moderate	Low significance	Low ‑ Moderate	Not significant	Opportunistic hunters and new settlers will create additional pressures on mammals. Residual impact low with mitigation measures.
Forest-dependent birds	Moderate	Low significance	Moderate	Low significance	Ongoing impact of low impact with canopy retention measures
River dependent birds	Low	Not significant	Low	Not significant	Operation of the dam will bring forward new impacts on river dependent birds
Grassland and ubiquitous birds	Low	Not significant	Low (positive)	Not significant	New open areas created by the access road will be colonized by grassland and ubiquist birds.
Amphibians	Low	Low significance	Low	Low significance	Cane toads will continue to colonize areas along the access road. Micro-wetlands along Tina River reach may suffer from water shortage
Reptiles	Moderate	Not significant	Neutral	Not significant	Some species will take advantage of forest openings other will suffer from ongoing feral cats predation

Group of animals	Construction		Operation		Species situation with Project operation
	Impact before mitigation	Residual impact	Impact before mitigation	Residual impact	
Wetland dependent insects	Low	Low significance	Low	Low significance	Micro-wetlands along Tina River reach may suffer from water shortage. New ATCZ habitats may arise.

11. ASSESSMENT OF IMPACTS ON THE BIOLOGICAL (AQUATIC) ENVIRONMENT

11.1 BACKGROUND

This section includes an analysis of hydrology, water quality, water use, sediment dynamics, fish and aquatic biota.

Four types of impacts can be described: direct impacts, indirect impacts, general impacts and cumulative impacts.

- Direct impacts are those that will likely accrue due to the Project footprint. These impacts are habitat-specific or species-specific, and are quantifiable.
- Indirect impacts are those that will take place as a consequence of the Project but with a degree of separation both temporally and spatially. These impacts are generally non-quantifiable since their extent and intensity are hard to predict.
- General impacts are those that will take place regardless of the Project specificity (e.g., noise from traffic, habitat fragmentation, oil spills, etc.), are not site-specific, and are not quantifiable. Best management practices help to address such impacts.
- Cumulative impacts are impacts arising from the Project that may add to or aggravate existing impacts from other existing or reasonably anticipated projects in the study area. Cumulative impacts are presented in Section 14.

11.2 ASSESSMENT METHODOLOGY

Impact assessment methodology for environmental components (both aquatic and terrestrial) is presented in Annex 19 of the Annex Report. Impacts significance has been applied using a standardized method based on the integration of the following steps:

- Identification of impact sources - the first step of the impact assessment is to determine which activities will have an impact on environmental components. This identification is done using an impact matrix.
- assessment of impacts using the criteria of impact duration, extent, magnitude / intensity, and probability of occurrence;
- application of mitigation measures; and
- determination of post-mitigation residual effects and significance, the latter being determined to be either Not Significant, or Significant.

Where a residual effect is deemed to be Significant, it falls to decision makers within government to determine whether the need for the project outweighs the concerns for potential, non-mitigable, significant impacts.

11.3 ACTIVITIES AFFECTING THE AQUATIC ENVIRONMENT

Activities that may affect the aquatic environment are, in most cases, the same as those described for terrestrial ecosystems in Section 10. However, the following additional activities related to operation of the dam and powerhouse will generate specific impacts on the aquatic environment:

11.3.1 Operation of the headrace tunnel

11.3.1.1 Reduced flows in the bypassed river section

The potential effects of hydroelectric dam developments are mostly related to the change in flows. Where there are large flow reductions, an environmental flow will usually be provided to prevent or mitigate potential detrimental effects of low or zero flow.

For the Tina River Hydropower Development Project, environmental flows will be required for the river reach between the dam and tailrace and downstream of the tailrace. The magnitude of the environmental flow will be the flow that provides an adequate amount of suitable habitat for the fish species in the river, as determined from an instream habitat survey and information of habitat use by the various fish species. The necessary information on habitat use is gathered from a field survey to determine the relative densities of fish in the various habitats, depths and velocities present in the Tina River, in the vicinity of the tailrace. The instream habitat analysis uses a hydraulic model based on cross-sections surveyed in each of the habitat types, and habitat suitability models for the various species, as well as fish density and species richness. The model predicts how habitat suitability for the various species varies with flow.

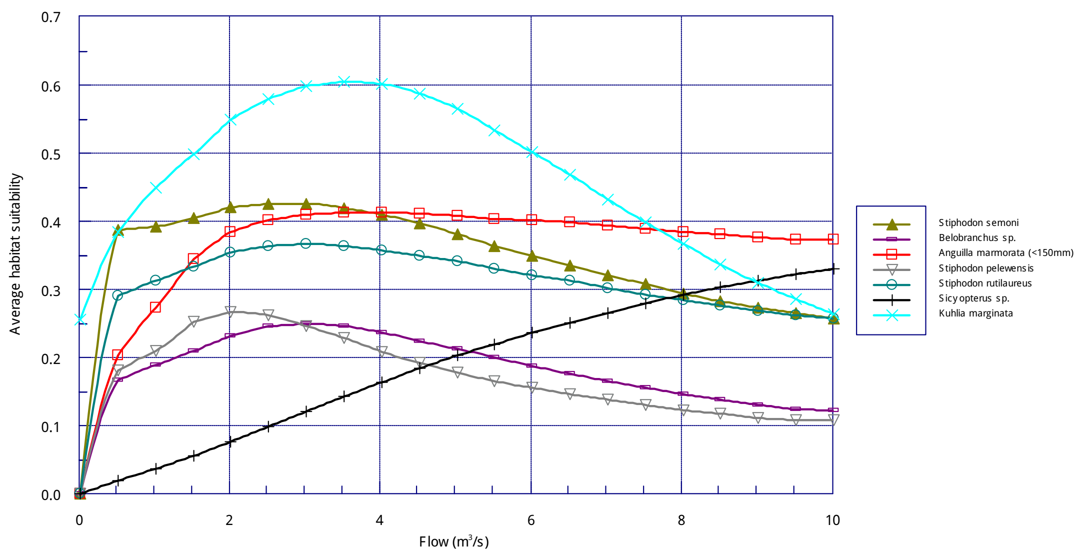
A reduction in flow from the median flow of 11.1 m^3/s to an environmental flow of 1 m^3/s between the dam and the powerhouse reduces the water surface width by 27%, the average depth by 41%, and the average velocity by 68% (Table 11-1).

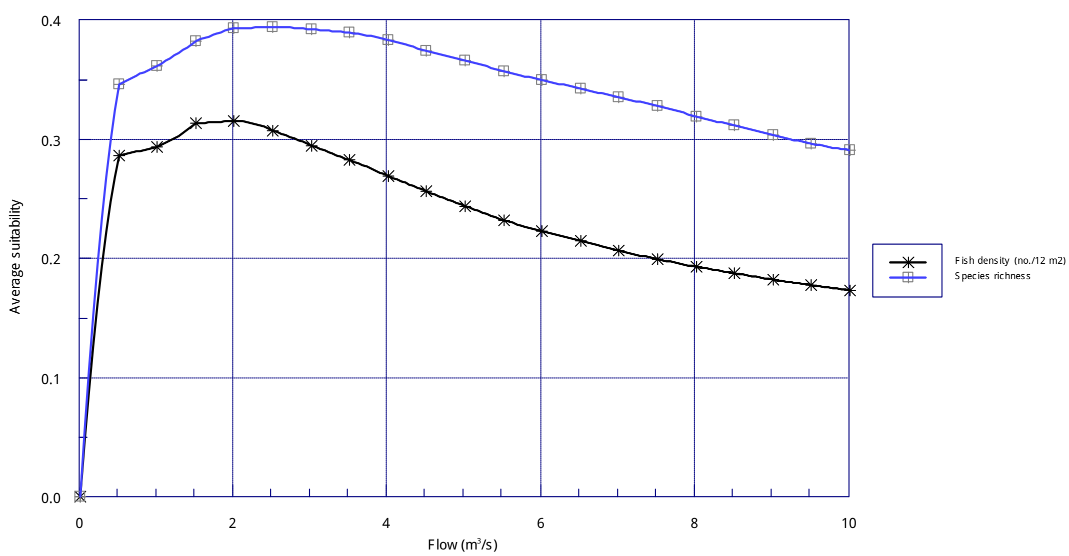
Table 11-1 Predicted variation of water surface width, average depth and width weighted average velocity with flow in the Tina River between the dam and powerhouse

Flow (m^3/s)	Width (m)	Depth (m)	Velocity (m/s)
1	18.0	0.36	0.23
2	20.1	0.40	0.29
3	21.0	0.44	0.35
4	21.4	0.47	0.42
5	21.8	0.50	0.47
6	22.3	0.53	0.52
7	22.7	0.55	0.57
8	23.1	0.57	0.61
9	23.5	0.58	0.65
10	23.9	0.60	0.69
11	24.6	0.60	0.72

The analysis of habitat variation with flow suggested that a flow of 2-4 m^3/s would provide maximum habitat for most of the common species, fish density and species richness. Figure 11-1 shows the variation in average habitat suitability with flow for the 8 common fish species (upper) and for fish density and diversity (lower) in the reach between the dam and powerhouse. However for the species that live in very swift water (Sicyopterus cyanocephalus and S. lagocephalus), habitat suitability is greatest at flows greater than 10 m^3/s.

Figure 11-1 Variation in average habitat suitabiliy



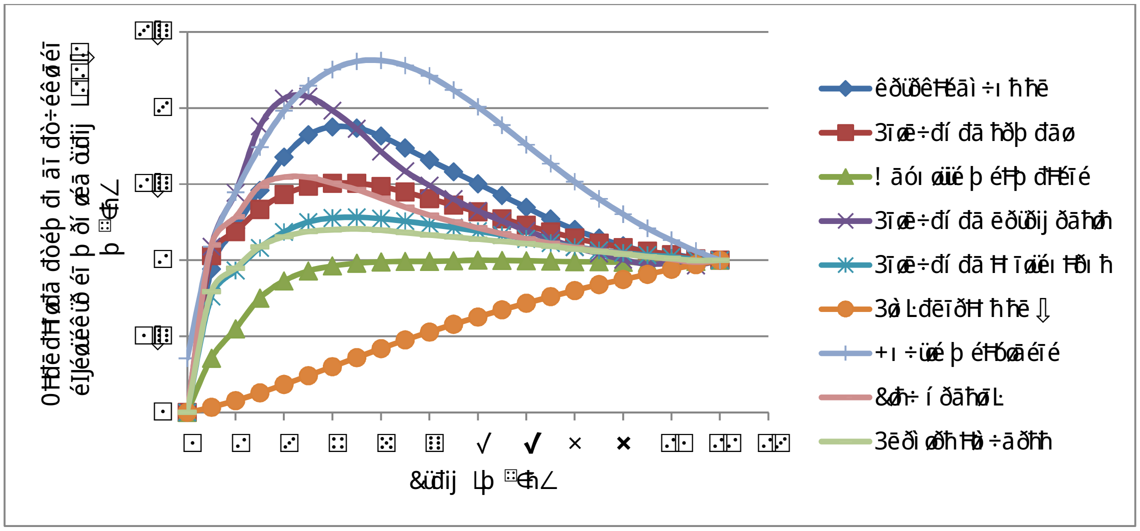


The standard of environmental protection provided by an environmental flow can be assessed by comparing the amount of habitat (m^2/m of river length) at the environmental flow with the amount of habitat at median flow.

A flow of 1 m^3/s would provide more habitat than is available at median flow for Stiphodon semoni, Belobranchus sp., Stiphodon pelewensis and Kuhlia marginata and a similar amount for Stiphodon rutilaureus (Figure 11-2). Fish density and species richness are likely to be greater with a flow of

1m³/s than with the median flow of 11.1 m³/s. The estimated fish density at an environmental flow of 1 m³/s is approximately 50 fish per 12 m². This is slightly less than the average of 60.4 fish/12m² observed in the Toni River and considerably higher than the 6.7 fish/12m² observed in the Tina River. Similarly, the estimated number of species per quadrat with an environmental flow of 1m³/s was 2.1 compared to the observation of 2.61 and 1.17 in the Toni and Tina rivers, respectively.

Figure 11-2 Variation in habitat availability at median flow of 11.1 m3/s



At present, a large amount of sediment is transported through the steep, relatively narrow section of river between the dam and powerhouse sites. The movement of sediment during floods and in the deeper swifter areas of the river at normal flows reduces algal growth, benthic invertebrate production and fish habitat. The creation of a dam will prevent much of this sediment movement and will gradually coarsen the substrate. This will improve the fish habitat considerably, as the habitat observations showed a clear preference for coarse substrate and avoidance of deep swift water where sand was being transported along the riverbed.

The selection of an environmental flow depends on the balance between environmental effects and loss of generation, and the relative values placed on the environment and generation. Based on the available data, the amount of habitat provided by a 1 m³/s environmental flow is similar to the amount of habitat at a median flow of 11.1 m³/s for most of the common fish species. Predicted overall fish density should be higher than at present and should be similar to that in the Toni River. A 1 m³/s flow would provide for fish passage and would maintain pool habitat for the pool dwelling species and good riffle habitat for the riffle dwelling species that comprise the majority of fish in the river. In addition, there would be an improvement in habitat quality resulting from a reduction in the amount of fine gravel and sand in the river channel.

The gradient of the Tina River between the tailrace and its confluence with the Toni River is less than the gradient between the dam and tailrace. Environmental flow requirements tend to increase as the gradient decreases, so that the flow requirement downstream of the tailrace would be higher than the flow requirement upstream of the tailrace. The critical period will be the off-peak hours in the evening, when the reservoir will be refilling. The recommendation is to maintain a discharge through the power house during that period at least equal to what is needed to operate one turbine at minimum capacity, i.e., 2.43 m³/s (which is desirable for other reasons discussed below). When added to the environmental flow of 1 m³/s and the varying amounts of inflow from the tributaries between dam and powerhouse, this would result in a minimum flow downstream of between 3.43 and 4.43 m^3/s.

Entura (2015b) estimated that with a 1 m^3/s environmental flow, potential long-term generation (powerhouse plus generator on environmental flow, less transmission losses) would be about 80.6 Gwh/a with 3 turbine/generator units compared to this report˜s estimate of 81.8 GWh/a (i.e., 83 Gwh/a less 1.2 Gwh/a transmission loss). The current design proposal does not include a generator on the environmental flow.

11.3.1.2 Disturbance of amenity values in the reduced flow section of the river

The reduction in mean flows in the Tina River between the dam and powerhouse tailrace will alter the channel size and form throughout this section. This together with changes in flow patterns will lead to a modification in the littoral zone and river bed associated wetted vegetation areas. These modifications will disturb existing amenity values of the river, which derive from its availability to provide access to water collection, recreational and clothes washing opportunities.

11.3.2 Operation of the dam and powerhouse

11.3.2.1 Changes in hydrology ¯ Variability of flows

The river between the dam and powerhouse requires some flow variability, particularly for floods and freshets. The maximum capacity of the powerhouse and the amount of storage in the reservoir are not large compared to the flow in the river, and the sizes of floods and freshets. Thus, it is likely that there will be frequent periods of spill between the dam and tailrace. Simulation of the hydro operation indicated that floods or freshets would occur on average every 6 weeks, and their average duration would be between 4 to 6 days. This frequency is probably sufficient to prevent prolific periphyton (algae attached to substrate) accumulation in this low nutrient river.

11.3.2.2 Changes in hydrology ¯ Hydro-peaking

Large scale hydro-peaking can severely affect fish and benthic invertebrates. During the dry season, the intention is to generate electricity at full discharge during the day and reduce to zero power station discharge during the night, leaving only the environmental flow in the river. This means that the flows could fluctuate between 18 m^3/s and the environmental flow on an almost daily basis. The maximum flow from the generators is relatively low compared to the magnitude of floods and freshes during the wet season, so that it is unlikely that fish habitat will be affected by hydro-peaking. Nonetheless, impacts remain a possibility given the very limited current understanding of fish habitat use at different times of year. Depending on the mobility of the species, there is the possibility of fish stranding and a reduction in benthic invertebrate and periphyton abundance. A reduction in periphyton or benthic invertebrates (as long as within natural variation) is unlikely to affect fish, because there is no evidence of a reduction in species richness during the wet season when there are frequent floods and freshets that reduce periphyton and benthic invertebrate abundance.

Local people make considerable use of the river, and sudden increases in water level can endanger people if they are caught in the river bed. Usually, a rate of rise of 0.3 m per hour is considered safe. Safe rates of change in flow were calculated from data collected at a wide riffle at the powerhouse tailrace site during the instream habitat survey. Water levels at this cross-section were measured at flows of 8.7 m^3/s and 19.7 m^3/s and a rating curve (relationship between water level and discharge) was developed. This indicated that a flow change from minimum generation (2.4 m^3/s) to maximum generation (18 m^3/s) will increase the water level by about 0.38 m. This is likely to be conservative since much of the river downstream of the tailrace is less confined than at the powerhouse tailrace location. Thus, it might be advisable to ramp up generation from minimum to maximum load over a period of 1 to 1.5 hours.

Sudden reductions in water level can strand fish. Therefore, it is recommended that an adaptive management approach be taken to determining whether ramping flows are needed to mitigate potential fish stranding. This would involve carrying out studies during initial operation to determine whether fish are stranded on sudden reductions in flow. If necessary, the rate at which flow is reduced (i.e., flow ramping) could then be decreased to see if that prevents stranding.

Maintaining the minimum flow downstream of the powerhouse of 3.43 m3/s, as recommended to preserve aquatic habitat, would also reduce the magnitude of fluctuations in flow and thus the risk to river users and the likelihood of fish stranding and interference with downstream water uses.

11.3.2.3 Reservoir establishment - Change from riverine to lacustrine (lake) habitat

The creation of the reservoir will replace about 2.6 km of riverine habitat with a reservoir (Entura 2014). The average width of the reservoir would be about 118 m at a FSL of 175 m amsl. There are very few lakes on Guadalcanal, so it is not known what riverine fish species will take up residence in the newly formed lake with its lacustrine environment. Non-native fish species could be introduced into the lake, but this should be avoided if possible because of potential effects on native species..

11.3.2.3.1 Sediment in the reservoir

The reservoir volume up to the invert of the sediment scour outlet (155m) is 2344x10^3 m^3, and 6900x10^3 m^3 up to Full Supply Level (175 m). Entura (2014) estimated that the annual suspended sediment load would be about 500 t/km^2/year, which would deposit about 45000 m^3/year of sediment in the reservoir. They estimate that it would take approximately 65 years before it became necessary to flush deposited sediment from around the power station intake.

11.3.2.3.2 Changes in downstream sediment dynamics

The dam will trap all bed load sediment (sand and coarser material) and a proportion of suspended sediment, and reduce the amount of bed load in the river downstream of the dam. This will result in a coarsening of the substrate within the river downstream of the dam, as reduced sediment input, combined with high flows that wash the sand and fine gravel component from the substrate, will leave coarser gravels and cobbles. An increase in the amount of coarse substrate will improve habitat for eels, gobies and benthic invertebrates that live around and under coarse substrates. In addition, the reduction in sand supply would tend to deepen pools and improve habitat for the pool dwelling species like kuhlia and grunters. Any effect of sediment removed by the reservoir will gradually reduce with distance downstream, as sediment is entrained from the sands and gravels on existing river banks and introduced from tributaries.

Observations downstream of New Zealand hydro dams on gravel bed rivers (Waitaki, Clutha) indicate that the riverbed will not degrade (erode) to any noticeable degree because the surface will be armoured by cobbles and larger gravels once the surface fines are removed.

11.3.2.3.3 Water quality

Because there is little diurnal and seasonal temperature variation and little wind mixing, tropical reservoirs often become stratified (Barrow 1988) and there is a risk that dissolved oxygen concentration is reduced in the lower layers (hypolimnion). Shallow lakes with high inflow are least at risk of stratification.

The residence time of the proposed reservoir when full is approximately 7 days at median flow of 11.1 m^3/s and the average flow depth is approximately 10 m (Entura 2014). Entura's analysis (see Table 11-11 in Section 11.4.4) indicates the potential for stratification. However, relationships between temperature differential thermal (stratification) and residence time (Jorgenson et al. 2005) show virtually no thermal stratification in a reservoir with a residence time of 7 days. Some stratification may occur, and a hypolimnion with a low dissolved oxygen concentration may develop. However, with the reservoir bottom at 122 masl and full supply level at 175 masl, it is unlikely that the hypolimnion would extend upward to 162.5 masl, the level from which water is withdrawn for the turbines and the environmental outlet. Consequently, the discharge of surface water from the reservoir through the spillway, tailrace and environmental flow outlet is unlikely to cause any measurable change in dissolved oxygen downstream because these withdrawals are all from what would be the epilimnion in a stratified lake. The Reservoir Management Plan will include monitoring of dissolved oxygen and temperature at multiple depths to provide advance warning of potential water quality problems.

11.3.2.3.3.1 Water temperature

As water flows down a river, it is heated by solar radiation and cooled by evaporation until a thermal equilibrium is reached. If the amount of shade and radiation or ambient air temperatures changes, the water temperature adjusts towards thermal equilibrium. Usually, this will mean that water temperature will increase in a downstream direction.

In the Tina River during the rainy season, measured spot temperatures increased from 24.5°C at the Tina Village to 32.0°C at the Ngalimbiu River Bridge. The Toni River flows into the Tina River just downstream of Tina Village. Water temperatures in the Toni River were 28.4 to 29.4°C so that the Ngalimbiu River water temperature downstream of the Tina/Toni confluence was 26.4 to 27.2°C.

Water temperatures were also measured in the Toni River and in the Tina River between the Toni River confluence and approximately 1.5 km below the dam site over the period 11-15 July 2016. There was no rain over the period 11-15 July 2016. The daily maximum water temperature was 26°C at all sites over the 5 days. The daily minimum temperature was 23°C indicating diurnal variation of about 3°C. The lack of any downstream increase in temperature and the similarity of the water temperatures in the Toni and Tina rivers suggest that the water temperature was in equilibrium and therefore a change in flow would have minimal effect on daily mean water temperature.

The formation of a reservoir will generally alter the seasonal thermal characteristics of the river immediately downstream of the outlet. Since the thermal capacity of a reservoir is greater than that of a river, the reservoir tends to store heat resulting in smaller daily temperature fluctuations, lower summer temperatures, and higher winter temperatures. However, there is little variation in the annual air temperature in the Solomon Islands, so seasonal variation in water temperature is unlikely. Measurements in other lakes suggest that the reservoir water temperature is likely to be less than 28 °C (pers. comm., Robson Hevalao).

A reduction in flow generally does not change the daily mean water temperature significantly, but it does increase the daily maximum and decrease the daily minimum temperature. However, during the wet season at least, water velocities are high and river water temperatures may be below the equilibrium temperature, so that a reduction in flow would certainly increase the daily maximum water temperature and may increase the daily average water temperature in the river between the dam and powerhouse. With a flow of 1 m^3/s in the river between the dam and powerhouse, water temperatures are likely to be similar to those in the Toni River. The fish community in the Toni River is similar to, or better than, that in the Tina River. Thus, an increase in water temperature in the Tina River is unlikely to have any effect on its fish community.

11.3.2.3.4 Fish passage

The dam will create a barrier to the passage of migratory fish species to the catchment upstream of the dam. It is possible to provide fish passage past the dam for most species. The options include a natural stream fish pass (if there is sufficient space), or a trap and haul system. These systems are used in New Zealand for a variety of climbing species and in UK, France, and the US for eels (Paterson & Boubee 2010, Solomon & Beach 2004). Fish pass systems developed in Europe and North America for salmonids and similar species are expensive, difficult to modify and will not necessarily suit the Tina River species. The 5 m operating range of the reservoir would necessitate a complicated system of hydraulic structures at the upstream end of a conventional fish pass to maintain a constant flow under the range of reservoir levels.

11.3.2.3.4.1 Upstream passage

Because of their climbing ability, it is relatively easy to provide effective upstream passage for gobies and eels using either a natural stream channel[72] pass, or trap and haul system. It is likely that a trap and haul system will be the least costly, most adaptable and most practical option for fish passage. A photo of a ramp and trap components of a trap-and-haul system for climbing fish is shown in Figure 11-3 Fish from the trap can and should be released in or upstream of the reservoir at a location that will avoid the possibility of fish being entrained by spillway or power station flows. The ramp allows migratory fish to climb to the trap, where they remain until transferred to an upstream location.

One advantage of a trap and haul system is that fish caught in the trap can be identified and counted before they are transferred to areas upstream of the dam. Thus, a trap system will provide very useful monitoring data on the state of the goby and eel populations which is very difficult, if not impossible to obtain by other means.

Neither a trap-and-haul system, or natural fish pass, is likely to provide passage for Kuhlia and grunters, both of which are a swimming species. Kuhlia appear to be reluctant to use fish passes (Lewis & Hogan 1987). However, if Kuhlia and/or grunters accumulate at either the powerhouse tailrace or the base of the dam, it will be possible to net them and transfer them to a more suitable environment such as the Toni River or upstream Tina River. This is considered to be another variant of the trap-and-haul system. Transfer to the Toni River would be preferable because some mortality would occur when the adult fish migrate from the upper Tina River to the estuary area to spawn.

[72] A gravel/cobble channel similar to a riffle which would zig-zag up the dam face or abutments with resting pools at the changes of direction.

Figure 11-3 Photo of ramp and trap at dam

Figure 17 shows the trap system with ramp leading to a holding tank and piped water supply installed at Waitaki Dam, New Zealand. The ramp can be lined with bristles, gravel or a drainage product called Miradrain or Cordrain (Patterson & Boubee 2010). The optimum slope is about 15 degrees.

While bristles appear to best for eels, gravel or drainage products suit both gobies and eels. New Zealand traps have been used to collect eels, galaxiids, redfin bully (Gobiomorphus huttoni) and to a lesser degree torrentfish (Cheimarrichthys fosteri). The ramp should also have a transverse slope to provide deep water on one side and shallow water on the other to provide a choice of velocities and depths for the fish that move up the ramp. The climbing abilities and modes of locomotion of these New Zealand species are the same as those used by crawling and climbing species in the Solomon Islands, as described in the ESIA.

11.3.2.3.4.2 Downstream passage

Gobies spawn on substrate in the area in which they live. When the eggs hatch the larvae are carried passively downstream. It is not clear whether goby spawning is seasonal, or occurs all through the year. It is possible that spawning seasonality varies between species. Larval fish return to the estuary during the dry season and this indicates that spawning and downstream migration takes place early in the wet season. Thus, it is likely that hatching and downstream movement occurs during floods and freshets with the high flows ensuring rapid and safe transport to the sea. If so, the dam may be spilling and larval fish will pass over the spillway. Although there are very few studies of larval survival through turbines, it is well known that the length of fish is the primary determinant of survival (e.g., Larinier and Travade 2002) and with larval fish potential mortality caused by striking the turbine blades or wicket gates will be low. Morris et al. (1985) describe quantitative data on entrainment mortalities that were gathered at the Ludington Hydro Plant on Lake Michigan, which has a head of 110m. Survival tests on 9 species of larval fishes indicated that passage through the Ludington turbines decreased survival rates by an average of 15%. Large smelt larvae (15-42 mm) experienced much greater mortality than did smaller (<15 mm) smelt larvae. Some larvae were apparently robust and seemed to survive turbine passage (i.e., ninespine stickleback, lake whitefish, turbot larvae). Goby larvae are small (<10mm) and there is unlikely to be significant mortality through the turbines.

Although the gobies in the Solomon Islands are generally considered diadromous, large numbers of 10 mm gobies were observed in the shallow low velocity margins of the river between the dam and power house sites on 11-15 July 2016. It is unlikely that fish of this size have the swimming ability to make the 25 km journey from the sea and this suggests that these fish are rearing in the river rather than the sea. Shallow low velocity margins are the type of rearing habitat used by non-diadromous bullies in New Zealand.

Adult eels migrate to the sea at the beginning of the wet season. They are likely to migrate on the first fresh so that the deeper swift flowing water facilitates their passage to the sea, similar to the migration of New Zealand eels. The mortality of adult eels through turbines is significant, and screens should be installed at the intake. Releases over the spillway during high flow could be timed to facilitate eel passage downstream.

11.4 IMPACT ASSESSMENT

11.4.1 Impact identification Matrix

Table 11-2 identifies potential impacts on the aquatic environment.

Table 11-2 Potential impacts on the aquatic environment

	Potential impact causing activities	Impacts on hydrology and sediment dynamics	Impacts on water quality	Impacts on aquatic life	Impacts on water uses
Pre-Construction and construction	Pre-construction site investigations (hydrological, topographical, geological, geotechnical surveys)	Increase in suspended solids and siltation	River pollution (oil, explosive residues)	Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Access road construction	Increase in suspended solids and siltation		Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Site clearing (access road, dam and powerhouse sites, quarries, transmission line, work areas)	Increase in suspended solids and siltation		Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Traffic movements (heavy haul trucks, heavy machinery, light duty vehicles) crossing the river	Increase in suspended solids and siltation		Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Construction/dewatering of the coffer dams and diversion tunnel	Increase in suspended solids and siltation	River pollution (cement leachate, explosive residues)	Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Excavation of the river bed and construction of dam foundations	Increase in suspended solids and siltation	River pollution (cement leachate)	Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Mining quarries in/near the river bed	Increase in suspended solids and siltation		Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Construction of RCC dam and powerhouse	Increase in suspended solids and siltation	River pollution (cement leachate)	Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
	Construction of off-site facilities (work areas, transmission line)	Increase in suspended solids and siltation			Disturbance of water uses
	On-site maintenance and work areas		River pollution (oil and other hazardous substances)	Over-fishing	Disturbance of water uses
	Reservoir preparation (clearing)	Increase in suspended solids and siltation			Disturbance of water uses

	Potential impact causing activities	Impacts on hydrology and sediment dynamics	Impacts on water quality	Impacts on aquatic life	Impacts on water uses
	Reservoir filling	Temporary dewatering of the river downstream of the dam		Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
Operation	Operation of the dam & powerhouse	Reservoir establishment ‾ change from riverine to lacustrine environment Sedimentation - in the reservoir Changes in hydrology - variability of flows Changes in sediment dynamics downstream	Reservoir stratification	Establishment of a lake ecosystem Barrier to migratory fish species Disturbance of aquatic habitats and aquatic life	Disturbance of water uses
Operation	Operation of the headrace tunnel	Reduced flow in the by-passed river section Disturbance of amenity values in the reduced flow section of the river		Degradation of aquatic habitats Barrier to migratory species	Disturbance of water uses

11.4.2 Impact Assessment Limitations

Assessment of impacts on the aquatic ecology of the Tina River is constrained by the limited availability of bibliographical data available for Solomon Islands freshwater ecology and other sources of information dealing with species migratory behaviour and habitat requirements.

11.4.3 Construction Impacts on Aquatic Environment

This section identifies potential construction related impacts on the aquatic environment during construction. Proposes mitigation measures, and discusses residual effects and their significance.

11.4.3.1 Increase in Suspended Solids and Siltation

Field observations conducted in August 2013 on the Tina/Ngalimbiu River indicated that low concentrations of suspended solids except following periods of heavy rain. In the upper reach of the Tina River, the water was fully transparent (< 1NTU). In the lower reach (e.g., where the Tina becomes the Ngalimbiu River), it appeared slightly turbid (5NTU to 9NTU), with 5NTU being regarded as the perception threshold. The maximum value during the dry season was observed at the mouth of the river (12.8 NTU). However, peaks in turbidity are known to occur after heavy rains and after cyclones. No turbidity or TSS data was available for immediate post cyclone conditions. However, they are likely to be similar to turbidity levels observed during the rainy season when it was 16.1NTU at Tina village (Tina River), 8.69NTU to 15.5NTU at Ngalimbiu River, and 15.3NTU to 18.4NTU at the mouth of the Ngalimbiu River.

11.4.3.1.1 Impact Identification and Rating

During construction, increased TSS concentration (both base values and peaks) occurs due to: (i) re-suspension of fine streambed sediments due to activities within the river (e.g., gravel extraction from borrow sites located within the river, vehicles crossing through the river, construction works for diversion cofferdams and the diversion tunnel, dam foundations, intake gallery, power-plant, and tailrace); (ii) increased load of soil and organic particles following heavy rains, from runoff and erosion in clearing and earthwork areas (construction work for access road, dam and supporting site facilities, reservoir vegetation clearing); and (iii) dewatering operations during headrace tunnel construction due to intersected water seeps within the rock. The tunnel drainage will contain crushed rock materials.

The increase in turbidity is likely to temporary affect the river far downstream of the dam area. Increased suspended matter will cause significant deposit of fine particles (silting) of the streambed and banks in sections of slow velocity downstream of the dam.

Impacts on aquatic life and water users downstream of the dam are considered to be moderate, since construction impacts will most likely persist only for the short 3-year construction period. Table 11-3 summarises the impact significance rating for suspended sediments on the aquatic ecosystem and water uses.

Table 11-3 Suspended sediment impacts on aquatic ecosystem and water uses during construction

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate to high	Major	Localised – dam to river mouth	Temporary (3 years)	Moderate	Moderate

11.4.3.1.2 Mitigation Measures

Unfortunately, increased suspended sediment load, as measured by TSS is an unavoidable impact, since most construction work will take place within or adjacent to the river. However, it can be mitigated by implementing best environmental management practices (BEMPs) during construction especially on terrestrial areas. BEMPs for controlling the introduction of sediment into the river include plans for the following (see Section 13 – ESMP):

- Reservoir preparation;
- Point source pollution management, including concrete work;
- Spoil soil management during earthwork;
- Forest clearance practices;
- Stream crossing practices;
- Drainage and erosion control;

11.4.3.1.3 Residual Effects and Their Significance

Notwithstanding that BEMPs will be applied to control sediment entering into the river, moderate residual impacts will continue following application of mitigation measures, since most suspended solids, as measured by TSS, will originate from sources that cannot be fully mitigated. However, due to the effects of heavy rainfall within the catchment and the flashy nature of the Tina River, including tributary streams that enter the Tina River downstream of the damsite, sedimentation will be somewhat masked by the natural situation, as long as best efforts to employ BEMPs are made to prevent soil eroded from the project site from entering the Tina River. Overall, the residual effect is considered to be not significant.

11.4.3.2 River Pollution

Pre-project physico-chemical and bacteriological water quality is considered to be: (i) excellent in the vicinity of the damsite as human activities are almost non-existent here and upstream into the upper catchment (e.g., due to there being no habitation, only selective harvesting of trees in the last 10 years, and no gold placer or bedrock mining); and (ii) slightly degraded downstream, due to community activities (e.g., domestic uses of the river, domestic waste waters, gardening, pig rearing).

11.4.3.2.1 Impact Identification and Rating

Construction works will represent an important additional source of potential river pollution originating from different activities, including: (i) loss of cement leachate from the pug mill, concrete batch plant, and concrete pours on the RCC dam, head race tunnel and powerhouse; (ii) risk of fuel / oil spills and spills of other hazardous substances, and release of explosive residues from blasting; and (iii) release of waste waters from worker cafeteria and toilets (175 staff) and from potential increased population in the nearby villages.

Impact significance is considered to be potentially major in the Tina River downstream of the construction site for a distance of approximately 9km by river. Impacts are likely to be less significant in the Ngalimbiu River, after being diluted with the discharge of the Toni River. The risk of river pollution will last throughout the construction phase, approximately for 3 years.

Overall impact significance is considered to be moderate, as river pollution is considered a potential risk rather than a confirmed impact. Table 11-4 summarises the impact significance rating for potential river pollution and water uses.

Table 11-4 River Pollution impacts on aquatic ecosystem and water uses during construction

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate to high	Major due to risk of accidental release of pollutants	Localised – dam to river mouth	Temporary (3 years)	Low if BEMPs implemented	Moderate

11.4.3.2.2 Mitigation Measures

River pollution is an avoidable impact if BEMPs are implemented during construction. BEMPs for controlling the introduction of pollutants into the river (see Section 13 – Environmental and Social Management Plan) include plans for:

- Point Source pollution management, including concrete work;
- Spoil soil management during earthwork;
- Forest clearance practices;
- Stream crossing practices;
- Drainage and erosion control; and
- Localization of hazardous material.

11.4.3.2.3 Residual Effects and Their Significance

Even with the implementation of BEMPs, the moderate pre-mitigation impacts will persist as residual impacts, primarily because of the potential risk posed by a release of hazardous substances into the river. However, this residual impact is considered to be not significant if BEMPs are properly implemented.

11.4.3.3 Disturbance to Aquatic Habitats and Aquatic Life

11.4.3.3.1 Impact Identification and Rating

Water quality degradation, including increased TSS, and stream bed siltation due to construction activities and alluvium extraction in the river bed, are likely to affect aquatic life downstream of the construction area, if no appropriate mitigation is applied, especially where ecological conditions are almost pristine.

These changes may affect aquatic habitats and the life of existing aquatic communities: impact on trophic resources, spawning microhabitats and shelters, survival of migrating larvae and pollution-sensitive species. Although, aquatic communities are naturally exposed to habitat disturbance associated with frequent flash floods that result after heavy rain episodes, and exceptional events such as occurred with Cyclone Namu (1986).

In the event of an accidental spill of fuel /oil or other toxic substance, the effects on aquatic life might manifest far downstream.

The potential for impacts on aquatic life will last throughout the construction phase, approximately for 3 years. Overall pre-mitigation impact significance is considered to be moderate, as the spill of hazardous substances into the river is considered to be a potential risk as opposed to a certainty. Table 11-5 summarises the impact significance rating for disturbance to aquatic habitat and on aquatic life.

Table 11-5 Impacts of disturbance to aquatic life and water uses during construction

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate to high	Major due to risk of accidental release of pollutants	Localised ‑ dam to river mouth	Temporary (3 years)	Low if BEMPs implemented	Moderate

11.4.3.3.2 Mitigation Measures

Disturbance to the aquatic ecosystem is unavoidable, and is the consequence of constructing a hydropower dam. BEMPs will be implemented to minimize disturbance wherever possible. BEMPs for controlling the disturbance to aquatic habitats and aquatic life (see ESMF) include plans for:

- Point Source pollution management, including concrete work;
- Spoil soil management during earthwork;
- Forest clearance practices;
- Stream crossing practices;
- Drainage and erosion control; and
- Localization of hazardous material.

11.4.3.3.3 Residual Effects and Their Significance

Even with the implementation of BEMPs, the moderate pre-mitigation impacts will persist as residual impacts, primarily because of the potential risk posed by a release of hazardous substances into the river. However, this residual impact is considered to be not significant if BEMPs are properly implemented.

11.4.3.4 Overfishing

11.4.3.4.1 Impact Identification and Rating

The presence of workers in the construction area were the fishery pressure is currently low, and the potential influx of population in villages along the Tina River downstream, may represent an additional pressure on the fishery resource, especially on those fish species considered to be particularly valuable (i.e., Khulia, Mesopristis, gobbies, prawns) to communities, which could be potentially overfished.

Impacts will last throughout the construction phase, approximately for 3 years. Although the magnitude of potential impacts is considered to be moderate, it is of short duration and confined to the local area. Therefore, impact significance is considered overall to be low. Table 11-6 summarises the impact significance rating for potential overfishing.

Table 11-6 Impacts of potential overfishing during construction

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate to high	Moderate	Localised – dam to powerhouse	Temporary (3 years)	Low if BEMPs implemented	Low

11.4.3.4.2 Mitigation Measures

It is recommended that workers be prohibited from fishing in the Tina River, and that the Project's food services / caterers be prohibited from purchasing fish from local villagers.

11.4.3.4.3 Residual Effects and Their Significance

It is expected that the pre-mitigation moderate impacts will be mitigated through worker and camp prohibitions of catching or buying fish. Therefore, residual effects are low and considered to be not significant.

11.4.3.5 Diminished Water Quality and Water Quantity

11.4.3.5.1 Impact Identification and Rating

Water quality degradation, including increased TSS, bacteriological and physico-chemical pollution, and siltation may lead to diminished availability of water for occupants of riparian villages, for which the river represents the major source of water.

Turbid water makes it difficult or impossible to practice subsistence fishing especially using the preferred method of snorkelling / spear fishing, to wash clothes, and to bath. Turbid water is also less attractive for recreational activities.

Bacteriological pollution caused by leaking portable toilets that will be used in the work areas, or urinating or defecating out in the open in areas adjacent to work sites, presents a potential risk of waterborne diseases for people using the river for drinking or bathing.

In the event of a major accidental spill of hazardous material (e.g., fuel / oil) from the construction area all water uses all along the river, including commercial fishing at the mouth of the river, would be significantly affected.

Concrete production from the onsite batch plant will require 30Mm^3 of water from the Tina River to construct the dam over two dry seasons..On average, this will lead to an estimated reduction of flow downstream of the dam ranging from 7% to 10% as shown in Table 11-7.

Only minimal impacts to water quality are anticipated at the mouth of the river as a result of project construction. The use of cofferdams and diversion works will ensure that construction of the dam, and powerhouse tailrace, are undertaken in isolation from the river, thereby preventing introduction of concrete slurry, fine sediments and other potential contaminants. Use of good practice techniques for clearing and grubbing operations, and implementation of sound management plans to control erosion and sedimentation, construction wastes, hazardous materials, and other similar plans, will minimise the threat to water quality. With these measures in place, along with on-site monitoring to identify potential issues, it is unlikely that any construction related adverse water quality impacts would accrue to the estuary.

Table 11-7 Water required for concrete production

Total water extracted for concrete in m3	Total time for concrete work in months	Water extracted for concrete in m3 per month	Water extracted for concrete in m3 per second	Average Tina flow in dry season at dam site (m3/s)*	Estimated additional flow between Dam and Tina junction with Toni in m3/s**	Estimated additional flow from Toni***	Estimated total flow during dry season downstream of Toni river
30,000,000	8 to 9	3,750,000 to 3,333,333	1.29 to 1.45	12.72	1	4.24	17.96

Estimated average flow reduction in % due to concrete work	Between dam and Tina junction with Toni	Downstream of Toni (Ngalimbiu River)	
	9.37 to 10.54	7.18 to 8.07	

* based on gauging station data from June 2010 to September 2013. Dry season range from April to November.

** based on Average specific yield of 0,097 $m^3/s/km^2$ of Tina River

*** based on BRLi field measurement showing that Toni has roughly 1/3 of Tina's flow

Impacts will last throughout the construction phase, approximately for 3 years. Although it is of short duration and confined to the local area, the magnitude of potential impacts water quality and quantity is considered to be moderate, due to the potential for the project water requirements to become a larger percentage of dry season flows, especially in a very dry year, and due to the risk of project related pollution affecting downstream water quality. Therefore, impact significance is considered overall to be moderate. Table 11-8 summarises the impact significance rating for potential water quantity and quality issues.

Table 11-8 Potential water quantity and quality impacts during construction

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate to high	Moderate due to potential for project water use to become higher percentage of available water, and risk of pollution	Localised – dam to river mouth	Temporary (3 years)	Moderate without BEMPs implemented	Moderate

11.4.3.5.2 Mitigation Measures

Mitigation measures, such as the provision of domestic water supply system to local affected communities, is proposed (see Section 12 – Assessment of Socio-economic / Socio-community Impacts), to offset the of the Project withdrawing a quantity of water during construction that could affect availability of water to downstream communities. In addition, the same BEMPs that would be used for pollution control (see Section 11.2.3.2.2 – Mitigation Measures for river pollution) would apply to protecting water quality.

11.4.3.5.3 Residual Effects and Their Significance

Post-mitigation residual impacts are considered to be moderate due to the potential for affecting the availability of water for downstream communities, and due to the risk that water quality of the Tina River could be adversely affected by a project related spill of a hazardous substance. However, with application of BEMPs to control potential pollution, and compensation measures, such as distribution of water for domestic use, the post-mitigation residual effects are considered to be low (i.e., not significant).

11.4.3.6 Temporary River De-watering During Reservoir Filling

11.4.3.6.1 Impact Identification and Rating

Reservoir filling is estimated to take 7 days, based on a FSL reservoir of $7Mm^3$, and an average filling rate of $11.5m^3/s$). However, reservoir filling could significantly longer or shorter, depending on the hydrology and occurrence of heavy rains /floods following closure of the dam.

Unless some flow is released, the river will be dewatered during the period of reservoir filling, with severe consequences on the aquatic ecosystem and water uses, especially on the reach between the dam and the confluence with the Toni River.

Impacts will be very short in duration, confined to a short section of river, but severe in magnitude, and are considered overall to be moderate, but recoverable. Table 11-9 summarises the impact significance rating for potential water quantity and quality issues.

Table 11-9 Potential river dewatering impacts during reservoir filling

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate to high	Severe due to potential complete dewatering of Tina River between dam and Toni River confluence	Localised ‑ dam to confluence with Toni River	Very short (estimated 7 days)	Moderate without EF	Moderate

11.4.3.6.2 Mitigation Measures

To mitigate impact of reservoir impoundment, an environmental flow will be implemented. In its 2014 feasibility Study, Entura recommended that a low level outlet through the diversion plug be provided for this purpose. It is suggested that an environmental low (EF) of $1m^3/s$ be maintained through this outlet during reservoir filling.

11.4.3.6.3 Residual Effects and Their Significance

With a minimum EF release of 1m^3/s at all time during reservoir filling, the post-mitigation residual impact of dewatering the river is considered to be low (i.e., not significant).

11.4.3.7 Conclusions Regarding Construction Impacts

Table 11-10 summarises the pre-mitigation impact ratings, and the significance of residual impacts that will potentially remain following the application of mitigation measures, for the construction phase of the Project.

Table 11-10 Pre-mitigation and residual impact ratings for construction phase

Impact from construction	Pre-mitigation impact rating	Post-mitigation Residual impact rating
Increase in suspended solids and siltation	Moderate	Not Significant
River pollution	Moderate	Not Significant
Disturbance to aquatic habitats and aquatic life	Moderate	Not Significant
Overfishing	Low	Not Significant
Disturbance to water uses	Moderate	Not Significant
Temporary river dewatering during reservoir filling	Moderate	Not Significant

Many impacts resulting from dam construction activities are unavoidable and mitigation measures are limited. Residual impacts will, in most cases, reflect the pre-mitigation impact significance ratings. Notwithstanding, it is recommended to maintain an EF during reservoir filling. By employing BEMPs during construction, providing domestic water supplies to all affected communities, and monitoring water quality, construction related impacts can be held to acceptable levels, especially if the construction contractor is required to address any issues that arise during construction.

11.4.4 Operation Impacts on Aquatic Environment

This section discusses potential impacts on the aquatic environment that may accrue during operation, proposes mitigation measures, and assesses residual impacts and their significance.

11.4.4.1 Reservoir Operation

The project will create a reservoir with the characteristics shown in Table 11-11.

Table 11-11 Characteristics of proposed dam & reservoir

Feature	Measurement
Location of the reservoir	3.7km upstream of Senge (CH 7km)
Reservoir level & depth Max flood level Full supply level (FSL) Normal operating level. Minimal operating level. River level at dam	 186masl 175masl 172masl 170masl 122masl
Reservoir depth at FSL (deepest point) (= dam height above river bed)	53m
Reservoir volume Volume at FSL Active volume (NOL to MOL) Dead storage to spillway gate level	 $7Mm^3$ $1.4Mm^3$ $3.2Mm^3$
Length of impounded river (FSL)	2.5km
Reservoir surface area at FSL	30.52ha
Froude coefficient	0.02 (*)
Retention time	7d
Water intake level to powerstation(head race tunnel)	161-164masl
Mean water inflow	$11.5m^3/s$
Length of river with reduced flow (dam to powerhouse)	5.7km

Source March 2014: Entura TRHD Phase 3 Report

(*) Froude (F) = 320 (L/D)(Q/V) were L = length of the reservoir (meters); D = mean reservoir depth (for which dam height may be a proxy) ; Q = mean water inflow :(m3/s) and V = reservoir volume (m^3)

Entura's TRHD Phase 3 Report (March 2014), provides a description of the reservoir for the preferred alternative, Option 7C. The reservoir at FSL is approximately 53m (max depth), 150m wide at its downstream end, and 2.5km long, with an estimated volume of $7Mm^3$.

11.4.4.1.1 Impact Identification and Rating

The aquatic habitat within the impounded section of the Tina River will change from lotic conditions (fast flowing river with rapids and pools on a streambed of cobbles and pebbles) to lentic conditions (deep reservoir, up to 53 m in depth, with slow velocity).

The predicted exchange period for reservoir water is estimated to be 7 days. This is low compared to other reservoirs on tropical rivers that have a more seasonal flow regime. In terms of minimizing negative impacts on water quality (i.e., increased temperature, oxygen depletion, and other adverse effects), short exchange periods are preferable to long exchange periods.

The reservoir˘s presence reflects a permanent impact, in a very localized area, having a moderate magnitude on the river system. Therefore, impact significance is considered to be moderate. Table 11-12 summarises the impact assessment rating for reservoir operation.

Table 11-12 Reservoir operation impact rating

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate for its power generating capacity	Moderate	Localised ˉ over 2.5km length of Tina River	Permanent	High	Moderate

11.4.4.1.2 Mitigation Measures

The reservoir will be operated for many decades in support of a peaking hydropower generating station and, therefore, represents a permanent change to the Tina River. There are no mitigation measures that can be applied to the reservoir operation to reduce the impact of converting 2.5km of riverine habitat to lentic habitat.

11.4.4.1.3 Residual Effects and Their Significance

Loss of 2.5km of riverine habitat is a long-term (permanent) condition that will continue as long as the hydropower project is operational. Therefore, no mitigation is possible, and the residual impacts are considered to be moderate, but not significant.

11.4.4.2 Reservoir Sedimentation

5.1.1.1.1 Impact Identification and Rating

The flux of solid material from the upstream watershed consists of: (i) bed load of coarse materials (i.e., boulders, cobbles, pebbles, gravels, coarse sands); and (ii) suspended sediments (clay, fines and organic particles), the concentration of which is very low except after heavy rains.

All of the bed-load is expected to be trapped in the reservoir, with larger materials deposited at the upstream end of the reservoir, and lighter fractions deposited at the deeper downstream end. However, a significant proportion of suspended sediments will likely pass through the reservoir, either through the power intake and turbines, or spillway (i.e., during floods).

Over time, the trapping of solid material in the reservoir will result in a decrease in its active volume. At a FSL of 175masl, and assuming a sediment inflow of 45,000m^3/y, it is estimated that the dead storage volume would be full within a period of 65 years (Entura, March 2014).l

Impact significance is considered to be moderate. Table 11-13 summarises the impact assessment rating for reservoir sedimentation.

Table 11-13 Reservoir sedimentation impact rating

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Low as it is an artificial environment	Moderate	Localised ¯ over 2.5km length of Tina River	Permanent	High	Moderate

11.4.4.2.1 Mitigation Measures

Inclusion of large flushing outlets as part of the dam˘s design has been ruled out, primarily because they are only efficient at removing sediment deposited within relatively close proximity to the dam. Constructing large flushing outlets into an RCC structure is complicated and costly, for very little benefit. However, in place of flushing outlets, an outlet of 3x3m is proposed near the power intake at 160masl, to extend the filling period. Once sediments reach this level, the outlet will be used either for local flushing or for lowering the reservoir to permit dredging/excavating of accumulated sediments.

11.4.4.2.2 Residual Effects and Their Significance

As there is no feasible mitigation, residual impacts are considered to be moderate, but not significant.

11.4.4.3 Barrier to Passage of Migratory Fish Species

As with other Indo-pacific islands, all native fish species in streams and rivers on Guadalcanal (i.e., gobioids, eels, Kuhlia, prawns, and other endemic species) are amphihaline migratory species with a life cycle that shifts between the sea and the river.

11.4.4.3.1 Impact Identification and Rating

The dam and reservoir, and to some extent the associated by-passed section of the Tina River, will represent a barrier to the upstream and downstream migration of all native fish species that currently utilise the river system upstream of the dam site.

As mentioned in Section 7, fish within the Tina River follow either a catadromous or amphidromous lifecycle migration scheme, as follows:

- Catadromous migration involves downstream migration of adults to spawn in the sea, and upstream migration of juveniles to mature within the upper catchment area.
- Amphidromous migration involves downstream migration of larvae and upstream migration of juveniles to mature, reach adulthood, and spawn in the upper catchment area.

Creating barriers to fish migration is not so much an issue of depriving communities of fish resources that support a livelihood as it is an issue affecting fish biodiversity and local cultural experience for those who venture into upstream areas on traditional fishing trips.

Impacts on the Upstream Migration of Juveniles

For both catadromous species (e.g., eels) and amphidromous species (e.g., gobies, prawns), juveniles undertake mass upstream migrations from the sea to colonize rivers and streams to the upstream areas of the watershed.

Juveniles show different migration behaviors according to their taxa. Syciinidae are able to climb a quasi-vertical wet smooth concrete surface whereas eels or prawns need a less steep slope and a rough surface for crawling. Many other species are strict swimmers (e.g., Kuhlia sp. / silver fish, mullets, Mesopristis sp.).

Unless mitigation measures in the form of trap-and-haul systems are put in place to enable upstream migrating fish to move past the dam, or releasing EFs to enable fish to pass upstream of the powerhouse tailrace to the base of the dam, the TRHDP facilities will present a non-passable obstacle to upstream migrating fish given:

(i) the height of the dam (approximately 53m);

(ii) the absence of water discharge along the face of the spillway (no possibility for Syciinids to climb);

(iii) the length of the by-passed section of river and its reduced flow stage most of the time; and

(iv) the absence of attractive outflow towards the by-passed section and toe of the dam.

Furthermore, Syciinids might be attracted by the power-station outflow and climb up into the turbines were they might accumulate and die in mass, causing a potential maintenance issue.

Without measures to enable fish to move up to, and over, the dam those fish species that currently utilize sections of the Tina River upstream of the dam will disappear from the river above the dam. The catchment upstream of the dam covers approximately 125km^2 and represents 50% of the Tina/Ngalimbiu watershed.

Some short life cycle species, like Gobiidae and prawns, will quickly (within 2 to 4 years) disappear from the upper catchment, whereas eels with a life span of up to 10 years or more, will continue to be found as large specimens many years after the dam is built. There are examples of Anguillidae (e.g., European eels), which are known for their longevity and are able to survive in captivity over a period of 80 years.

Assuming a sufficient EF is released in the by-passed section to attract upstream migrating juvenile fish, to the toe of the dam, an efficient trap-and-haul system will be required to enable climbing / crawling juveniles to pass up over the dam. Since it is technically difficult to reliably design a fish pass for strict swimmers, a trap-and-haul system is recommended. Strict swimmers represent about 40% of the number of identified species in the Tina River.

Impacts on Downstream Migration of Silver Eels and Larvae Of Migratory Species

Assuming an efficient system for moving upstream migrating juvenile fish (e.g., eels, Syciinids, Gobiids, prawns) past the dam is implemented, the downstream migration of mature eels and larvae of migratory species is likely to be significantly affected by entrainment into the power intake and headrace tunnel, followed by mortalities in the turbines due to contact with the runner blades, pressure fluctuation, turbulence and cavitation.

However, unlike Salmonids, these species do not present a homing behavior that sees adults returning to their natal streams. Rather, the upper watershed will be continuously stocked by upstream migration of juveniles that have had a life cycle in other coastal rivers in the Solomon Islands, as long as they can move, or be moved, upstream past the dam. In addition, downstream migrating species will be able to pass the spillway when floods take place since the spillway will release flood-waters in by the by-passed river, on average, 8% of the time (when the flow is higher than $24 m^3/s$). Otherwise, TRHDP will raise reservoir levels to spill water over the dam spillway during the short windows of seasonal outmigration.

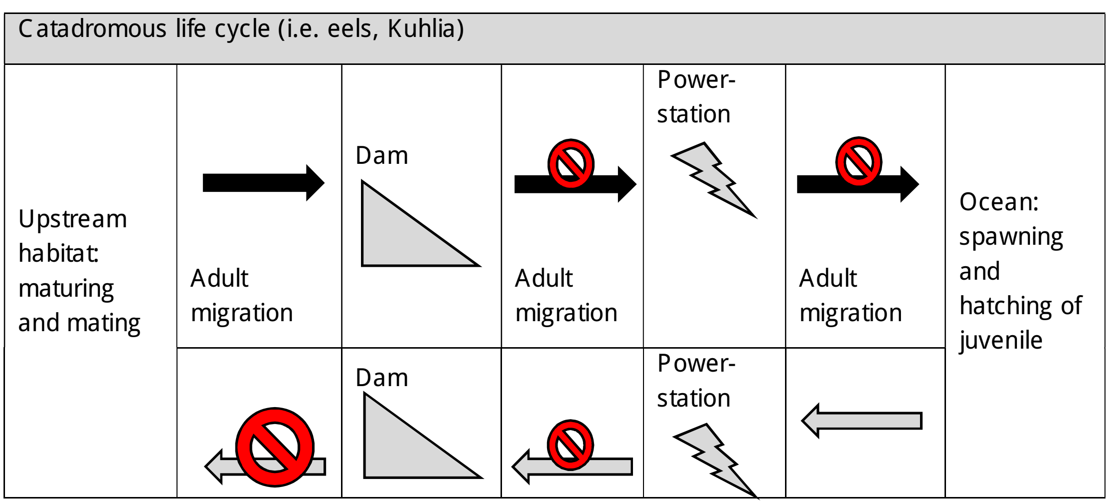
Impact significance pre-mitigation is considered to be major, since without specific measures to enable fish to move past the dam to the upstream Tina catchment, populations will become depleted within a few years. Table 11-14 summarises the impact assessment rating for barrier to fish passage.

Table 11-14 Impact rating for barriers to fish passage

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
High for fish and crustaceans	Major – potential disappearance of fish in upper Tina River cathcment	Localised – within Tina River	Permanent	High	Major

Table 11-15 is a synthesis of fish migration impacts on the two types of lifecycle migration schemes (catadromous and amphidromous) due to the dam and the powerhouse. The large bi-sected circles represent total blockage to fish migration, and the small bi-sected circles represent partial blockage or mortality of some fish species.

Table 11-15 Synthesis of fish migration stages and impacts



	Juvenile/ maturing migration		Juvenile migration		Juvenile migration	
Anadromous life cycle (i.e. Gobiidae, Sicydiinae)						
Upstream habitat: maturing, mating and spawning	Larvae migration	Dam	Larvae migration	Power-station	Larvae migration	Ocean: larvae maturing into juvenile
	Juvenile migration	Dam	Juvenile migration	Power-station	Juvenile migration	

Impacts on Fish Movement at the Mouth of the Ngalimbiu River

Sicydiinidae juveniles gather en masse at the mouths of rivers before commencing their upstream migration. This massing of fish in a relatively confined area supports important traditional fisheries. This has been described in rivers on other Islands (e.g.,Tahiti, La Reunion), and was observed at the mouth of the Ngalimbiu River during the field survey (see Annex 1 of the Annex report).

Local fishermen have a certain knowledge regarding what the triggers mass gatherings. Concentrations of Sicydiinidae juveniles at the mouths of rivers is said to be triggered by freshwater flow into the marine environment, together with tidal cycles, with the drop in salinity in the coastal zone being the main factor.

At the mouth of the Ngalimbiu river, the daytime (peak hour) operation of the dam will not noticeably affect flow given the short retention time of water in the reservoir. During nighttime, flow will be reduced by up to 66% at the Ngalimbiu River mouth. Considering the long term, the Project is unlikely to affect the baseline situation of juveniles massing at the mouth of the river and subsequently entering the river as they commence their migration upstream.

Overall, the effects of changed water flows between the dam and the powerhouse will have only minimal effects on aquatic ecosystems downstream at the mouth of the river, where the effects will be diminished due to proportional changes that will occur as the river flow is supplemented by contributions from tributaries downstream of the project.

Blockage of the river mouth due to changes in river discharge brought about by the project are unlikely, since the combination of peaking flow releases, E-flow releases during non-generation periods, and periodic flood releases over the dam spillway, will ensure that a channel continues to be cut through the bar at the mouth of the river. This will ensure access into and out of the river for fish species undergoing diurnal or seasonal migration.

11.4.4.3.2 Mitigation Measures

To mitigate impacts, the following measures will be implemented:

- Trap-and-haul system for upstream migration of `target species_ juveniles; and
- Fish screens at the power intake to minimise entrainment of adult eels (i.e., silver eels) into the turbines

These measures are detailed in Appendices G and H, respectively.

11.4.4.3.3 Residual Effects and Their Significance

With the installation of a trap-and-haul system, and fish grids to prevent eels from becoming entrained into the power intake and suffering damage or mortality in the turbines, the major pre-mitigation impacts could be reduced to moderate impacts, as long as a minimum EF release is implemented.

11.4.4.4 Changes of Flow Downstream of the Dam

11.4.4.4.1 Impact Identification and Rating

The flow to the powerhouse will be diverted through a 4.5km long power tunnel. The 5.7km by-passed section of river between the dam and the powerhouse, will experience reduced flow most of the time.

The engineering assessment showed that the power station will generally operate at, or in excess, of historic minimum river flow, supplemented by water from the reservoir when inflow is less than minimum machine flow. The maximum machine flow is 24m^3/s (4 turbines x 6 m^3/s).

Figures 11-4 and 11-5 provide the following information:

- River inflow to dam upstream of the dam (blue line)
- River flow directly downstream of the dam (with the 1m^3/s EF) (red line)
- River flow directly upstream of the powerhouse (with the lateral inflow in the by-passed river section estimated to be about 1m^3/s) (green line)
- River flow directly downstream the powerhouse (purple line).

These figures do not show the daily variation in flow pattern due to storage and daily release for peak hours. For the daily variation, see Figure 11-6.

Figure 11-4 Dry year river flows - daily balance operation of Tina Hydro (no peak operation)

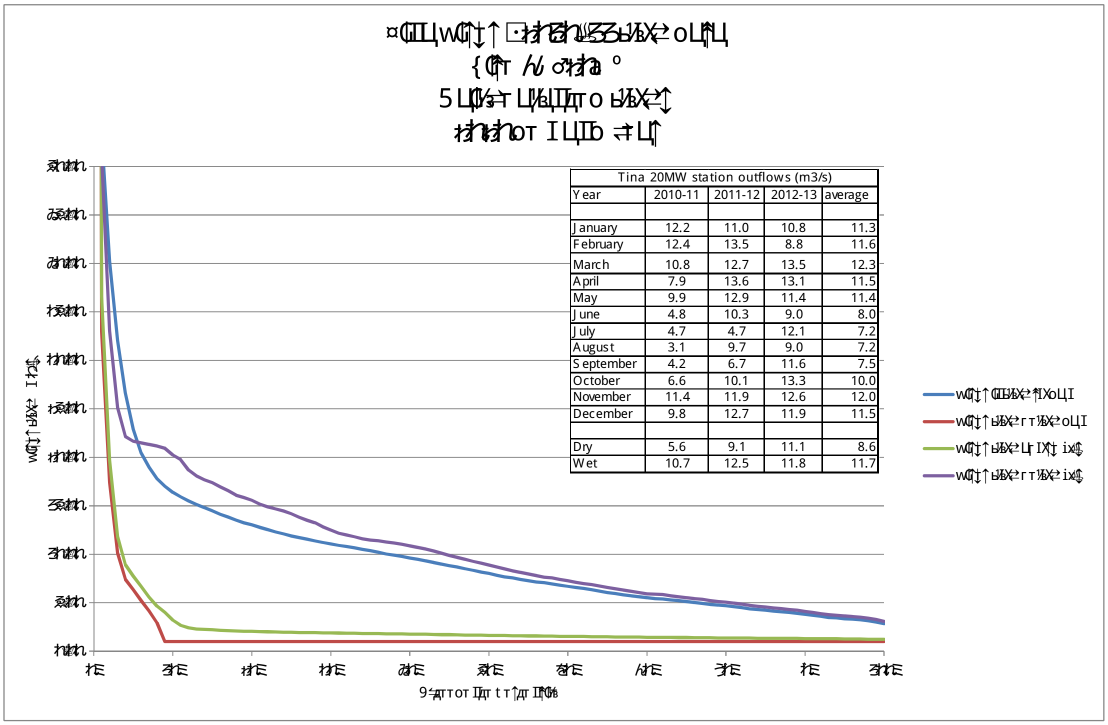
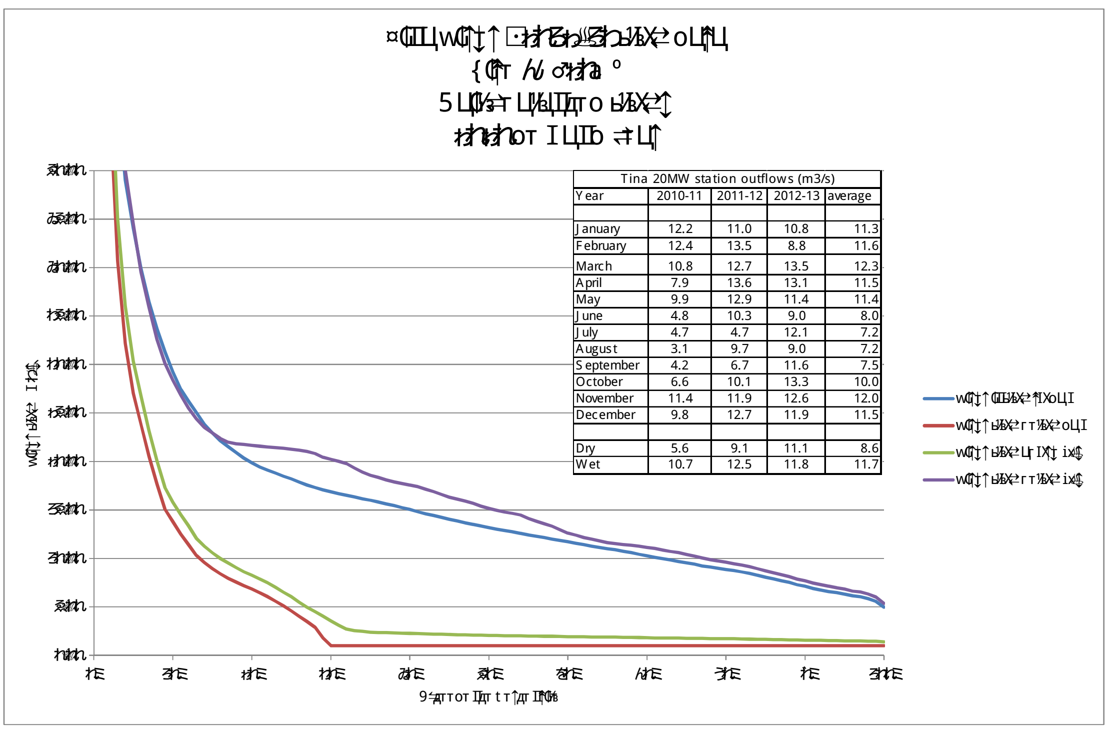


Figure 11-5: Wet year river flows ¯ Daily balance operation of Tina Hydro (no peak operation)



Based on these figures, the following impacts are predicted to occur:

During a dry year:

é River flow directly downstream of the dam (red line) ¯ for 92 % of the time, the River will not receive more than 1m^3/s EF, and 8 % of the time the spillway will overflow releasing floods.

é River flow directly upstream of the powerhouse (green line) - lateral inflow in the by-passed river section is estimated to be about 1m^3/s and will add to the 1m^3/s EF directly downstream of the dam.

é River directly downstream of the powerhouse (purple line) ¯ the flow daily balance will mimic natural flows as seen upstream of the dam (blue line). However, variation within a given day will be significant as shown in Figure 11-6.

During a wet year:

é River flow directly downstream of the dam (red line) - for 70% of the time, the River will not receive more than 1m^3/s EF, and 30% of the time the spillway will overflow releasing floods.

é River flow directly upstream of the powerhouse (green line) - lateral inflow in the by-passed river section is estimated to be about 1m^3/s and will add to the 1m^3/s EF directly downstream of the dam.

é River directly downstream the powerhouse (purple line) - flow daily balance will mimic natural flows as seen upstream of the dam (blue line). However, variation within a day will be significant as shown in Figure 11-6.

Flows will not change upstream of the reservoir as a consequence of the Project.

Flow Variation Within a Typical Day

TRHDP PO has provided an example of a typical weekday flow regime and a typical weekend day flow regime, as shown in Figure 11-6.

Figure 11-6 Flow variation within a typical day

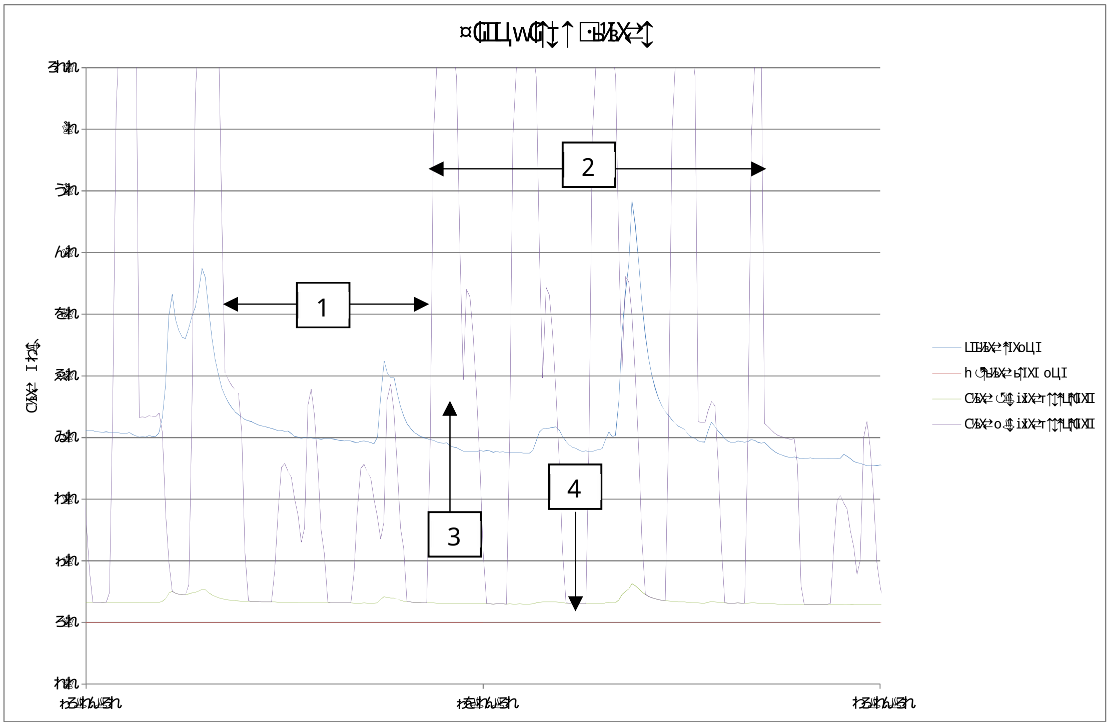


Figure 11-6 can be interpreted as follows:

- Box 1 - during weekends, the powerhouse will generate less power, creating lesser flow releases downstream of the powerhouse (4m^3/s to 5m^3/s).
- Box 2 - during weekdays, the powerhouse will generate more power, creating higher flow releases downstream of the powerhouse (up to 24 m^3/s)
- Box 3 - shows an example of release during a weekday. These releases will take place during the daytime and evening (peak hours).
- Box 4 - shows an example of powerhouse not producing any electricity during the nighttime (off-peak hours), thus not releasing any water. During nighttime, flow downstream of the powerhouse will equal the 1m^3/s EF (red line in Figure 11-4) plus the ~1m^3/s of inflow from the lateral tributaries (green line). During nighttime, the flow will, therefore, be significantly reduced until the confluence with Toni River (~ 2m^3/s) and will be reduced by 66% in the Ngalimbiu River (i.e., since the Toni River accounts for roughly 33% of the Ngalimbiu River system).

A significant flow reduction, mainly noticeable during nighttime and during dry years, will break ecological continuity of the river and create disturbance for water uses. As mentioned in Section 7 – Biological Environment Baseline - Aquatic, in the Solomon Islands, many aquatic animals, especially eels and prawns, are active at night.

In comparison to current baseline flow conditions, the nighttime flow of 2m^3/s in the Tina River will be slightly lower than the lowest recorded flow of 2.85m^3/s, which is the lowest recorded flow between 2010 and 2013, The daytime flow of approximately 24m^3/s will be higher than the average flow during a typical wet season month (i.e., March with 21.94m^3/s).

Due to a lack of specific details on planned operational regimes, it is still not possible to assess the dam and reservoir operation impact on the river hydrology on a seasonal basis.

Figure 11-6 assumes that the EF will be released during off peak and peak hours, with the bypass valve continuing to remain open to release the EF.

River System Response to Rainfall

Under baseline flow conditions, the Tina/Ngalimbiu River system is highly responsive to rainfall on the upper watershed. The flow varies over short periods of time and the river is subject to several flash floods throughout the year.

The operation of the hydropower systems is driven by power demand and is unlikely to mimic natural flow regimes. As such, schemes typically result in major changes to flow patterns from baseline conditions.

Once the dam is operational, the flow regime will be attenuated due to the presence of the reservoir, with low flows being supported and high flows being reduced.

The design of the dam may allow a certain regulation of flash flood events, especially if a storage capacity is planned to store these peak inflows for energy production. Entura (2014) anticipated such a management regime - the dam is designed a normal operating level (NOL) of 172masl three meters lower than full supply level (FSL) of 175masl), giving a flood storage volume of approximately 1Mm^3.

It should be noted that this regulation effect is only valid for a moderate rainfall event. The regulation volume of 1Mm^3 corresponds to a runoff volume after 8mm of rainfall on the whole watershed

Beside this regulation, exceptional discharge of storage water from water outlets may occur (e.g., to create a storage capacity or for maintenance or safety reasons), resulting in an artificial flash flood effect.

11.4.4.4.2 Impact Identification and Rating

The impact is considered to be major as the change to the flow regime is permanent and will lead to:

é Major modifications of the 5.7km by-passed river reach; and

é Noticeable changes at night, downstream of the powerhouse.

In addition to this, there is some health and safety risk associated with the sudden release of flows downstream of the powerhouse as power is dispatched. A warning system that reaches as far as the river month would need to be implemented (Section 12 ¯ Assessment of Socio-economic / Socio-community Impacts, and ESMP).

Table 11-16 summarises the impact on changes of flows downstream of the dam.

Table 11-16 Impact rating for river flows downstream of the dam

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating

Moderate ‾ for river ecosystem	Major ‾ impact on ecological continuity	Localised ‾ 5.7km section of the Tina River	Permanent	High	Major

11.4.4.4.3 Mitigation Measures

To mitigate the effects of peaking operation dewatering of the Tina River between the dam and the powerhouse, it is proposed to release an EF of 1m^3/s into the by-passed section of river.

Detailed analysis of the EF as a mitigation measure is included as Appendix I.

The main rationale for EF release is to create an environment within the by-passed section of the river current that enables fish to move to the toe of the dam, and an attraction flow at the top of the dam, to entice fish to enter a trap-and-haul fish pass system.

The release of an EF is a necessity required to maintain spatial and temporal hydraulic continuity in the by-passed river section to provide for the needs of aquatic life and riparian communities. This EF must be maintained day and night expect during flood spill events.

If no EF is released, the 5.7km section of by-passed river is likely to be severely dewatered most of the time (i.e., approximately 92% of the time) (see Entura Phase 3 report, March 2014) as the capacity of the 4 turbines (24m^3/s) will exceed the Tina River inflow.

11.4.4.4.4 Residual Effects and Their Significance

With the implementation of EF of 1m^3/s EF, combined with an expected additional 1m^3/s dry season inflow from smaller lateral streams, and designing the system to release up to 2m^3/s based on an adaptive environmental management approach, the pre-mitigation impacts that were noted as major, would be reduced to moderate and, therefore, are not significant.

11.4.4.5 Conclusions Regarding Barriers to Fish Movement

11.4.4.5.1 Fish Passage and Exclusion

Various types of mitigation measures were considered for maintaining upstream and downstream fish passage, and protecting fish from physical damage. These include:

- Upstream migration of juveniles of targeted fish species:
  - Trap-and-haul system ‾ trap juvenile fish that have congregated at the toe of the dam, and haul them up over the dam by tanker truck to be released in the upper catchment area. This would require an EF of 1m^3/s to facilitate movement of fish upstream through the 5.7km of by-passed section of river and provide sufficient attraction water to entice fish into the trap.

    A variant of this mitigation method would involve capturing juvenile fish at the mouth of the Ngalimbiu River, when they congregate to commence their seasonal upstream migration, then trucking them to a point upstream of the dam.

- o Fish barrier ‾ fish screens or other form of barrier would be installed at the turbine tailrace to exclude upstream migrating juvenile fish of climbing species from entering the turbines.

- Downstream migration of adult eels:

  - o Adjust reservoir level ‾ during the period when adult eels move downstream on their annual migration, the reservoir would be filled to the point where water is spilled over the spillway, drawing adult eels with it.

  - o Install fish screens ‾ fish screens would be installed at the power intake structure to exclude eels from being entrained into the power tunnel and turbines (see Appendix H).

A trap-and-haul system combined with an EF of $1m^3/s$ is considered the only potentially viable system to ensure fish can continue to populate the upper catchment area and, therefore, warrants additional study. The EF of $1m^3/s$ has the further advantage of ensuring river users along the by-passed section or river (i.e., at Choro, Koropa, Sengue) continue to have access to water, that ecotourism at Sengue is maintained, and that the aquatic ecology of the by-passed stretch of river is supported.

A fish barrier or repelling system is recommended for installation in the powerhouse tailrace to prevent mortality of upstream migrating juvenile Syciinids when they enter the turbines.

Further, it is recommended that the potential to farm fish within the reservoir be considered if this could be accomplished using species of fish that are native to the Ngalimbiu river system, and which could thrive in a lentic environment. Monitoring of species would need to be done to verify the efficacy of such a program.

Although, none of the fish species utilizing the Tina/Ngalimbiu River system will be permanently lost from the Solomon Islands if these mitigation measures are not implemented, the loss of viable fish populations from the upper Tina River catchment is an unnecessary impact, given the apparent efficacy of mitigation measures that are available.

11.4.4.5.2 Adaptive Environmental Management

An adaptive environmental management approach will be implemented in support of the proposed trap-and-haul fish passage system. This will involve the implementation of new or modified mitigation measures in response to unanticipated environmental effects. This could include the need to modify environmental flows at given times of the year, or modify the location, timing or design of trap structures to improve the efficiency of the trap-and-haul fish pass system.

The adaptive environmental management approach will follow that suggested by the European Bank for Reconstruction and Development (EBRD)[73], and includes to following five steps:

1. Incorporating structural and operational mitigation measures into project design and construction, that are tailored to the fish population(s);

[73] EBRD, Environmental and Social Guidance Note for Hydropower Projects (undated).

2. Maintaining mitigation structures (e.g., attraction water flows, trap structures, tanker trucks, etc.) to ensure functionality;
3. Monitoring fish populations throughout project development (pre-, during, and post-construction) to identify residual impacts;
4. Modifying structural components (e.g., location and design of trap-and-haul system) or operations (e.g., quantity, ramping, timing of flow releases; timing of trap-and-haul activities), to mitigate significant unexpected impacts; and
5. Striving for no net loss, and preferably net gain, of fish biodiversity and abundance within the Tina River.

11.4.4.6 Changes in Sediment Downstream Dynamics

11.4.4.6.1 Impact Identification and Rating

Suspended sediment and bed-load will enter the reservoir from the upper catchment. A significant proportion of suspended sediment is likely to pass through the reservoir through either the powerhouse or. However, bed load will be trapped in the reservoir. According to Entura (2014) the dam could accumulate approximately 50,000m^3/y of suspended sediment, and 45,000m^3/y of bed load material.

Dams interrupt the action of the conveyor belt of bed load sediment transport. Typically, downstream of a dam water will have enough energy to move lighter sediment fractions (i.e., silts, sand), but has little or no capacity to transport the heavier (pebbles, cobbles and boulders) bed load sediment, thereby starving the river below the dam of the lighter sediment fractions. The effect will be to erode the channel bed and banks, and produce a river channel that is incised and comprised of coarse bed material.

The lack of sediment recruitment, downstream of the dam, especially sand and gravel sized particles, is associated with the changes in hydrologic and hydraulic conditions, including a decrease in occurrence and magnitude of flash floods. The effect is a significant change in sediment dynamics on the riverbed and banks downstream of the dam.

These changes may occur over the long term, since in the short term, unrestricted sediment inflows will continue from below the damsite and from the Toni River. Potential increased erosion and geo-morphological changes of the banks and riverbed may have consequences on river dependent biota (terrestrial and aquatic), and river uses (see Section 12.8 ¯ Impacts on Natural Capital).

Effects on gravel recruitment will be somewhat augmented by the periodic flood releases over the dam spillway. Although gravel recruitment into downstream reaches will be regulated by the dam, there is a significant amount of gravel remaining within the river bed and along its banks, such that recruitment will continue downstream to the mouth of the river with each flood release. An assessment by a fluvial hydrologist will be undertaken to determine the approximate time period before these processes may have a negative impact on the mouth of the river. Periodic flushing or dredging of sediments from the reservoir will be required to control reservoir sedimentation. The assessment to be undertaken by the fluvial hydrologist will help to determine the extent to which reservoir sediment removal will mitigate the issue of downstream gravel recruitment.

Impacts associated with changes in downstream sediment dynamics are considered to be moderate. Table 11-17 summarises the impact assessment.

Table 11-17 Impact rating for downstream sediment dynamics

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate ¯ for river ecosystem and resource users	Minor	Localised ¯ damsite to Toni River confluence	Permanent	Moderate ¯ but difficult to predict	Moderate

11.4.4.6.2 Mitigation Measures

According to Entura (2014), provision of large flushing outlets at the base of the dam would be expensive and technically complicated due to the RCC type of dam. The feasibility study proposes a local flushing outlet (scour outlet) in front of the headrace tunnel intake, which would enable flushing material from within the vicinity of the intake tunnel. The beneficial effect of flushing on sediment continuity would be limited, since flushing would affect only a localised area nearby the tunnel intake and would only be done once the tunnel intake is threatened by buildup of sediments.

The design of the dam does not provide for a low-level outlet to sluice sediments. To mitigate impacts of reduced sediment transport and recruitment an equal amount of sediment that is retained within the reservoir could be artificially added downstream by dredging or excavating from within the reservoir, hauling the material to locations downstream of the dam, and depositing it along the riverbed. According to Entura (2014), mechanical removal of trapped sediment or upstream sediment from gravel bars to inject into an area downstream would cost roughly US$1m every 5 years, based on a few US$/m^3. By comparison, sediment removal from California reservoirs ranges from US$15/m^3 to US$50/m^3 (Kondolf, 1997). When required, the reservoir level could be lowered through the outlet during the dry season to expose the sediment beds, which could then be excavated and removed from the reservoir and injected downstream of the powerhouse or provided to downstream affected communities that rely on gravel extraction as a source of cash income. This measure would mitigate the impact on sediment dynamics downstream.

Monitoring of river geomorphology and sediment transport could be done to study long terms effect of sediment recruitment downstream and to follow up on erosion downstream. Parameters that could be studied include:

é Quantity of gravel extracted along Ngalimbiu River by local industries, versus quantity that would need to be artificially injected;

é Sand and gravel inputs from upstream areas;

é River bed sediment grain size analysis; and

é Depositional areas and pattern of sediment-starved water erosive behavior.

11.4.4.6.3 Residual Effects and Their Significance

The residual impact is considered to be low if sand and gravel is artificially deposited downstream and is, therefore, not significant.

11.4.4.7 Reservoir Stratification

11.4.4.7.1 Impact Identification and Rating

Stratification in a reservoir occurs when the upper zone of the reservoir (epilimnion), which is characterized by well-oxygenated water, is thermally divided from the deeper zone (hypolimnion), such that the hypolimnion becomes stagnant and is lacking in dissolved oxygen. This results in an anaerobic environment.

According to Entura (2014), a rapid estimate of stratification tendencies in a reservoir can be obtained with the Densimetric Froude Number (F):

$F = 320 (L/D)(Q/V)$ with L = length of the reservoir (meters); D = mean reservoir depth (for which dam height may be a proxy); Q = mean water inflow (m^3/s) and V = reservoir volume (m^3)

Therefore, for the TRHDP reservoir, the Froude number is:

$F = 320 (L/D)(Q/V) = 320 \times (2{,}500 / 53) \times (11.5 /7{,}000{,}000) = 0.024$

If the Froude number is less than 1, some stratification is expected, the severity of which increases with a smaller F. If the Froude number is greater than 1, stratification is not likely to occur (Ledec and Quintero, 2003).

The Froude number for the proposed reservoir, calculated based on the characteristics of the preferred alternative (Option 7c) is 0.024.

This rapid assessment suggests stratification is possible and a further analysis of reservoir residence time is required. The more detailed analysis of residence time (Jorgenson et al. 2005) suggests that reservoir stratification is not likely but may occur.

The residence time of the proposed reservoir when full is approximately 7 days at median flow of 11.1 m^3/s and the average flow depth is approximately 10 m (Entura 2014). Relationships between temperature differential thermal (stratification) and residence time (Jorgenson et al. 2005) show virtually no thermal stratification in a reservoir with a residence time of 7 days. Some stratification may occur, and a hypolimnion with a low dissolved oxygen concentration may develop. Stratification will be more likely during the lower inflows of the dry season. There is a significant possibility of short-lived periods (weeks to months) of stratification during periods of low flow. Higher flow periods are likely to break down the stratification.

However, with the reservoir bottom at 122 masl and full supply level at 175 masl, it is unlikely that the hypolimnion would extend upward to 162 masl, the level from which water is withdrawn for the turbines and the environmental outlet. Consequently, the discharge of surface water from the reservoir through the spillway, tailrace and environmental flow outlet is unlikely to cause any measurable change in dissolved oxygen downstream because these withdrawals are all from what would be the epilimnion in a stratified lake.

A variable-depth outlet for the environmental flow is under consideration, and the Reservoir Management Plan will include monitoring of dissolved oxygen and temperature at multiple depths to provide advance warning of potential water quality problems.

Based on this analysis, the impact is considered to be moderate. Table 11-18 summarises the impact assessment.

Table 11-18 Impact rating for reservoir stratification

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate – for aquatic life in the reservoir	Minor	Localised – reservoir	Permanent	Low - Moderate	Moderate

11.4.4.7.2 Mitigation Measures

No mitigation is required to address reservoir stratification since the location of the water intake for the headrace tunnel and the outlet valve for the EF are both located in the epilimnion of the reservoir, not the deeper hypolimnion. EF releases downstream of the dam and released from the powerhouse will not be affected by low oxygen concentrations.

11.4.4.7.3 Residual Effects and Their Significance

As long as the water intake takes water from the epilimnion there will be no appreciable impact on water quality and, therefore, no impacts to downstream ecosystems. Residual impact significance is low and, therefore, not significant.

11.4.4.8 Reservoir Water Quality

11.4.4.8.1 Impact Identification and Rating

Unless the reservoir area is cleared of vegetation, reservoir filling will inundate rainforest covering the slopes and bottom of the valley.

The decomposition of organic matter can result in depletion of oxygen levels in the hypolimnion layer of the reservoir, and produce greenhouse gases and other reductive compounds (ammonium, hydrogen sulfur, carbon dioxide and methane).

Even with most of the vegetation removed, water quality in the hypolimnion layer is likely to be significantly altered, at least during the first months after impoundment.

However, impact significance is considered to be low, as this impact is temporary. Table 11-19 summarises the impact assessment.

Table 11-19 Impact rating for reservoir water quality

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate – for aquatic life in the reservoir	Moderate	Localised – reservoir	Temporary – first few months after impoundment	Moderate – based on the Froude Number	Low

11.4.4.8.2 Mitigation Measures

To mitigate impacts on reservoir water quality and production of GHG, vegetation will be cleared from the area of the future reservoir. This vegetation consists mainly of herbaceous and woody stemmed (bushes, vines and tree) plant communities. Their removal will mitigate impacts on water quality by reducing oxygen demand as vegetation disintegration consumes oxygen. Vegetation clearance will be carried out during the dry season. Organic matter in the riverbed and sediment matrix will also contribute to some oxygen depletion. However, relative to the amount of organic material bound up in vegetation, the amount of organic material in the river bed and sediments is low.

Access in the forest to allow for vegetation clearing within the future reservoir area is an issue since:

é Access from the river valley to clear vegetation will be difficult due to the tography of the steep-sided river gorge, where flash floods would pose a threat to worker safety; and

é Two possible quarry sites have been identified by Entura (2014) in the reservoir area without defining any access road. Once access roads have been identified, they could be used to provide access for vegetation clearing and timber removal.

Due to the steep topography, it is recommended that vegetation be manually removed by workers hired from local communities, and that the relatively thin layer of organic topsoil be left in place. Sawn timber could be transported either by access road or by river as it is currently done from Choro and Koropa.

11.4.4.8.3 Residual Effects and Their Significance

By removing most vegetation from the reservoir prior to inundation, the residual impacts resulting from decomposition effects on water quality are considered to be low, and not significant.

11.4.4.9 Alteration of Water Quality Downstream of the Reservoir

11.4.4.9.1 Impact Identification and Rating

The intake to the headrace tunnel at 161masl to 164masl will be situated a few meters below the MOL (170masl). The operation of the powerhouse will release water from the epilimnion layer. Although the reservoir will be stratified, by taking water from the upper oxygen rich layer, water quality issues will be avoided. The lower oxygen concentration and toxic reduction compounds found in the hypolimnion will not affect downstream water releases.

Nevertheless, in comparison with the baseline condition, the presence of the reservoir may induce a small increase in water temperature, a higher concentration of organic matter and nutrients, and a lower concentration in suspended solids during heavy rain periods. On those occasions when accumulated sediment is expelled from in front of the power tunnel intake, sediment-laden waters will be released downstream. Otherwise, the water released downstream will be clear.

Water released as EF from the dam and from the powerhouse tailrace is unlikely to have significant impacts on aquatic life and water uses. Therefore, impact significance is considered to be low. Impact duration will be temporary, likely lasting only a few months after impoundment. Table 11-20 summarises the impact assessment.

It is not anticipated that reservoir operation will have a deleterious effect on water quality at the mouth of the river during operation. Rather, the reservoir will act as a sediment filter, settling out sediments and organic debris, as water it enters and passes through the reservoir. The exception will be during major flood events, when suspended sediment laden water will be released over the spillway and through the powerhouse tailrace. However, this condition is already part of natural storm events that regularly affect the Tina River

Table 11-20 Impact rating for downstream water quality

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate – for aquatic ecosystem and water uses downstream	Minor – in the hypolimnion	Localised – river downstream of dam and powerhouse	Temporary – first few months after impoundment	Moderate – based on the Froude Number	Low

11.4.4.9.2 Monitoring Measures

No mitigation is anticipated to manage quality of water released as EF and power generation flows from the reservoir. However, dissolved oxygen and temperature will be monitored at multiple depths in the reservoir and water quality monitoring will be undertaken downstream (see Section 13 – Environmental and Social Management Plan) to confirm this prediction.

11.4.4.9.3 Residual Effects and Their Significance

No residual impacts are anticipated and, therefore, impacts are low and not significant.

11.4.4.10 On-Going Disturbance to Downstream Aquatic Habitats and Aquatic Life

11.4.4.10.1 Impact Identification and Rating

Changes in flow patterns and sediment dynamics downstream of the dam, have the potential to affect aquatic life in this part of the river, with possible loss of breeding and rearing habitats. However, aquatic life downstream of the powerhouse is naturally adapted to rapid flow changes and should be quite resilient to new flow patterns caused by the TRHPD facilities.

Assuming water quality is not appreciably affected during operation of the dam, no significant impacts should accrue to the most sensitive species or life stages, or to the commercial fisheries at the mouth of the river.

Therefore, impacts are considered to be moderate, it is a permanent impact. Table 11-21 summarises the impact assessment.

Table 11-21 Impact rating for disturbance to downstream aquatic habitats and aquatic life

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate - for aquatic life and habitats downstream	Low - no significant disturbance	Localised - river downstream of dam and powerhouse	Permanent	Moderate - based on the Froude Number	Moderate

11.4.4.10.2 Mitigation Measures

Measures mitigate impacts on downstream aquatic habitats and life of aquatic organisms will include:

- Water quality monitoring, including for suspended solids downstream of the construction site;
- Ensuring EF releases to the by-passed section of the river;
- Maintaining a minimum flow of at least 3.43m^3/s below the powerhouse plus inflows (equivalent to the minimum operational discharge of one turbine (2.43 m^3/s), in addition to the by-passed reach environmental flow (1 m^3/s)); and
- Installation of fish screens to prevent entrainment and mortality of silver eels.

It is recommended that as part of the Stakeholder Engagement Plan downstream communities who depend on the fishery at the mouth of the river be consulted on a regular basis.

11.4.4.10.3 Residual Effects and Their Significance

Since mitigation is primarily in the form of monitoring to ensure problems are avoided, residual impacts will persist as moderate impacts, but are not significant.

11.4.4.11 Establishment of a Lake Ecosystem in the Reservoir

11.4.4.11.1 Impact Identification and Rating

The construction of a reservoir usually leads to a change in the baseline fish assemblage, with development of pelagic or low velocity/stagnant water species and regression of rheophillic species.

In Guadalcanal, some native species are likely to benefit from the reservoir environment, assuming that trophic resources are available. These species include Kuhlia, Mesopristes (silver fish), and mountain mullet. These are usually strict swimmers that are not expected to migrate upstream of the dam if a fish pass was available. However, with a trap-and-haul place is implemented, these fish species will potentially be moved above the dam and continue to produce within the upper catchment area.

Invasive aquatic plant macrophytes such as Water Hyacinth, are unlikely to become well established in the reservoir if accidentally or intentionally introduced, given the short water retention time with its expected low concentration of nutrients, and the daily fluctuations in water levels. Nonetheless, a prevention and control plan will be prepared and implemented.

Impact significance is considered to be moderate. Table 11-22 summarises the impact assessment.

Table 11-22 Impact rating for lake ecosystem in reservoir

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate ‑ for aquatic life and habitats in the reservoir	Low ‑ assuming no introduction of invasive species	Localised ‑ reservoir	Permanent	Moderate ‑ based on the Froude Number	Moderate

11.4.4.11.2 Mitigation Measures

Aside from proposing a plan to prevent / control the introduction and growth of invasive aquatic plant macrophytes within the reservoir, no other mitigation measures are considered. Reservoirs generally provide an opportunity for a fishery to be developed. Such fisheries have the potential to be more productive than the previous riverine fisheries, depending on whether native or invasive fish species are to be introduced.

In the Tina River, native species such as silver fish (Kuhlia or Mesopristes), which grow to relative large size, and are appreciated by local communities, may potentially thrive in the reservoir and might support a fishery. However, due to their freshwater / ocean life cycle that will be interrupted by the dam, it will be necessary to stock the reservoir by collecting fry at the toe of the dam, or at the mouth of the Ngalimbiu River and then transfer them into the reservoir.

11.4.4.11.3 Residual Effects and Their Significance

Restocking native Tina River fish into the reservoir to maintain a viable population, if successful, will reduce potential residual impacts to a level where they could be considered not significant, notwithstanding that the species assemblage will change.

11.4.4.12 Ongoing Disturbance to Water Uses

11.4.4.12.1 Impact Identification and Rating

Though people in local communities are used to flash floods on the Tina River, the flow variations induced by the dam and powerstation operation - and to a lesser extent, the alteration of water quality - might disturb the way people use the river for subsistence fishing, collection of drinking water, washing clothes, and recreational activities, especially between the dam and the confluence of the Tina/Toni rivers. This will require that people their activities. Another challenge will be to ensure the safety of people downstream of the powerhouse as flow releases ramp up in response to peaking generation flow releases.

Impact of disturbance to water uses is considered to be moderate, based on it being a permanent impact. Table 11-23 summarises the impact assessment.

Table 11-23 Impact rating for disturbance to water uses

	Impact Significance Rating				
Component value	Magnitude	Extent	Duration	Probability	Overall Rating
Moderate ‑ water uses	Moderate	Localised ‑ river downstream of dam and powerhouse	Permanent	High	Moderate

11.4.4.12.2 Mitigation Measures

Proposed mitigation measures to address disturbances to water use are provided in Section 12 ¯ Assessment of Socio-economic / Socio-community Impacts. In summary they include:

- Providing river-based supply with appropriate treatment systems and supply points for each village;
- Providing rainwater collection and storage tanks;
- Establishing alternative supplies from local streams, and;
- Providing borehole / ground water supplies, piped to several villages / hamlets.

Transportation and distribution of clean water will be done by tanker truck on a regular basis. The water will be stored in tanks at the village level.

11.4.4.12.3 Residual Effects and Their Significance

Although the proposed mitigation measures will help to reduce impacts, residual impacts will continue. They are considered to be moderate, but not significant.

11.4.5 Conclusion Regarding Operation Impacts

Impacts on aquatic ecology during operation are related to the presence of a dam, which presents an impassable barrier to all native fish due to its height. In addition, the by-passed section of the river, with its modified flow will also affect fish migration. Unless mitigation is implemented, all native fishes will disappear from the upstream Tina River catchment. In addition, fish mortality in the powerstation turbines is foreseen as some larvae will be entrained into the power intake and juvenile fish will be attracted to the tailrace outflow of the powerhouse.

With the implementation of an EF of $1m^3/s$ (almost $2m^3/s$ when combined with inflow from the intermediate catchment area), a trap-and-haul system to move eels, silver fish and Gobidea over the dam, use of fish screens or barriers at the powerhouse outlet, and fish monitoring, impacts may be reduced to an acceptable level.

Due to the limited efficacy of fish pass systems the fish pass option was rejected. However, combining an EF of $1m^3/s$ with a trap-and-haul system to move upstream migrating juvenile target fish species past the dam remains a potentially viable mitigation option, especially when combined with an adaptive management approach. The minimum flow of $1m^3/s$ will also be maintained in the by-passed reach to ensure that social impacts are mitigated (see Section 12 ¯ Assessment of Socio-economic / Socio-community Impacts) and fish stocking/farming program will be developed for reservoir fishery as a separate study.

Long-term operation of the Project should not adversely affect on the baseline situation regarding juvenile fish entering en masse the mouth of the Ngalimbiu River from the sea. Since observed species do not present a homing behavior, juveniles can colonize any river, not only their natal stream, so the Ngalimbiu River will continue to support fish.

Table 11-24 summarises impacts as well as residual impacts during operation of the Project.

Table 11-24 Summary of aquatic impacts

Impact from operatio	Impact before mitigation	Residual impact
Establishment of a reservoir	Moderate	Not Significant
Sedimentation of the reservoir	Moderate	Not Significant
Changes of flow downstream of the dam	Major	Not Significant[74]
Changes in sediment dynamic downstream	Moderate	Not Significant
Stratification in the reservoir	Moderate	Not Significant
Alteration of water quality in the reservoir	Low	Not Significant
Alteration of water quality in the river downstream	Low	Not Significant
Barrier to migratory fish species	Major in the upstream catchment. Minor in terms of overall fish biodiversity in the Solomon Islands	Potentially significant if recommended mitigation is not successful – follow adaptive management approach
On-going disturbance of aquatic habitat	Moderate	Not Significant
Establishment of a lentic biocenosis in the reservoir	Moderate	Not Significant
Disturbance of water uses	Moderate	Not Significant

[74] Pending results from ongoing Project monitoring

12. ASSESSMENT OF SOCIO-ECONOMIC / SOCIO-COMMUNITY IMPACTS

12.1 INTRODUCTION

This section addresses the potential socio-economic / socio-community effects of construction and operation of the preferred project alternative (Option 7c), while taking into account the issues identified by the local communities, stakeholder agencies and organisations, and the potential funders of the project. This section also presents the potential means of avoiding, mitigating, and managing project impacts that are consistent with policies and regulations of the SIG, World Bank, and donor agencies. It also addresses compliance of the TRHDP planning process with the World Banks Operational Policies and WB Performance Standards, including PS 7 on Indigenous People.

12.2 APPROACH

Each hydro development project has its own particular characteristics and features and will, therefore, generate specific beneficial and adverse social impacts. A Social Impact Assessment (SIA) was undertaken, the aim of which was to identify opportunities to maximise the benefits of the Project for the project-affected communities, and to minimise problems.

To assess the TRHDP, identification and evaluation of the social and cultural impacts were based on:

- Analysis of the records of consultations and awareness campaigns undertaken by the Project Office;
- Analysis of the project features and the social context by the ESIA team, drawing on experience of similar projects elsewhere, and international research (e.g., the World Commission on Dams), and;
- Several rounds of consultation via community workshops, and a householder survey, carried out by the ESIA team with the potential project-affected communities, individuals, and stakeholder agencies and groups

The SIA was prepared as part of the SIG˜s project environmental approvals. The assessment report ensures that the proposed development will comply with the World Bank Performance Standards for Projects Supported by the Private Sector (e.g., Performance Standard 7 on Indigenous Peoples).

A separate report, the Land Acquisition and Livelihood Restoration Plan (LALRP), sets out the impacts of the land acquisition for the Project. As the Solomon Islands˜Government is responsible for land acquisition, the LALRP is prepared in compliance with World Bank Operational Policy 4.12 (involuntary resettlement).

12.3 SOCIAL IMPACT ASSESSMENT METHODOLOGY

The social impact assessment methodology included the following:

- Review of the project planning documents, including the social impacts scoping study conducted by Entura, the fieldwork and background reports by the Pacific Horizons Consulting Group (PHCG), and other reports and briefing materials prepared for the project;

- Review of existing information (secondary data) covering the project area, its population and local customs, recent history of conflict, available census and other quantitative data related to population and resources as well as a review of any recent hydroelectric developments in Melanesia and in the South Pacific region;
- Review of the records of the three-year awareness raising/education programs and consultations conducted by the PO with local communities, organisations, agencies, and individuals;
- Rapid fieldwork visit in mid-2013 combined with consultation with key agencies and community leaders in the project area. This fieldwork enabled the project area to be zoned into 3 areas for social assessment: Downstream Area, Infrastructure Impacts Area and Wider Impact Area.
- Four-week interview program and participatory workshops in July-September 2013 with the Tina and Ngalibiu River communities, and adjacent land owner's communities in Malango. The 15 community focus workshops covered all of the villages in the project area, and had a total recorded (minimum) attendance of 511 people, 45% of whom were females, and covered the full range of age groups. In the Bahomea district at least 48% of participants attending the workshops were females. The workshops were arranged in advance with the help of the TRHDP PO and involved directly the locally-based community liaison assistants (CLAs);
- Rapid fieldwork visit in mid-2013 combined with consultation with key agencies and community leaders in the project area. This fieldwork enabled the project area to be zoned into 4 areas for social assessment: Direct Impact Area (DIA), Downstream Area, Infrastructure Impacts Area and Wider Impact Area.
- Four-week interview program and participatory workshops in July-September 2013 with the Tina and Ngalibiu River communities, and adjacent land owner's communities in Malango. The 15 community focus workshops covered all of the villages in the project area, and had a total recorded (minimum) attendance of 511 people, 45% of whom were females, and covered the full range of age groups. In the Bahomea district at least 48% of participants attending the workshops were females. The workshops were arranged in advance with the help of the TRHDP PO and involved directly the locally-based community liaison assistants (CLAs);
- List of all of the households in the villages that were involved in the community workshops. This was done by the local indigenous member of the ESIA team in discussion with senior women of each village;
- Face-to-face survey of over 50 female householders from across the villages within the project area. Survey questions covered the following topics: household's livelihood/s; division of labour; food and nutrition; health issues; access to resources; and anticipated issues with the TRHDP. The survey interviews were conducted, for the most-part, by the female community liaison assistants for the project in Bahomea and Ghaobata districts, and by the cultural issues specialist on the ESIA team.
- Face-to-face interviews and discussions with male and female officers of government agencies and non-government organisations having a direct or indirect interest in the Project;
- Review of the results of the community public awareness, consultation and mitigation workshops (e.g., in Bahomea (x2), Malango (x2), and Ghaobata (x1) in January-February 2014). These ESIA findings provided information on the potential impacts of the project and proposed responses to those impacts. Senior TRHDP officers were present to respond to technical questions or policy issues.

12.3.1 Village Community Workshops

All consultations, including workshops, were preceded by local announcements of the timetable, the purpose and the program. They were facilitated locally by members of the TRHDP PO CLAs and by community relations officers.

During the brief introduction of the village community workshops (which was given in English, Pidgin, and relevant indigenous language), participants were advised that:

- The ESIA team was independent of the TRHDP PO;
- Individuals' comments and viewpoints would be treated anonymously in the assessment; and
- People were free to stay or leave the meeting as they wished.

A consent form was distributed by the village chief/s.

During the workshops, questions were asked regarding peoples' awareness of the proposed project, and whether the participants and their communities supported the proposed Project, or not. As shown by the following photographs (see Figure 12-1 and 12-2), the community workshops were participatory and interactive. Each key topic of the project was discussed and displayed on a whiteboard.

Figure 12-1 Young people discussing the Project's impacts during the village workshops (Antioch (left) and Pachuki (right))

Figure 12-2 Householder's interviews

12.3.2 Mitigation Workshops

Mitigation workshops were used to discuss and obtain input on opportunities to mitigate potential project related impacts. The mitigation workshops followed the same methodology as the village community workshops: prior announcements, on the ground organisation by the project liaison officers and community liaison assistants, a brief introduction of the Project and meeting, and the distribution of consent forms.

The mitigation workshops were district-wide and were, therefore, larger than the village community workshops with larger venues (e.g., meeting halls). The workshops were attended by the TRHDP PO technical personnel who answered questions and provided technical explanations, when required. A buffet meal was provided by the TRHDP PO, in keeping with local custom. The minutes of these meetings are provided at Annex 14.

Figures 12-3 and 12-4 present photographs of mitigation workshops held in Bahomea and Malango.

Figure 12-3 Mitigation workshop in Bahomea

Figure 12-4 Mitigation workshop in Malango

12.3.3 Requirement for Free, Prior, and Informed Consent

The World Bank Performance Standards 1 and 7 stipulate that Free, Prior, and Informed Consent (FPIC) (see Appendix J) is required for the affected indigenous peoples at each stage of the project development. The TRHDP PO was responsible for planning delivery of the program and for informing, and consulting with, local communities and other stakeholders regarding the Project, including the overall project concept and design, generation option investigations and selection, detailed proposals, and matters related to the use of land and resources belonging to local communities. As noted in PS 1, paragraph 32, FPIC is also required for the assessment of the project˜s adverse and beneficial impacts.

12.3.3.1 Free, Prior and Informed Consent and Project Planning

As part of the ESIA, the question must be asked regarding whether the project processes have been consistent with the WB PS requirements for FPIC. This assessment can be made in two ways: a) by evaluating the awareness raising and stakeholder engagement plans of the TRHDP PO and the records of its meetings and interactions with stakeholders, combined with observations of field practice by the TRHDP PO˜s offices, and b) by noting feedback received from the communities and other stakeholders regarding the TRHDP PO˜s activities.

The TRHDP PO˜s community-wide engagement began in July 2010 with a program of awareness raising in the Bahomea and Malango districts, working with members of the then Land Owner Council (LOC). Prior to these activities, the TRHDP PO had been working with local leaders to establish processes and terms for involvement and land identification, and had participated in the establishment of the LOC, which included landowners from Gold Ridge, Bahomea and Malango.

Since 2012, consultations were largely guided by MMERE˜s :Tina River Hydro Development Project˜s Stakeholder Engagement Plan, March 2012˝, supplemented by additional activities as required. Annex 14 contains an overview of the TRHDP˜s community engagement activities. The objectives of the stakeholder engagement, as stated in the plan, included:

1. Deliver accurate, free and timely provision of information, manage expectations, and promote widespread awareness of the project;

2. Facilitate two-way communication with communities directly affected by the Project to:

(a) Understand the views and opinions of the community, including vulnerable, social and cultural groups regarding ways the Project may affect people, how these impacts can be limited or mitigated, and ways the project may provide benefits;

(b) Ascertain the level of broad community support for the Project at all stages;

(c) Ensure those being resettled (if any) by the Project have ample avenues to participate in resettlement planning and implementation, including their location and housing structure; and

(d) Address project concerns in a timely manner (MMERE, 2012).

As noted in the Socio-economic / socio-community Baseline, the engagement plan, MMERE˜s records of meetings with communities and their representatives, and other engagement activities since 2010, together suggest an ethical, well-organised, well-resourced, adaptative, and culturally appropriate ongoing program of consultation and involvement by the TRHDP PO with the project-affected people and communities.

With respect to `free_ consent, the TRHDP PO˘s activities and program suggest that there has been no coercion or intimidation on the part of the developers, and there has been no evidence of bribery or inducement for local people to be involved in discussions about the project. Conversely, some landowners and their tribal/clan leaders have demanded and received sizeable `access payments_ from the government, to allow site investigations, consultations, and related planning activities and meetings to proceed in the proposed project areas. In keeping with local custom and the expectations of local communities, the TRHDP PO has presented chupu (customary presentations) and extended hospitality to local chiefs and communities, as part of its activities.

Since the Ethnic Tensions, expectations of :compensation˘ payments by communities, and expectations of cash benefits derived from project planning steps, appear to have become the norm for any development in the Solomon Islands. This is in part born out of a concern that projects will not reach an operational stage, (exacerbated by repeated closures of Gold Ridge Mine and neighbouring oil plantations), and a concern that communities which lose access to natural resources will not receive adequate benefits from operational stages. This mentality, sometimes referred to as :rent seeking˘ is a considerable problem for ethical developers. Since the TRHDP represents a significant development for Guadalcanal and Solomon Islands, from time to time aspiring clan leaders, politicians, and `big men_ have attempted to utilize the community engagement and internal tribal consultation processes for their own purposes. So far as these attempts affect the sharing of cash benefits from the land acquisition, they are discussed and considered in the Land Acquisition Livelihood Restoration Plan. Local awareness-raising (information sharing) and consultation activities have been strongly supported by communities and local leaders.

Among the Ghaobata communities and their HOC, which have a lot of experience in dealing with industrial and resource developments within their region of the Guadalcanal plains, requests for payments to engage in project planning have been quite explicit. Under advice by knowledgeable senior people from this area, the TRHDP PO has avoided being drawn into direct negotiations with the HOC, and has instead been working through a Guadalcanal provincial government officer, and its own CLAs to provide information and to encourage local people to consult about the Project among themselves.

The flow of information from the TRHDP PO to the affected communities appears to have been of a high standard. The TRHDP PO recruited a well-known indigenous media person to develop and document the information sharing and awareness raising activities of the TRHDP PO. The presentation of information briefings to local communities and various groups of stakeholders at key points in the project planning process has been done in local languages, and has been accompanied by the use of audio-visual aids. Examples of material produced for communicating with stakeholders and the public generally included a project website, information booklets in English and Pidgin, posters, satellite and aerial photographs, and a DVD. Engagement activities by the TRHDP PO were recorded, lists of attendees were taken, and minutes were prepared of consultations, meetings, and issues arising. The TRHDP PO has also made a photographic record of its community awareness raising and consultation activities within the indigenous communities.

The awareness raising and consultation activities by the TRHDP PO commenced in the Tina/Ngalimbiu River catchment early in the development process (2009-10), prior to any investigations of suitable dam sites. Initially, consultations focused on landowner consent to undertake geological and hydrological investigations in the catchment. This involved identifying all the relevant clans and developing processes and arrangements for consultation with them. These arrangements evolved over time, and - as noted above - consultation processes were formalized in a stakeholder engagement plan, which was made available to the public. Project planning, including environmental and social assessment, has been ongoing, with information about the project design and its potential impacts being regularly provided to the relevant communities and stakeholders. At the time of this assessment report application for project approvals had not been made, nor had construction commenced. The early and sustained engagement with the affected communities has enabled the development of a good working relationship between the Project and local people, and for the inclusion of their concerns and knowledge into the consideration of various options for the hydro development.

The TRHDP PO has made use of a variety of culturally acceptable means for communicating with local communities and stakeholders. Important communications have been, and continue to be, done face-to-face, starting with clan and village chiefs, and senior women, and then extend out to the wider village communities. Local communications are undertaken by the project's indigenous community relations staff and CLAs, and endorsed by community leaders. A wide variety of communications tools have been used to inform the communities, and to receive comment and advice in return. Among these are: printed materials, including a project booklet; face-to-face briefings and discussions with groups of community leaders, individuals, community interest groups (e.g., mother's clubs, and church groups) and agency representatives; and mobile phone and SMS, presentations using video, photographs, maps, and posters and site visits.

Based on the records of the TRHDP PO, discussions with TRHDP PO staff and CLAs, observations, and explicit comments from participants during the 2013 ESIA village community workshops and 2014 mitigation workshops, it appears that:

- There is broad support among local communities for the Project and there is no clear direct opposition to it. A minority of clan leaders and aspirants objected publically to the land identification and acquisition process. A discussion of some of the current issues raised by a minority of clan leaders with respect to compensation is provided in the LALRP;
- Hydroelectric development is widely seen as the most preferred and least destructive development opportunity for the Tina/Ngalimbiu River catchment (others being gold mining and logging of primary forest);
- community concerns about the project are generally confined to the mitigation of potential impacts and the securing of benefits;
- There has been a comparatively high level of participation of community members of both genders and all ages in the TRHDP PO's activities.
- There is wide-spread understanding of the purpose of the TRHDP, and what it generally involves, although the details of particular hydropower generation options are not well understood, especially by women;
- There is a high degree of trust of the TRHDP PO and the information it has provided, and a sense that local peoples' concerns are being heard and dealt with, even though there is little trust in government, generally; and
- There has been considerable discussion within the communities about the Project, including its benefits and potential impacts.

In addition, written consent to the Project was provided by the five landowning tribes who negotiated with SIG for the acquisition of the land to construct and operate the Project ('Process Agreement'). This is discussed further in the LALRP.

Further to the common or mutual concerns outlined above, the particular concerns of each village, relating to the preferred alternative, are presented in Annex 15 of the Annex Report, along with the perceived benefits of the development. These were recorded in the participatory workshops and in the follow-up mitigation workshops.

A summary of the feedback received in the 15 ESIA mitigation workshops and the manner in which the feedback has been incorporated into project design and key safeguard documents is set out in Appendix N ‒ Resoultion of Community Feedback.

In summary, the TRHDP planning process appears to comply with the requirement of FPIC and, to date, community consent has been achieved at each stage.

12.3.3.2 Free, Prior and Informed Consent and the Social Impact Assessment

The ESIA process has been described in the Socio-economic / socio-cultural Baseline and above. As noted, the community workshops and consultations conducted by the ESIA team with the people of the project area were consistent with FPIC. That is:

- The community workshops and interviews were preceded by a briefing on the forthcoming ESIA, and then advanced notice was given of the workshop date, program, and the purpose of the meeting;
- Meeting organisation, selection of venue and timing was brokered by local members of the TRHDP PO's team of indigenous CLAs and agreed with the relevant communities. Women were specifically encouraged to attend and to participate;
- local community leaders agreed in advance for the ESIA team to visit and engage with local people on the impacts issues, to record the participants' comments and information, and to make observations in the community. Village and clan chiefs attended the meetings. One of the mitigation workshops was held for the members of the Bahomea HOC;
- a verbal briefing about the ESIA was provided to workshop participants in English, Pidgin, and the local language. Participant consent was explicitly sought to proceed with the workshop and individual interviews, to record discussions, and make use of the findings, and;
- the workshop process also included specific questions on whether the participants and their communities broadly supported the proposed hydroelectric development, or not.

12.3.4 Women's Participation

The TRHDP PO's records on awareness raising and consultation activities indicate that women have attended and participated in community level activities and stakeholder consultations. This was facilitated by the recruitment of mature local women as CLAs. In general, women in Solomon Islands tend to have a lower status than men and are often unable to attend workshops due to their home duties. This means that younger women are not always able to attend presentations to receive information and to engage in discussion regarding the Project during meetings. However, older women, especially those with a higher level of education, tend to be more actively involved. In addition, due to customary gender roles, women may not be encouraged by men to state their point of view or raise issues in larger gatherings. This issue did not seem to be a significant problem during the ESIA workshops.

It appears that women were successfully involved in workshops, awareness raising programs and consultation activities. Ninety-three percent reported they attended community meetings (see Annex 16 of the Annex Report). On the other hand, the household surveys suggest that women are less involved in land acquisition discussions, as only 41% of adult women reported that they were involved in deciding on land issues in their household. By comparison, in a national survey in 2007, 55% of adult women reported that they were involved in land decisions.

For example, 45% of the participants of the ESIA community workshops in 2013 were indigenous women and girls. Although it seems that women have limited decision-making power in Guadalcanal societies, their active involvement in the ESIA process is a positive sign, especially when looking at their willingness to participate in the household survey. Finally, the SIA takes into account women's perceptions and concerns about the proposed TRHDP as well as their preferences for mitigations and benefits sharing. Measures to incorporate gender inclusion in land acquisition discussions and agreements are set out in the LALRP.

12.4 Constraints of the SIA

A lack of or delay in information sharing in some key areas limited the conduct of the ESIA and of the mitigation workshops. This information included:

- The preferred project option and its location, scale, and access road alignments;
- Ownership and use rights for the 'core area'; and
- Current census statistics.

12.4.1 Preferred Project Option

The SIA for the TRHDP was commenced at a time when Option 6E was being evaluated, but when Option 7C was being discussed as a lower impact alternative, as described in Entura's Phase 3 Report (2014). This uncertainty presented some challenges for the workshop consultations in Senge Communities that could be impacted by the choice of dam and power station location, in particular whether they would experience physical displacement. The workshop discussions therefore had to cover the impacts of Option 6E and Option 7C. In practice, the choice of option made little difference to the impacts likely to be experienced in the Infrastructure Impact Area, Downstream Area, and the wider Malango district (Wider Impact Area), providing the basic project parameters were similar. Despite the uncertainty, the discussions in the Senge Communities helped the TRHDP PO to refine the project's concept and parameters, design policies, and ultimately the preferred option (Option 7C), which was announced as the preferred alternative in early 2014.

In late January 2014, the TRHDP PO provided a verbal briefing prior to the community and agency consultations on proposed impact mitigations. The draft ESIA was subsequently updated to reflect specific requirements and potential impacts of Option 7C. However, opportunities to conduct additional SIA fieldwork were not available.

12.4.2 Land Ownership

At the time of the SIA and of the Socio-economic / socio-cultural Baseline, no details on land ownership were available for either Option 6E or Option 7C.

The new, localised land identification process was underway at the time of the draft ESIA preparation. Since it had not been completed, its findings had not been disclosed beyond the TRHDP PO and the particular landowners. Direct consultation with the landowners in the Core Area was therefore not possible, with `the impacts resulting from land acquisition_ only being covered at the community or village level. In practice, however, SIA workshops, householder interviews, and follow-up consultations on mitigations were conducted in those communities where most of the landowners for the Option 7C Core Area reside.

Since a LALRP was necessary for the loss of livelihood assets acquired for the Project, relevant data needed to be subsequently collected to enable the Plan to be prepared. This additional research was done in 2015 by means of a Livelihoods Assets survey and through fieldwork for the creation of the Tribal Register.

12.4.3 Census Data Availability

Despite several attempts by the TRHDP PO, individual government officers, and ESIA team members, it was not possible to obtain project area or village level data from the 2009 Census of Population and Housing in time for the initial preparation of the ESIA report. This data became available in 2015 for all census enumeration areas and has been integrated into the ESIA where possible.

12.5 POTENTIAL ADVERSE SOCIAL IMPACTS AND MITIGATION

Below is a summary of the construction and operations phases of the Project, and the potential socio-economic / socio-community impacts that may potentially accrue.

12.5.1 Potential Impact Causing Activities

12.5.1.1 Construction Phase

Specific activities are likely to generate impacts during the construction phase of the TRHDP, include:

- Building the RCC dam, including installing temporary diversion works within the river, excavating the dam site, and upstream and downstream quarrying of materials;
- Constructing new access roads, one from Managikiki[1] to the core land and then to the dam site, and a second road from near Managikiki to the power station and tailrace site upstream of Pachuki. Construction of both roads will require felling and clearing forests and disposing of vegetation, earthmoving (cutting/benching and filling to create a roadway), and installing culverts and drains. Some of the roadways may interact with existing tracks, household food gardens, and/or areas where materials are collected;
- Presence of road works to improve and widen the existing Black Post Road, from the Black Post (on the Kukum Highway) to Managikiki;
- Movement of equipment, materials, and people to and from the construction sites, using the new and improved roads;
- Excavating the headrace tunnel;

- Clearing forested areas within the hydro storage reservoir, and possible recovery of the logs and/or timber;
- Erecting the transmission line pylons and conductors from the powerhouse along the Black Post Infrastructure Corridor, and;
- Employment and management of local and non-local workers to undertake the various tasks involved in building the hydro scheme and in mitigating its impacts.

12.5.1.2 Operation Phase

Once constructed and commissioned, the Tina River hydro scheme could cause long lasting impacts on local communities. Operation activities that may affect them include:

- Modifying the natural flow of the Tina/Ngalimbiu River between the storage reservoir and the ocean in the dry season - mainly arising from peaking operation that will involve reservoir filling and refilling and releasing water through the headrace tunnel to the powerhouse. The reservoir will be refilled at night and water will be released for power generation during the peak daytime power demand periods;
- Diverting much of the Tina River's flow from the natural river course into the head race tunnel, located between the dam and the powerhouse, leaving the river with a supplementary environmental flow (EF) from the dam, combined with inflow from lateral streams;
- Using the access roads by workers and contractors working on the maintenance of the dam, reservoir, power station, and transmission lines;
- Employing and managing local and non-local workers to undertake various tasks involved in operating, protecting, and maintaining the hydro scheme, and;
- Possibly using the storage reservoir and the access roads by non-project personnel, including local community members and outsiders.

12.5.2 Types of Social Impacts

During the three-year construction phase and the long-term operation phase of the TRHDP, a combination of direct, indirect, positive and negative social impacts on local communities may arise.

Several types of social impacts may occur. These include:

- Direct physical impacts on nearby communities (e.g., intrusive noise, vibration, explosion shockwaves, dust, air and ground discharges, and visual intrusion) some of which could have potential health consequences and negative impacts on way of life and local amenities;
- Loss of access to abundant clean fresh water;
- Damage to and/or loss of access to livelihoods assets, including fishing areas, food garden areas, hunting areas, plant and related materials, planted and wild fruit and nut trees, and timber woodlots and plantations, with potential negative impacts on household and community wellbeing;
- Opportunities for improved incomes due to increased employment opportunities;

- Opportunities for improved quality-of-life, through the upgrading of services and facilities.

- Increased risk of accidents due to project related vehicle traffic;
- Improved road mobility between villages in the project area, and with Honiara; and
- Threats to indigenous lands, natural resources, security, community health and well-being, and local culture.

The communities that are most likely to be negatively affected by the project are those located adjacent to, and make livelihoods-related use of, the Core Land area, and/or the low-flow section of the Tina River.

12.5.3 Health, Safety and Wellbeing - Impacts and Mitigation

12.5.3.1 During Construction

The construction of the TRHDP may present threats to local people's health and wellbeing. These threats include:

- Outbreaks of gastrointestinal and skin infections arising from run-off and contamination of drinking and washing water from the Tina/Ngalimbiu River and local streams;
- Increase in malaria outbreaks due to more standing water around construction sites;
- Rise in road accidents, lost loads and spillages due to more traffic on Black Post Road, as well as work related accidents;
- Social threats arising from inappropriate behaviour of outside construction workers, and local people employed on the Project. Issues of concern are associated with a potential increase in:
  - unwanted pregnancies;
  - sexually transmitted diseases such as HIV/AIDS;
  - domestic financial issues due to gambling or drinking; and
  - alcohol and drugs consumption by men, leading to domestic conflict and violence, and sexual abuse.

Nevertheless, with sufficient preparation and investment by the TRHDP PO and the SIG, each of these potential health threats may be avoided or mitigated, as follows:

- The construction of the project (and access roads) should be planned and executed according to good international industry practice (GIIP) to avoid any physical or biological contamination of water sources. This should be explicitly addressed in a Construction Environmental Management Plan (CEMP), along with cleanup procedures. Alternative drinking water supplies should also be installed throughout the project area, prior to the beginning of the construction phase.
- Unfortunatelly, some social threats cannot be completely avoided, as they involve individual personal choices of community members (e.g., level of alcohol and drug consumption). However, it is the responsibility of the Project to prohibit disruptive behaviours and one means of prohibiting such behaviors is the decision already taken to avoid the establishment of a workers camp in the Tina/Ngalimbiu River catchment.

é The threat of anti-social behaviour by local male workers could be minimized by the TRHDP PO and the construction contractor implementing strict drug and alcohol prohibition for all workers. This prohibition may also help reduce the risk of work related accidents and road accidents on Black Post Road.

é In addition, the development of a Health and Safety Plan by the construction contractor, for both workers and villagers living near the site, could minimize the potential risks for road accidents, injuries and property damage resulting from lost loads. The Plan should include measures such as:

  ¿ For work-related accidents, the construction contractor will need to provide tailored workplace health and safety training and personal protective equipment (PPE) (helmet, safety boots, gloves, goggles or safety glasses, hearing protection) for construction workers prior to the work commencing; provide a full-time first aide/nursing post on site and arrangements for medical evacuation (including helicopter transport) for serious injuries.

  ¿ Ensuring that all drivers and plant operators are appropriately qualified and trained for their work;

  ¿ Installing protective roadside fencing (particularly in the most vulnerable areas such as Mangakiki/Verakuji), and hamlets (in the Grassy hill area);

  ¿ Installing a separate pedestrian walkway and well-marked road crossing points in the vicinityof Mangakiki/Verakuji, Marava, Rate, Verakabikabi, and on the roadside hamlets in the Grassy Hill area;

  ¿ Enforcing speed limits for all traffic on the upgraded Black Post Road;

  ¿ Using good international industry practice for the transport of dangerous goods, and;

  ¿ Developing a protocol for managing contractor-related road accidents and injuries, including compensation and compensation arrangements.

é The TRHDP PO and the Construction Contractor will have to conduct awareness on HIV/AIDS and STD to prevent and mitigate the impacts of social behaviors which will encourage sexual behaviours. The TRHDP PO and construction contractor may have to engage outside parties to carry out these awareness programs if these issues are sensitive and cannot be discussed openly by project area parties such as the community Liaison Assistant currently engaged by the TRHDP PO.

12.5.3.2 During Operation

Stakeholders˘are concerned about water quality in the Tina/Ngalimbiu River once the project is operational, especially with respect to the water in the reservoir and in the stretch of river that will have a significantly reduced flow on which three villages depend.

Communities are concerned about increased water-borne diseases, especially diarrhea and malaria. Downstream communities are concerned about water borne diseases from human waste, and have requested independent water quality monitoring and reporting. The monitoring of water quality and the incidence of water borne diseases should begin just prior to commencing construction, and should be part of an ongoing environmental management and monitoring program.

It is unlikely that the operation of the hydro-scheme will cause any noise disturbance to local households. Locally, the project operation will have no effect on air quality. Owing to reduced diesel being consumed for power generation, the air quality should improve in the Lungga area, which may have positive impacts on villagers˘health.

Despite repeated awareness raising and consultations regarding the dam design and dam safety, local communities, especially women, are still concerned about the potential risk of possible dam failure during earthquakes or cyclones. Some community members expressed a lack of trust in the SIG to safely manage the hydro facility and are asking the SIG and the TRHDP PO to resettle them away from the river. However, according to the TRHDP PO, the risk of a dam failure is extremely low and there is no need for resettlement. This position is consistent with the World Bank˘s policies on resettlement. However, it remains crucial to implement carefully tailored awareness programs to educate communities about hydro dams, the TRHDP design, and and the provisions being made for dam safety in order to prevent unnecessary fears amongst local communities and to avoid any unnecessary resettlement.

Finally, the sudden release of up to 24 m^3/s of water from the powerhouse tailrace is seen as a potential safety hazard to local communities, particularly for persons who use the footpaths along the rivers bars and riverbanks. At times, the powerhouse will operate during daytime (peak hour) and will shut down during the night, with the potential ramping flow releases occurring during the daily startup of power generation. To mitigate this hazard a staged release of flows is proposed to alert people to the rising water level, together with awareness on the staged releases and approximate proposed release times.

12.5.4 Women - Impacts and Mitigation

During the village household surveys, women were asked to indicate their thoughts about potential adverse and beneficial impacts of the proposed TRHDP on them and their household.

The greatest concerns expressed by women include: water pollution, reduced river use/amenity, children˘s safety, bad influence of outsiders, loss of fish stocks and noise (see Figure 12-5). In terms of the long-term adverse impacts of the TRHDP, women were most concerned about catastrophic failure of the dam, and potential for social and cultural disruption arising from increased outside influences and access to money, by youth and men (see Figure 12-6). Measures to avoid or mitigate short and longer terms impact concerns are outlined in the relevant sections.

Figure 12-5 Women's perception on potential adverse impacts of the TRHDP

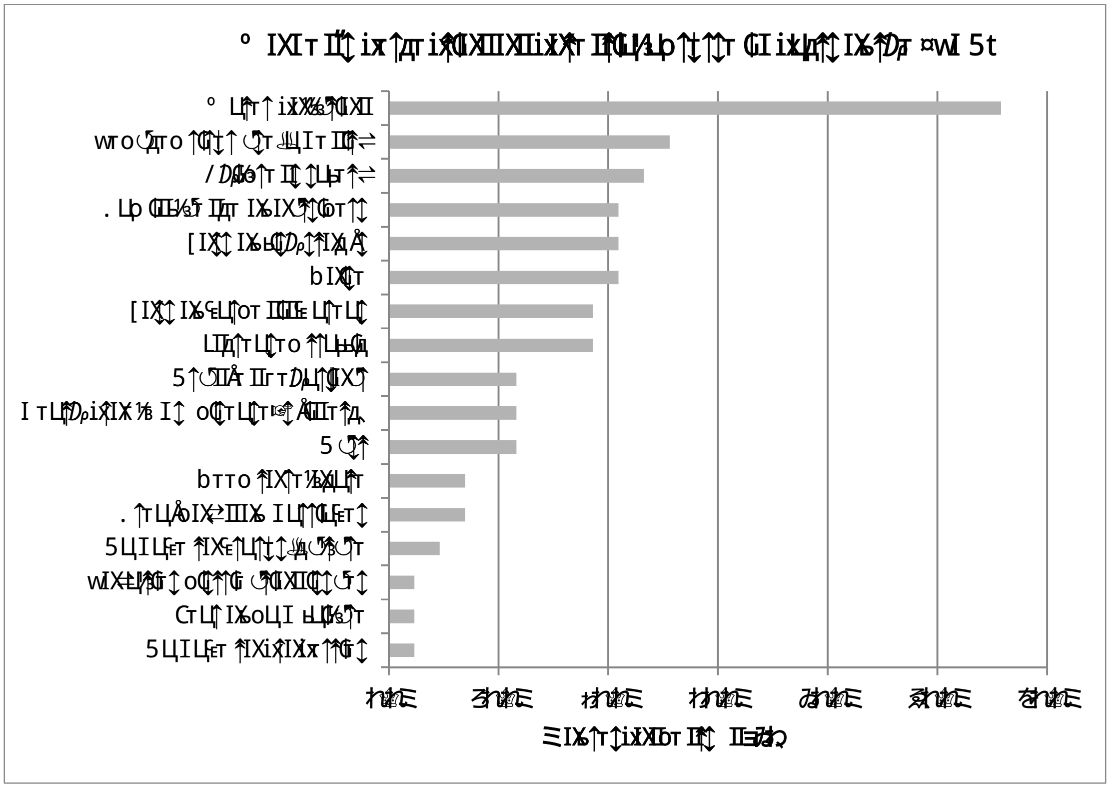
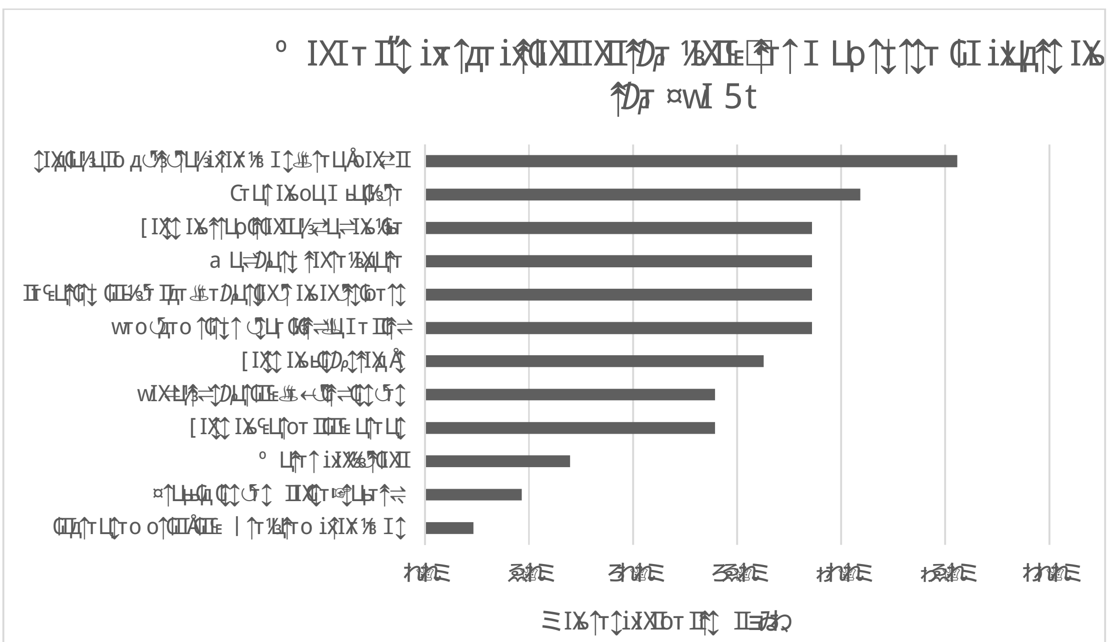


Figure 12-6 Women's perception on the long-term adverse impacts of the TRHDP



12.5.4.1 Women's Safety and Wellbeing

Women in the project area are concerned about possible risks and threats to their overall safety and wellbeing, as well as that of their children. Their primary concerns include:

- Disaster caused by dam failure;
- Sexual or other assault by outside workers or strangers involved in the Project;
- Road accidents;
- Negative social influences coming from people that are unfamiliar with, or are not sensitive to, local customs;
- Family breakdowns due to potential increase of alcohol consumption, drug use, promiscuity, and gambling associated with increased incomes of men employed on the Project.

According to Slovic's findings on risk perception, people tend to rate the risks of new technology (such as a hydroelectric dams and household electricity in the Solomon Islands context) greater than the actual risks. To avoid or reduce feelings of anxiety associated with the dam's safety, the TRHDP PO and/or the construction contractor and operator should carry out, prior to the start of construction, educational programs about dams and their risks, safety around power transmission lines and powerhouse outlets. Prior to electrification of villages, which will occur under the proposed benefits sharing program, public education about electricity and its safe use in the home and community will be proposed for communities and children in local schools.

No workers camp shall be established for the TRHDP. Security jobs will be given to local villagers. To avoid potential social and cultural issues for women, the construction contractor should maximize as much as possible the employment of local people on the project, develop and enforce a Code of Conduct for appropriate behavior for incoming workers, and provide cultural awareness training for all staff. To minimize potential social disruption due to increased amounts of cash in the community, budgeting and money management education should be provided as part of the induction and training of locally recruited workers.

Local communities adjacent to the Black Post Road have suggested a number of measures to improve the safety of children travelling to and from school at Rate and Valesala. These measures include footpaths, boundary fencing at Vera'ande, Marava, Verakuji, and Mangakiki, and speed controlled areas and/or a police checkpoint near the beginning of the road. The TRHDP PO, construction contractor and transport providers for the Project should be required to ensure that all their drivers are suitably qualified and skilled, and enforce strict codes of practice and road safety rules.

12.5.4.2 Women's Work and Roles

The household survey included questions on the division of labour and on the responsibilities within the household. These findings have been summarised and presented graphically in Annex 16 of the Annex Report. The data clearly show that women are heavily involved in working in the household (e.g., laundry, growing, preparing and cooking food, caring for the household yard, cleaning the house, and selling produce and cash crops), whereas men tend to be involved in building and maintenance of the house, clearing forest, hunting, fishing, and dealing with land issues.

Potential adverse impacts that may especially affect women and girls and, therefore, require additional work to avoid or mitigate the effects, include:

- Deterioration of the river water quality and supply, and/or damage to other water supplies;
- Increased amount of dust from exposed river bed, road building, and additional road use;

- Loss of nearby gardening area; and
- Loss of forest resources (materials, foods).

As a result of the TRHDP, women's quality of living may improve due to the provision of safe and reliable water supplies, safer roads and more reliable public transport. As part of a benefits package, women's and girl's lives are expected to be made easier by the provision of education and health facilities, and electrification of houses (with labour-saving devices, home entertainment, and opportunities for home-based small businesses). The mitigation measures and the benefits package are crucial to women's welfare and development in the TRHDP area, and arrangements should be included in project implementation for ongoing consultation with local women, perhaps through existing women's groups and associations.

12.5.4.3 Minority and Vulnerable Groups

Potentially the most vulnerable group in the Wider Area is comprised of people who lack formal rights to the land they occupy and to local resources (e.g., 'squatters'). These people are primarily located in the lower part of the catchment adjacent to the northern section of Black Post Road and on abandoned or government land between Grassy Hill and Kukum Highway Road. Squatters are vulnerable to attacks by landowners who accuse them of consuming local resources.

The second most vulnerable group in the project area is comprised of the 'settler' communities. While they lack of formal ownership of land and local resources, their occupancy is legitimate because they have made customary agreements with landowner tribes. Their vulnerability is primarily due to limits of the land and resources available to them for their livelihoods, as well as their lack of participation in local tribal decision-making. Despite being Guale people, they remain vulnerable to occasional attack by community members from villages in Bahomea. These communities could be affected by the construction and use of the Transmission Corridor(s). The effects are discussed in depth in the LALRP.

As the project progresses, issues affecting the communities will need to be dealt with through procedures such as the grievance mechanism and nominated community representatives for project liaison.

The main concern noted by the Bahomea villages is the loss of their lands. Landowners and the PO/SIG are responsible for avoiding and resolving these issues by actively engaging with the informal settlers during the detailed design of the transmission corridors.

12.5.5 Social Relations and Social Organisation – Impacts and Mitigation

12.5.5.1 Identification of Potential Social Conflicts

Participants of the community workshops highlighted the existence of potential social and political conflicts and their concerns about trusting local leadership and the central government. The planning, construction, and operation phases of the TRHDP may affect local social organization.

Members of the consulted communities expressed their anxiety about the potential risk for social conflicts between landowners groups and the SIG over various issues including: land and resource ownership and access rights; rent sharing; royalties; compensation payments; and access to development opportunities and benefits. Construction and operation of the TRHDP have the potential to generate both beneficial and adverse impacts on social capital in the project area. According to consulted communities, there are two main concerns regarding social relations:

- Potential internal tribal conflicts over the distribution of benefits, which may lead to social fragmentation; and
- Potential conflicts between local clans and the SIG.

According to the members (especially women) of the Bahomea communities (those closest to the main construction area) the main concerns about impacts on social relations are:

- Possible disruption of the local customary way of life and values due to the impacts of outsiders working on the TRHDP and passing through local communities. These disruptions may affect dress codes, behaviour, crime rates, and may represent a possible moral danger to young women;
- Possible social and family problems caused by local men having greater access to cash and, therefore, potentially greater access to prostitutes, alcohol, drugs, and gambling. These concerns are based on the previous experience with Gold Ridge mine.

To avoid the conflicts identified above, local inhabitants requested greater input and transparency on issues related to identification, monitoring and evaluation of land and resources that will be affected by the TRHDP. It is also important that development of the Project be undertaken in an inclusive and participatory manner with all of the affected communities. Chiefs and village leaders need to be reassured that all landowners in the project area will receive a share of the benefits. Conflicts and social disruptions may arise if these matters are not dealt with sensitively, and they may pose potential threats to the viability of the Project. These social matters have been dealt with so far by the TRHDP PO, government leaders, and the traditional Chiefs of Bahomea, in accordance with indigenous customs and practices. The process of engagement on land identification, and measures to ensure fair distribution of benefits between land owning tribes and within each tribe, are documented in the Land Acquisition and Livelihood Restoration Plan.

International and domestic development agencies could assist by providing training in conflict identification and resolution to church, community leaders and NGOs. The churches and existing civil societies have an important role to play locally in conflict avoidance and conflict resolution. Finally, the implementation of a social impact management plan and the benefit-sharing program aims to deal positively with the issues raised above.

12.5.5.2 Project Construction Workforce

The TRHDP PO has indicated that the peak construction workforce for the TRHDP will include approximately 175 workers. However, at the time of reporting, no definitive information was available on the proposed construction or operations workforce, its timing, occupational structure, required levels of skill and experience, and origin.

It is envisaged that residents of Bahomea, Ghaobata, and Malango would be employed as semi skilled and unskilled labour in the construction of the Project, along with non-local technical specialists and tradespeople. Entura suggested that the construction of the dam would take place at least six days per week, with work suspended during the rainy season, when the river is high. The Project shall have no workers camp on site. It is anticipated that expatriate staff, and workers outside of Central Guadalcanal, will be housed in Honiara and local staff will be bussed to the site from their villages. The size and characteristics of the population of the project area will, therefore, not change due to the project construction.

Suitable accommodation will need to be planned for well in advance, by the construction contractor, to cope with a temporary (seasonal) increase in Honiara's population.

12.5.5.3 Uninvited Visitors, Jobseekers and Settlers

As a significant construction project, the TRHDP may attract uninvited visitors, jobseekers and settlers, who are otherwise unable to find employment in Honiara, or in Solomon Islands. This is believed especially to be the case for young men. Some may squat on government-owned land within the Tina Valley if they are able to obtain indirect employment. In such cases, the whole family may move to the area, putting additional pressures on local services such as health clinics, schools, and water supplies. The TRHDP PO should investigate what occurred during the establishment of the Gold Ridge mine, to obtain better knowledge and understanding of what occurred on the Gold Ridge Mine Project, so that it is better able to manage the impacts of the potential migration and settlements issues in the Tina RiverValley

The project construction contractors could limit the influx of transient jobseekers and squatters by establishing a policy that would prioritise the recruitment of construction workers from: a) the existing registered members of the customary tribes within Bahomea and Malango; and b) local settler communities. Finally, when it is necessary to recruit others, the project construction contractors should publicize and use a formal application and vetting process through a recruitment office to be located in Honiara, thereby discouraging job-seekers from going directly to the construction site. The participation of local workers and youth should be promoted through the provision of relevant job skills training programs.

12.5.6 Local Customs and Way of Life ¯ Impacts and Mitigation

12.5.6.1 Local Communities

The migration of Malango people from the slopes of the central mountain range into the river valleys and ridges to the north has meant increasing exposure to multicultural Solomon Islands life and to Western cultural influences. The traditional hill peoples˘mixed livelihoods strategy of shifting subsistence agriculture, combined with hunting and gathering, has been supplanted by wage labour, royalty payments from large-scale logging, purchased goods and food, increasing contact with Honiara, and the use of Solomon Islands Pidgin. In the process, older people of Bahomea say that their traditional culture has changed considerably.

From the 1950s onward, such changes were resisted through the Guale cultural revival advocated and practiced by the followers of the Moro Movement (see below). In some cases, families have relocated away from larger settlements to quieter, and more natural areas, where they can practice a subsistence way of life, for example, in the upper part of the Tina valley. However, they remain quite strongly connected to modern day northern Guadalcanal and its urban influences and dependencies.

Some members of local communities expressed concern that developments such as electrification of houses and other lifestyle changes would lead to the loss of the traditional way of life. Others are fearful that construction workers and other outsiders will disrespect local customs and standards of behavior.

As noted previously, the likelihood of outsiders causing offence through culturally inappropriate behavior, or being inappropriately dressed, shall be largely avoided by preventing contractors from establishing a workers˘camp within the project area. In addition, the TRHDP PO and construction contractor should put in place an enforceable Code of Conduct for workers, and require all non-local employees to undergo cultural awareness training as part of their induction. This training should be provided with the assistance of the indigenous people of Bahomea. Households or groups that wish to follow a more isolated and traditional way of life will still have ample opportunity to do so. Local residents will be somewhat inconvenienced by construction activities, such as by periodic construction and traffic noise, and delays on roads related to construction traffic. However, these are likely to be minor and temporary.

In the longer term, the TRHDP, and the proposed package of benefits, could catalyze the process of exposure to other communities, and of cultural and social change that is already occurring. Increasing and more intense contact with the outside world could accelerate the loss of the Teha language, traditional knowledge of the natural environment and how to obtain a living from it, of tribal genealogy and history, and of the ancestors and spirits. Conversely, most people in the community have indicated that they welcome the possibility of an improved quality of life through electrification, improved water supplies and incomes, better services, and better quality roads. The most effective way to mitigate the impacts of cultural and social change, including loss of language, is to prevent a workers camp which would otherwise involve outsiders in the day to day lives of nearby communities. Given the remoteness of the key work sites, aside from road and transmission line construction, outside workers are expected to have limited daily interactions with all but the closest villages. The majority of awareness meetings and consultations will be undertaken by Solomon Islanders.

Impacts on the nature of traditional livelihoods are also expected to eventuate from the paid employment of local workers, and the possible paid engagement of local groups for catering or security services. Staff for semi-skilled construction positions are expected to draw from previous workers of the Gold Ridge, many of whom remain unemployed following the closure of the mine in April 2014. In this context, many of the project˜s workers will have had existing exposure to working with outsiders and to engaging in cash employment in lieu of traditional livelihoods. Baseline studies show an existing dependence on cash incomes in the area (with a weekly average income of SBD$870 per household), and a higher than average paid employment rate. While the Project embodies a growing trend towards greater involvement with Honiara and outside cultures, the temporary nature of the majority of jobs and impacts (during the construction period) will limit social and cultural change to an extent.

In part, TRHDO PO˜s method of customary land identification, and the involvement of a committee of elders and storytellers (the Bahomea Land Identification Committee), has created an increased emphasis on tribal genealogies, histories, ancestors, spirits and cultural sites, not just in the Core Land, but in the wider Bahomea area considered by Bahomea Land Identification Committee (BLIC).

12.5.6.2 Gaena˜alu (Moro Movement)

The TRHDP has the potential to disrupt the lives of those residents of the area who follow a less western influenced and more traditional way of life, such as the followers of the `Gaena˜alu Way_ (also known as the Moro Movement).

Fear of disruption to, and loss of, culture is the primary concern for the senior Moro/Gaena˜alu priest and village leader of Koropa and its related community of Namopila. With the selection of the preferred alternative (Option 7C) for the Project, much of the feared disruption to the quiet traditional Gaena˜alu lifestyle, and to sites of cultural significance, will be reduced. Fear that the customs and lifestyle of the Gaena˜alu followers will be disrespected will be avoided by not having a workers camp located within the Tina/Ngalimbiu area, and by the TRHDP PO and construction contractor enforcing a strict Code of Conduct for its workers with respect to contact with local minorities (see Annex 18 of the Annex report).

12.5.7 Livelihoods and Key Resources ¯ Impacts and Mitigation

The TRHDP is likely to affect the livelihoods of households using resources located close to the dam, reservoir, headrace, powerhouse, power transmission line, or access roads.

Based on the fieldwork and consultations with local people, stakeholders and experts, the impacts on local livelihoods of the development of the Project can be expected to mainly come from:

- Loss of, or damage to the natural assets upon which local communities˘livelihoods depend, including the Tina /Ngalimbiu River, food gardens, forests, and areas used for hunting, gathering and fishing;
- Damage or improvement of physical assets and infrastructure, such as tracks, roads, and water supplies, and;
- The opportunity for paid employment and provision of services to the project.

Most households of the study area rely on their own local natural capital as the basis of their livelihood and to meet their basic needs. However, they are increasingly tied into the modern urban-based economy. This is evident in the growing role of cash, which is needed for goods and services, such as food, household fuel and consumables, telecommunications, transport, and school fees. The construction and operation of the TRHDP could bring about change or opportunities for change, in the way some people obtain their livelihoods.

12.5.7.1 Infrastructure

The main impact of the TRHDP on the physical infrastructure of local communities is likely to be unintentional damage to infrastructure (e.g., houses, fences, foot tracks, village access roads, bridges, and water supplies), due to the construction and upgrading of the Black Post Road to allow the construction traffic. Once completed, the proposed road is expected to accommodate 25 to 40 project related vehicle trips per day, during the construction season, over a three-year construction period (Entura, 2014). Project traffic will mainly consist of light, medium and heavy vehicles, including vehicles carrying workers, materials, and heavy equipment. Most traffic movements will be confined to daytime.

Infrastructure damaged as a result of construction activities will be repaired or replaced by the TRHDP. A water system will be installed to provide villages with clean potable water. In addition, the access road will be an improved transportation infrastructure facility connecting villages in the project area with Honiara. Access to electricity will be provided through electrification of villages.

12.5.7.2 Small-Scale Timber Harvesting and Timber Milling

Small-scale timber milling represents a major financial input for indigenous communities of Bahomea. Forested lands, currently accessed for small-scale timber production, will be affected by the land acquisition process.

Landowners engaged in timber extraction in the Tina Valley (mainly between Senge and Choro) expressed their concerns regarding the impacts of an altered river flow on their ability to raft sawn timber downstream from the harvest sites to various transport pick up points. Non-timber forest products, including wild foods, medicinal plants, and building materials that are currently available in areas that may be required for the Project (e.g., near Mangakiki and Senge where new access roads will be built) will be lost and become locally scarcer.

Construction of the Project will require permanent clearing of 115.49ha of native vegetation, of which 51.0ha is forest (see Table 12-1). The majority of forest will be removed from within the reservoir area and along the access roads. In addition, the Project will modify the river hydrology, affecting the ability to transport sawn timber from the areas where it has been harvested, downstream to village haul out sites.

The potential impact of forest clearing is low; the amount of forest that will be cleared represents 0,9% of the total area of non-montane forest in the catchment. In the short term, the loss of timber will be partially offset by the plan to engage local workers to clear trees from the reservoir area.

Table 12-1 Area of vegetation permanently lost due to project

Grasslands (ha)	Undisturbed forests (ha)	Disturbed forests (ha)	Remnant forests (ha)	Montane forests (ha)	Riparian (ha)	Cliffs (ha)	Garden (ha)	Fallow brush land (ha)	Total surface of habitat directly lost to construction activities
20.30	9.54	29.65	11.87	0	21.62	16.12	0	6.40	115.49 ha
	51.06ha total forest area removed								

The reduction in the river flow between the dam and the powerhouse, will make it impossible during normal flow to float timber down the river from where it is harvested in the Choro and Koropa areas to the traditional haul out sites that are located near villages downstream. The TRHDP PO has suggested that, if necessary during periods of extended natural low flow, additional water could be released down the river channel to assist in timber rafting. If this is done, it should be preceded by warning to the public, since villagers, may increasingly use the dry banks created along the Tina River as walking paths. Other arrangements are also feasible, such as timber rafting during the anticipated dam spillover events, and if necessary, the creation of regular truck-accessible haul out sites beside the river and at the future reservoir, using the dam access road.

In the long term, the creation of a new dam access road could provide better access to areas in the upper catchment for small-scale timber production by local landowners. Use of the road for this purpose will depend on the proposed management by TRHDP, and the land-owning/holding company to be established as part of the Project. At present, it is proposed to limit the use of the road to Project related activities to prevent increasing logging of native forests.

12.5.7.3 Extraction of Aggregates from the River

The following discussion is predicated on the assumption that the proposed TRHDP dam may significantly reduce the recruitment of construction grade aggregates (i.e., sand and gravel) in the lower Ngalimbiu River where they are currently mined. However, the recent study by Ian

Jowett predicts that changes to downstream gravel levels, if any, will not eventuate for a considerable period of time.

Communities in the lowest part of the catchment are particularly concerned about the potential effect of the dam on the transport and deposition of aggregates. Were the dam to have such an effect, the construction of the dam may also have an impact of sale of sand and gravel, which is an important source of income for many communitities in the project area.

The Ghaobata people, located in the lower part of the catchment on the Guadalcanal plains, rely on royalties from gravel extraction from the Ngalimbiu River. This particular material is of high quality and is a key source of aggregate on northern Guadalcanal[75]. Gravel extractions by communities located in the Upper Ngalimbiu River and in the lower part of the Tina River catchment are sporadic, of low volume, and for domestic use. Throughout the Bahomea district, people occasionally use gravel and sand from the riverbed to make concrete for building their houses, or other types of construction. These extractions do not appear to be a source of revenue for the Bahomea landholders.

Participants in the ESIA workshops, household surveys (with the Ghaobata communities at Ravu and old Selwyn) and the mitigation workshops (held by the GPPOL settlement) expressed their concerns about the future of gravel resources once the upper part of the Tina River is dammed and once the flow regime is altered. They also expressed their willingness to provide more information about the gravel extraction rates and the royalties paid to local tribes.

Sand and gravel is excavated by loaders and trucks directly from several places in the lower river near Ravu, and downstream of the Ngalimbiu Bridge. There are stockpiles of sand and grit near old Selwyn, and there is a gravel yard, screen, and elevator at the Lee Kwok Kuen and Co (LKK) farm. In mid-2013, the Ghaobata landowners received royalties ranging from SB\$390/m^3 to SB\$500/m^3 of material. The main client was Dalgro Ltd, which was sourcing approximately 200 m^3 per day during the dry season. Solomon Sheet Steel Ltd was also reported to be sourcing gravel from the Ngalimbiu. Apart from the commercial operation of LKK, the communities involved in gravel extraction include Ravu (with about 16 hamlets) and Old Selwyn/Popoloi.

As confirmed from Geotech investigation at site option 6A, the alluvium depth at this site is 25 meters. As such, the river will continue to replenish gravel for the downstream communities, and the impact of reduced gravel may not be experienced, if at all, by the downstream communities for a very long time. A regular monitoring program to confirm gravel levels at intervals downsteam of the dam should be carried out to confirm whether any impacts on downstream gravel users are likely to occur.

75 According to Tawake (2005:17), in the Ngalibiu River near the bridge, `the river aggregate deposits are composed largely of igneous rock fragments with lesser limestone constituents. Igneous rock fragments comprise plutonic rocks and slightly less volcanic rocks_. The surface area of the resource at the extraction site in 2005 was estimated at 10,000 sq. m. Tawake also noted that there was `No standard compensation and royalty rate paid to resource owners to compensate for the use of sand and gravel on traditionally-owned land_ (p25).

12.5.7.4 Natural Capital

12.5.7.4.1 Access to Natural Capital

The loss of natural livelihoods assets is one of the main concerns of local communities. All the indigenous people of Bahomea and Malango have rights to utilise natural resources of the Tina/Ngalimbiu River catchment, though it is mainly the people of Bahomea who actively exercise those rights for their livelihoods. These include the people residing in the Downstream Area and Infrastructure Impact Area. However, only a limited number of local clans have ownership rights of the land and resources of the 4.288km^2 project Core Area[76].

Most of the permanent loss of natural capital will result from the creation of the hydro storage reservoir, the creation of the access roads and, to a lesser extent, the construction of the dam and powerhouse. Temporary loss of access to natural resources within the upper Tina River watershed will occur during construction.

12.5.7.4.2 Land Use

The land required for the project includes:

- Partially logged and intact forest lands, used by some households as a source of wild foods, building and craft materials, traditional medicines, hunting, and bush tracks;
- Sections of the Tina River, including:
  - the water of the river, along with the environmental and human-related services it provides (e.g.washing, bathing, water supply, transporting timber, and gravel extraction);
  - the riverbed, including rock pools, and other locations used for fishing, tracks, and sacred sites;
  - tributary streams, used as sources of wild foods, and as ownership markers, and;
  - riparian margins, used as sources of wild foods, and containing former habitation and sacred sites.

The creation of the proposed access road above Mangakiki is likely to require only minimal disturbance to garden land or areas for collecting forest resources, since the area has already been harvested for its timber and modified by logging. Building the road section down into the dam site from the ridge will require the removal of small amounts of relatively intact natural forest. Land for the access road, dam site, quarries, and the storage reservoir will be acquired by the project[77]. No land used directly for human occupation will be required for the construction of the project.

The powerhouse will require an area of very steep land several hundred meters downstream of Senge on the left bank of the Tina River. This area does not appear to be used by existing villages. The proposed powerhouse access road, which begins at the logging road south of

[76] The identification of the relevant landowners was completed subsequent to the preparation of the SIA report. According to a press release (dated 17 July, 2014) it was determined that the Core Area belongs to 4 landowning tribes: Kochiabolo, Roha, Buhu Garo, and Vuralingi, who together consented to make their land available to the SIG for the project.

77 Subsequent to the SIA, the identified landowners and the SIG entered into an agreement for the government to acquire the land for the project, and the formal declaration for acquisition by the Minister of Lands was gazetted in August 2014 (project office press release, 3 September, 2014).